GRADUATE POLICIES

&

PROCEDURES

&

COURSE CATALOG

2005

Virginia Tech
1872

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA 24061

The provisions of this document do not constitute a contract, expressed or implied, between any applicant or student and Virginia Polytechnic Institute and State University. The university reserves the right to change any of the provisions, schedules, programs, courses, rules, regulations, or fees whenever university authorities deem it expedient to do so.

Graduate students are invited to request the aid of the Graduate School in any matter of concern.

Contact Information:

The Graduate School
Sandy Hall (0325)
Virginia Polytechnic Institute and State University
Blacksburg VA 24061
540/231–6691; **fax** 540/231–3714
toll free: 877/453–1405
e–mail: gradrecru@vt.edu

The Graduate School maintains up–to–date information about programs on the World Wide Web. To access the home page, look up the following:

URL– http://www.grads.vt.edu

Key Telephone Numbers:

University Operator	540/231–6000
Graduate Admissions	231–4669
Graduate Fellowships and Scholarships	231–4558
Graduate School	540/231–6691

Academic Colleges:

Agriculture and Life Sciences	231–6503
Architecture and Urban Studies	231–6386
Pamplin College of Business	231–6152
Engineering	231–6641
Liberal Arts and Human Sciences	231–6779
Natural Resources	231–5481
College of Science	231–5422
Virginia–Maryland Regional College of Veterinary Medicine	231–7666

Publication date: December 2004

Policy on Sexual Harassment

Sexual harassment is considered to be a form of discrimination based on sex and falls within the statutory prohibitions against sex discrimination. The university is committed to maintaining a working and a study environment free of sexual harassment. Accordingly, in compliance with Section 703 of Title VII of the Civil Rights Act of 1964 and Title IX of the Education Amendments of 1972, it is the university's policy not to tolerate any verbal, nonverbal, or physical behavior which constitutes sexual harassment. Personnel with supervisory responsibilities are required to take immediate and appropriate action when incidents of alleged sexual harassment are brought to their attention. Violations of the policy prohibiting sexual harassment may lead to disciplinary actions, including reprimand, suspension, or termination of employment or academic status.

Sexual harassment is defined as unwelcome sexual advances, requests for sexual favors, and other verbal, nonverbal, or physical conduct of a sexual nature when: 1. submission to such conduct is made either explicitly or implicitly a term or condition of an individual's employment or academic decisions; or 2. submission to or rejection of such conduct by an individual is used as the basis for employment or academic decisions; or 3. such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance or creating an intimidating, hostile, or offensive working or academic environment.

Faculty, staff, students, and applicants for employment or admission with complaints of sexual harassment should contact the University EO/AA Office on a confidential basis and request an informal investigation.

Faculty, staff, and students may file formal complaints outside the university. Students may file formal complaints with the Office of Civil Rights of the Department of Education. Faculty may file formal complaints with the Equal Employment Opportunity Commission. Staff may contact the state EEO Office or the Equal Employment Opportunity Commission.

CONTENTS

GENERAL INFORMATION

KAREN P. DePAUW, Vice Provost for Graduate Studies and Dean of the Graduate School
ROGER J. AVERY, Senior Associate Dean
KAREN E. AKERS, Director, Northern Virginia Center
DONALD W. McKEON, Director, ESL/GTA Training
MONIKA GIBSON, Director, Graduate Student Services
MARILYN KERSHAW, Director, Graduate Student Recruiting
ANGELA W. WEBB, Manager, Applications, Plans & Clearances

University Mission

Virginia Polytechnic Institute and State University is a public land-grant university serving the Commonwealth of Virginia, the nation, and the world community. The discovery and dissemination of new knowledge are central to its mission. Through its focus on teaching and learning, research, and outreach, the university creates, conveys, and applies knowledge to expand personal growth and opportunity, advance social and community development, foster economic competitiveness, and improve the quality of life.

Graduate School Mission

The mission of the Virginia Tech Graduate School is to advance graduate education as a critical component in the transmission of new knowledge, new research, new ideas, and new scholarship in the university. The Graduate School is committed to providing a rich learning environment that attracts and retains outstanding graduate students. They work closely with outstanding faculty to advance knowledge and understanding that enables us to address the complex issues of today's society and tomorrow's future. Our viability as a top research university depends upon our ability to prioritize graduate education and research as central to the academic mission of Virginia Polytechnic Institute and State University.

Graduate School Responsibilities

The Graduate School is responsible for the development, administration, and evaluation of graduate education throughout the university. Graduate School personnel work in partnership with the faculty, program chairs and department heads, the deans, graduate students (particularly through the Graduate Student Assembly), and the Commission on Graduate Studies & Policies (CGS&P) to further graduate education at Virginia Tech. The Graduate School is responsible for:

- Developing academic policies and procedures;
- Assisting with the preparation of new graduate degree options and programs;
- Implementing enrollment management strategies at the graduate level;
- Overseeing admission of graduate students;
- Monitoring graduate students' progress toward degrees, accepting and approving theses and dissertations, and certifying the successful completion of graduation requirements;
- Certifying eligibility of graduate students to hold assistantships (GTAs, GRAs, GAs);
- Managing tuition remissions and scholarship and fellowship programs;
- Implementing the health insurance subsidy program;
- Coordinating university-wide graduate recruitment efforts;
- Advocating and promoting a nurturing climate for graduate education, including the sound mentoring of graduate students;
- Coordinating the university-wide graduate student orientation and GTA training;
- Processing documentation for international students (e.g., visas) and assuring federally mandated compliance;
- Administering the Honor System;
- Preparing the future professional;
- Facilitating interdisciplinary programs.

Graduate Education at Virginia Tech

Graduate studies at the university began in 1891, when the first advanced degree, a master of science in bacteriology, was awarded. A graduate department was established in 1907. At the time, there were only 13 students enrolled in the master's program.

Virginia Tech is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools to award doctoral, master's, bachelor's, and associate's degrees. Undergraduate and graduate programs, as appropriate, are accredited by the following agencies:

American Assembly of Collegiate Schools of Business
Accreditation Association of Marriage and Family Therapists
American Association of Family and Consumer Sciences
Accreditation Board for Engineering and Technology
American Chemical Society
American Council for Construction Education
American Dietetics Association
American Psychological Association (Clinical Psychology or Ph.D. program level only)
American Society of Landscape Architects
American Veterinary Medical Associations Council on Education
Foundation for Interior Design Education and Research
National Association of Schools of Theatre (B.A. and M.F.A. degree programs)
National Architectural Accrediting Board
National Council for Accreditation of Colleges of Teacher Education
National Institute of Food Technologists *
(lists the Department of Food Science and Technology as one of 40 departments in the U.S. and Canada offering this program of study)*
Planning Accreditation Board
Society of American Foresters
Virginia State Department of Education

Faculty

The success of Virginia Polytechnic Institute and State University's graduate program rests with the faculty and the facilities available for research and teaching. Virginia Tech is pleased that more than 1,800 faculty members are involved

in graduate education. Faculty members are attracted to the university from prestigious institutions across the nation and around the world, and support the institution's dedication to the values of teaching, research, and service for a setting well suited for professional growth.

Many distinguished scholars visit the university for lectures, seminars, and other visiting scholar programs and activities. A large number of Virginia Tech professors hold named professorships.

Disabled Student Services

Virginia Tech is an equal opportunity institution that admits students without regard to disabling conditions. The university makes reasonable accommodations to meet the needs of disabled students in the university setting. In doing so, a variety of supplemental services is offered to help offset the functional disadvantage of a disability and help increase students' educational opportunities. Disabled students attending Virginia Tech should contact the director of services for students with disabilities (ssd@vt.edu).

Graduate Student Assembly

The Graduate Student Assembly (GSA) is the pre-eminent governance organization for the graduate and professional student community at Virginia Tech. The GSA represents students' concerns and is their liaison with the university administration. GSA members also serve on many university commissions and committees. In addition, the GSA administers a grant program to promote research and educational efforts of its members.

Graduate Student Appeals

When a graduate student believes that work has been improperly evaluated, or believes that there has been other unfair treatment related to academic progress, they may request a hearing through the Graduate Appeals Process described in Appendix II of this catalog.

Graduate Honor System

The Graduate Honor Code establishes a standard of academic integrity. The code is founded on the concept of honesty with respect to the intellectual efforts of oneself and others. Compliance with the Graduate Honor Code requires that all graduate students exercise honesty and ethical behavior in all their academic pursuits at Virginia Tech, whether these undertakings pertain to study, course work, research, extension, or teaching. Graduate students, in accepting admission, indicate their willingness to subscribe to and be governed by the Graduate Honor Code and acknowledge the right of the university to establish policies and procedures and to take disciplinary action (including suspension or expulsion) when such action is warranted. The Constitution of the Graduate Honor Code is contained in Appendix III of this catalog.

Information Technology

The Information Technology organization is an integral element of the university community and is actively involved in helping Virginia Tech reach its goals. The Information Technology organization is a national leader in building technological resources to support, enhance, preserve, and publicize the work of faculty members and students. Its focus is on enhancing teaching and learning, advancing research activities, and supporting the university's administrative business requirements. Additionally, essential elements of the Information Technology organization's endeavors are associated with fostering outreach with Commonwealth communities.

The Vice President for Information Technology reports to the University President and manages Virginia Tech's information technologies. The Vice President's primary role is to serve as the University's Chief Technology Officer (CTO). The duties of the Chief Information Officer (CIO) are also the responsibility of the VP's office; however the daily CIO functions are delegated to line managers within the Information Technology's organization.

The university data networks are accessible from every office and residence hall, as well as off-campus via the modem pool and from university facilities statewide. A wireless LAN (local area network) service is available in approximately 85% of academic and administrative spaces across campus. This expanded coverage significantly increases student, faculty, and staff mobile network access. In addition, the university is a leader in a statewide Internet-like service known as NetworkVirginia, which serves the state's education infrastructure, as well as government agencies and business and industry subscribers.

The Network Infrastructure and Services department provides leading edge, high quality data, video, and voice infrastructure and services to all segments of the university community to meet their present and future communications needs. Operating as an auxiliary unit in support of university goals, it strives to emphasize sound fiscal management in its operations. It endeavors to advance the technological capabilities of the existing telecommunications infrastructure and to broadly disseminate information regarding new technological developments. Network management, operations, and support are provided, with an emphasis on the highest levels of network security and reliability while continually moving Virginia Tech forward as a leader in the advanced networking community. The department supports the instruction, research, and outreach missions of the university and recognizes its role as a corporate citizen within the local, state, regional, and international communities. It remains sufficiently flexible to address the expansion and enhancement of advanced network infrastructure to support the university communities and pursue the development of related new services.

Network Infrastructure and Services believes a state-of-the-art communications infrastructure is mission-critical to the university. Advances in technology, corresponding reductions in the cost of providing it, and increased demand from the university community and its clients for more sophisticated communications media will continue to grow exponentially in the next five to ten years. Virginia Tech's competitive position in regional, national, and global markets will rely heavily on continued success in identifying and incorporating the finest communications capabilities available.

The Learning Technologies department provides a teaching and learning infrastructure that meets modern needs for integrating technology across content areas. It seeks to create and support robust environments for teaching, learning, and discovery for faculty and students that are grounded in sound principles of learning, and in a

thorough knowledge of integrating technology for effectiveness and efficiency of effort. Learning Technologies seeks these aims in several ways: through comprehensive development programs and training activities in the appropriate use of emerging technologies; through systematic application of appropriate resources to designing, developing, implementing and evaluating technology–assisted instruction; and by providing highly responsive services that advance and support network–assisted teaching, research and outreach.

Security of the university information technology infrastructure and services has always been an important issue, but has become even more important with the number of threats that evolve and persist. Security is considered in all aspects of Information Technology's daily activities, but two elements of the organization have security as their primary focus. They are the University Security Office, which ensures that the university has the technology tools, education, awareness, and guidance necessary to work towards a safe and secure information technology environment, and the Secure Enterprise Technology Initiative, whose focus is on developing secure applications, middleware, and interfaces to support the university's computing and network services.

The Information Technology organization is an integrated partner in the support of cluster computing and research. The Andrews Information Building (ISB) has had its infrastructure upgraded to accommodate large cluster computers. A partnership between the Information Technology organization and university colleges has produced a Terascale facility with significant international recognition.

The Information Technology organization also provides Virginia Tech's computing infrastructure and major application systems along with the following functions:

- 4help, the "Get Connected" program and desktop support.
- Central computing resources and servers supporting email, administrative systems, research, and instruction.
- Developing and maintaining a data warehousing system that captures, structures, and delivers university data to support timely, effective decision making, in addition to being responsible for knowledgebase and content management services.
- Database Management Services (DBMS).
- Administrative information systems consisting of the Banner teams for Alumni/Development, Finance, General, Human Resources, and Student & Financial Aid.
- Middleware Services, Microsoft Integration, Portal and eProvisioning.
- Software distribution, student software sales, and computer purchasing.
- Managing and maintaining system access via user accounts and passwords and digital signatures

UNIVERSITY LIBRARIES

University Libraries consists of the Carol M. Newman Library, the main library, and three branch libraries: the Art and Architecture Library; the Veterinary Medicine Library; and the Northern Virginia Resource Center. The University Libraries are fully computerized and have become a model for other universities, especially in the area of electronic thesis and dissertations, a focus of the Digital Library and Archives department. The University Libraries' growing collection includes 2,210,645 volumes, 6,294,019 microforms, 14,208 videos and films, 9,690 cassettes and recordings, and 137,283 maps. The libraries currently subscribe to 29,079 print and e–journals.

The University Libraries' full range of on–line resources is accessible through the library Internet home page (*www.lib.vt.edu*). The home page provides access to numerous electronic databases supporting research in business and finance, engineering, the humanities, the life sciences, the physical sciences, and the social sciences. A complete list of searchable databases is available on the web page. These resources are available to all Virginia Tech students. The Extended Campus Users web page (*www.lib.vt.edu/help/extended*) provides information on accessing resources from off campus locations. The directions for Proxy Server Configuration (*www.lib.vt.edu/services/extended/extproxy.html*) are of particular interest to extended campus users.

The University Libraries home page also provides access to on–line reference assistance (AskUs and LiveRef) and to a list of subject resources and contacts (*www.lib.vt.edu/services/liveref.html*). Additional resources available through the library home page include Addison and e–journals database. Addison, the on–line catalog, lists books, journals, micro–forms and other library materials owned by the University Libraries. The e–journals database provides access to and additional information about on–line journals including full–text access available through many of the electronic data–bases.

Reference assistance is available at the Reference Desk in the lobby of Newman Library or in the Torgersen Hall Electronic Reading Room (Tower Reference Desk). Electronic consulting services and access to a variety of specialized databases are also available in the Tower Reference area.

Special Collections maintains major research and archival collections including the Archives of American Aerospace Exploration, the International Archive of Women in Architecture, the Josh Billings Civil War Collection, and the University Archives. Access to these collections is provided through the Special Collections web page (*spec.lib.vt.edu/*) and Addison.

Services provided by the University Libraries include photocopying, interlibrary loan, and a Special Services room for users with disabilities. Informational handouts on library collections and services are available throughout the library.

GRADUATE PROGRAM OFFERINGS

Programs leading to a master's and/or doctoral degree are available in multiple areas and can be found at the following website:

http://www.grads.vt.edu/common/colleges_degrees.htm

CENTERS, LABORATORIES, GROUPS, AND INSTITUTES

Like most comprehensive universities, Virginia Polytechnic Institute and State University is organized into discretely defined departments, divisions, and colleges. However, research needs cannot always be met through the traditional disciplinary organization of academic departments and/or colleges. Thus, a wider focus is often necessary to bring a variety of expertise to bear upon problems and concerns.

This is accomplished by the establishment of centers, laboratories, groups, and institutes that enable special talents to be directed on research areas and provide for an effective interdisciplinary approach to research programs. Listed below are some of these research centers:

COLLEGE OF AGRICULTURE AND LIFE SCIENCES
- Center for Food and Nutrition Policy

COLLEGE OF ARCHITECTURE AND URBAN STUDIES
- Center for Global Accountability Studies
- Center for Preservation and Rehabilitation Technology
- Center for Real Life Kitchen Design
- Community Design Assistance Center
- Henry W. Wiss Center for Theory & History of Art and Architecture
- Institute for Community Health
- Institute for Innovative Governance
- Institute for Policy Outreach
- Institute for Public Management
- Institute for Public Policy Research
- Institute for the Social Assessment of Information Technology
- International Archive of Women in Architecture

COLLEGE OF SCIENCE
- Center for Applied Behavior Systems
- Center for Research in Health Behavior
- Child Study Center
- Harvey W. Peters Research Center
- Psychological Services Center
- Statistical Consulting Center

PAMPLIN COLLEGE OF BUSINESS
- AT&T Center for Visualization of Organizations
- Business Leadership Center
- Business Technology Center
- Center for Global Electronic Commerce
- Center for Leader Development
- Systems Integration Center
- Virginia Tech Center for Leadership Studies

COLLEGE OF ENGINEERING
- Advanced Vehicle Dynamics Laboratory
- Center for Advanced Ceramic Materials
- Center for Advanced Separation Technologies
- Center for Automotive Fuel Cell Systems
- Center for Biomedical Eng.
- Center for Bridge Eng.
- Center for Composite Materials & Structures
- Center for Energy & the Global Environment
- Center for Geotechnical Composite Systems
- Center for Geotechnical Practice & Research at Virginia Tech
- Center for High Performance Manufacturing
- Center for Infrastructure Assessment & Management
- Center for Intelligent Material Systems & Structures
- Center for Photonics Technology
- Center for Power Electronics Systems
- Center for Power Eng.
- Center for Turbomachinery Propulsion & Research
- Energy Management Institute
- Fiber & Electro-Optics Research
- Human Factors Eng. & Ergonomics Center
- Mobile & Portable Radio Research Group
- Multidisciplinary Analysis & Design Center for Advanced Vehicles
- Polymer Materials and Interfaces Laboratory
- Rotor Dynamics Laboratory
- Software Technologies Laboratory
- System Performance Lab
- The Virginia Tech Construction Affiliates Program
- Vibration & Acoustics Laboratories
- Virginia Active Combustion Control Group
- Virginia Tech Information Systems Center

COLLEGE OF LIBERAL ARTS & HUMAN SCIENCES
- Center for Applied Technologies in the Humanitites
- Center for Assessment, Evaluation & Educational Programming
- Center for Digital Discourse and Culture
- Center for Information Technology Impacts on Children, Youth & Families
- Center for Teacher Education
- Child Development Laboratory
- Family Therapy Center of Virginia Tech
- Institute for Connecting Science Research to the Classroom
- Laboratory for the Study of Human Thought and Action
- Therapeutic Exercise and Community Health

COLLEGE OF NATURAL RESOURCES
- Center for Environmental Applications of Remote Sensing
- Center for Unit Load Design
- Conservation Management Institute
- Pallet Laboratory
- Wood-Based Composite Center

VIRGINIA-MARYLAND REGIONAL COLLEGE OF VETERINARY MEDICINE
- Center for Reproductive Excellence using Assisted Technology and Endocrinology
- Laboratory for Neurotoxicity Studies

UNIVERSITY CENTERS
- Center for Adhesive and Sealant Sciences
- Center for Gerontology
- Center for Human-Computer Interaction
- Center for Self-Assembled Nanostructures & Devices
- Center for Survey Research
- Center for Wireless Telecommunications
- Fralin Biotechnology Center
- Institute for Metropolitan Research
- Institute for Particle Physics and Astrophysics
- Interdisciplinary Center for Applied Mathematics
- Internet Technology Innovation Center
- Materials Research Institute
- Optical Sciences and Eng. Research Center
- Race and Social Policy Research Center
- Systems Research Center
- Virginia Center for Coal & Energy Research
- Virginia Center for Housing Research
- Virginia Museum of Natural History – Virginia Tech
- Virginia Tech Transportation Institute
- Virginia Water Resources Research Center

LISTING OF UNDERGRADUATE COURSES

Undergraduate courses (4000-level) approved for graduate credit and which may apply to graduate plans of study are listed in the *Graduate Catalog*.

ABBREVIATIONS

Miscellaneous abbreviations used in the course descriptions only include:

C–credits
H–hours in classroom
L–hours in laboratory
Pre–prerequisite

The following departmental or curricular abbreviations are used in the tables and course descriptions in this catalog.

AEE–Agricultural and Extension Education
AAEC–Agricultural and Applied Economics
AHRM–Apparel, Housing, and Resource Management
ALHR–Adult Learning/Human Resource Development
ALS–Agriculture and Life Sciences
ANSC–Animal Science
APSC–Animal and Poultry Sciences
AOE–Aerospace and Ocean Engineering
ARCH–Architecture
ART–Art and Art History
BC–Building Construction
BCHM–Biochemistry
BIOL–Biology
BIT–Business Information Technology
BMES–Biomedical Engineering and Sciences
BSE–Biological Systems Engineering
CEE–Civil and Environmental Engineering
CHE–Chemical Engineering
CHEM–Chemistry
CHN–Chinese
CLA–Classics
COMM–Communication
CS–Computer Science
CSES–Crop and Soil Environmental Sciences
DASC–Dairy Science
ECE–Electrical and Computer Engineering
ECON–Economics
EDAE–Administrative and Educational Services
EDCI–Curriculum and Instruction
EDCO–Counseling
EDP–Environmental Design and Planning
EDHL–Health Education
EDPE–Health, Physical Education, Recreation
EDRE–Research & Evaluation
EDSE–Special Education
ENGL–English
ENGR–General Engineering
ENSC–Environmental Science
ENT–Entomology
ESEN–Environmental Sciences and Engineering
ESM–Engineering Science and Mechanics
FA–Fine Arts
FIN–Finance, Insurance, Business Law
FIW–Fisheries and Wildlife Sciences
FOR–Forestry
FL–Foreign Languages
FR–French
FST–Food Science and Technology
GBCB–Genetics, Bioinformatics, and Computational Biology
GEOG–Geography
GEOS–GEOSCIENCES
GEN–Genetics
GER–German
GR–Greek
HCI–Human–Computer Interaction
HEB–Hebrew
HD–Human Development
HIST–History
HNFE–Human Nutrition, Foods and Exercise
HORT–Horticulture
HTM–Hospitality and Tourism Management
HUM–Humanities
IDS–Industrial Design
ISE–Industrial and Systems Engineering
IDST–Interdisciplinary Studies
IS–International Studies
IT–InformationTechnology
ITDS–Interior Design
ITAL–Italian
JPN–Japanese
JUD–Judaic Studies
LAR–Landscape Architecture
LAT–Latin
MATH–Mathematics
MASC–Mathematical Sciences
MCBB–Molecular Cell Biology and Biotechnology
ME–Mechanical Engineering
MGT–Management
MINE–Mining Engineering
MKTG–Marketing
MN–Military Navy (NROTC)
MS–Military Science (AROTC)
MSE–Materials Science and Engineering
MUS–Music
OCE–Ocean Engineering
PHIL–Philosophy
PHYS–Physics
PIA–Public and International Affairs
PPWS–Plant Pathology, Physiology, and Weed Science
PORT–Portuguese
PSCI–Political Science
PSYC–Psychology
REL–Religion
RUS–Russian
SOC–Sociology
SPAN–Spanish
STAT–Statistics
TA–Theatre Arts
UH–University Honors
UAP–Urban Affairs and Planning
UD–Urban Design
URPL–Urban and Regional Planning
VM–Veterinary Medicine
VMS–Veterinary Science
WOOD–Wood Science and Forest Products
WS–Women's Studies

FINANCIAL INFORMATION

The University Bursar's Office provides statements to students and receives and posts payments to the students' accounts. If a student wants financial information released to parents or others, he or she must provide written authorization to the Bursar's Office, which will allow us to release financial information. The Student Information Release Form can be downloaded from the Bursar's website (*www.bursar.vt.edu*) and sent to the Bursar either by fax or mail to authorize the release of information.

Detailed information regarding tuition and fees, payment deadlines, Customer Service Window hours, The Budget Tuition Plan, and much more can be obtained by viewing the website at *www.bursar.vt.edu*.

Summer School Fees

Information on summer school tuition and fees as well as costs for room and board can be obtained on the Bursar's website (*www.bursar.vt.edu*).

Auditing

Students are assessed the same rate for tuition and fees for auditing courses as for courses taken for credit.

Late Payment Fee

A $50 Late Payment Fee will be charged to students whose payments are received after the statement due date.

Reinstatement Fee

A $75.00 fee is charged to students whose registrations are cancelled due to non-payment of fees, but are given permission by their dean to add classes after the deadline. The $75 reinstatement fee is in addition to the $50 late payment fee.

Billing Address

Billing statements are sent to one of the addresses provided by the student on HOKIE SPA. If you wish to have all statements from the Office of the University Bursar sent to a **billing address**, please provide this address on the billing address segment of HOKIE SPA. If you choose this option, all statements will be sent to this address and other addresses listed will not be used in mailing statements to you.

If no billing address is provided by the student on the HOKIE SPA, statements are sent to the mailing address (MA) ***except*** for the July and December statements. These statements include tuition and fee charges for the fall and spring semesters and since the majority of students are not in Blacksburg at the time July and December statements are mailed, the permanent address (PR) is used for mailing statements for these two months.

In summary, the address hierarchy used for mailing monthly account receivable statements is BI (billing address), MA (mailing or local address), or PR (permanent address) for each month except July and December. For these two months the hierarchy is BI (billing address), PR (permanent address), or MA (mailing address).

Payment Information

Statements are prepared and sent out on the 15th of each month (If the 15th of the month occurs on a weekend, statements are processed on the Friday before the 15th). **Payments for monthly statements are due on the 10th of the following month.** (If the 10th of the month occurs on a weekend, payments will be due the following Monday.)

Billing statements for fall semester charges will be processed in July with an August 11th due date. However, should you add classes, a meal plan, or a room after the July statement is processed, you will be billed in August with a September due date for these additional charges.

Billing statements for spring semester charges will be processed in December with a January 12th due date.

Classes are dropped for non-payment of past due billed charges the second Friday after classes begin for fall and spring semesters.

Late fees will be charged to your account based upon the due date on the statement. For example, you have received a statement with an amount due of $3000 with a due date of January 12th. If your payment is received on January 13, a $50 late fee will be charged to your account.

A monthly finance charge of 1-1/2% per month will be assessed on unpaid prior term charges.

Payment Directions

Payment should be made in cash or by check/money order in the exact amount due by the date shown on the statement. Checks/money orders should be made payable to "Treasurer of Virginia Tech."

Payments should be mailed to our payment address: Virginia Tech, P.O. Box 7620, Merrifield, VA 22116-7620. Payments should be sent with the payment stub from your statement. Payments received without a stub will be delayed. Do ***not*** use the payment address for certified or express mail, scholarship checks, or any other correspondence; those items should be sent to our office address: Virginia Tech Office of the University Bursar, 150 Student Services Building, Blacksburg, VA, 24061

Budget Tuition Plan

Virginia Tech's Budget Tuition Plan (BTP) offers a convenient method for planning and budgeting tuition, fees, room, and board. The BTP can cover all or part of the fall and/or spring semester's charges. This plan provides the opportunity for the student or parent(s) to divide the cost of education into four monthly direct debits to the checking account of your choice, instead of paying one lump sum by tuition payment deadline each semester. The only cost for this service is a $45 non-refundable fee that is due with your application. Contact the Office of the University Bursar for additional information, call at (540) 231-9316, e-mail at *BTHELP@vt.edu*, or visit our website at *http://www.bursar.vt.edu*.

REFUND POLICY

If the student has provided the Bursar with bank information for the purpose of direct deposit, refunds will be paid by direct deposit. If not, refunds will be paid by check and held at the cashier's window for pick-up by the student on Tuesday's and Thursday's only. Refunds will be made to the student under the following rules:

TUITION REFUNDS

The refund schedules below list the possible student refund. Depending on your course load, you may or may not be entitled to a refund. If you are planning to withdraw, resign, or reduce your course load, please contact the Bursar's office at 231-6277 for refund information. If you are receiving financial aid, please contact your financial aid counselor prior to resigning or reducing your course load below full-time status.

FALL AND SPRING SEMESTERS

TUITION REFUND TABLE FOR REDUCED COURSE LOADS

SEMESTER CLASS DAY	STUDENT REFUND
One through five	100% of Tuition and Fees
Six through eight	90% of Tuition ONLY
Nine through nineteen	50% of Tuition ONLY
Twenty through thirty-seven	25% of Tuition ONLY
After day thirty-seven	0%

TUITION REFUND TABLE FOR WITHDRAWALS & RESIGNATIONS

SEMESTER CLASS DAY	STUDENT REFUND
One	100% of Tuition and Fees
Two through eight	90% of Tuition ONLY
Nine through nineteen	50% of Tuition ONLY
Twenty through thirty-seven	25% of Tuition ONLY
After day thirty-seven	0%

- The Comprehensive Fee, Technology Fee, and Capital Fee are nonrefundable and no reduction will be made after the beginning of classes for resignations.
- All refunds will be calculated from the official date of resignation, which may not necessarily be the last day of class attendance.
- No refund will be granted for a resignation that occurred in a previous fiscal year.

SUMMER TERMS

TUITION REFUND TABLE FOR REDUCED COURSE LOADS

SEMESTER CLASS DAY	STUDENT REFUND
One through three	100% of Tuition and Fees
Four through eight	50% of Tuition ONLY
Nine through fifteen	25% of Tuition ONLY
After day fifteen	0%

TUITION REFUND TABLE FOR WITHDRAWALS & RESIGNATIONS

SEMESTER CLASS DAY	STUDENT REFUND
One	100% of Tuition and Fees
Two through three	90% of Tuition ONLY
Four through eight	50% of Tuition ONLY
Nine through fifteen	25% of Tuition ONLY
After day fifteen	0%

- The Comprehensive Fee, Technology Fee, and Capital Fee are nonrefundable and no reduction will be made after the beginning of classes for resignations.
- All refunds will be calculated from the official date of resignation, which may not necessarily be the last day of class attendance.
- No refund will be granted for a resignation that occurred in a previous fiscal year.

MEDICAL RESIGNATIONS

- A student withdrawing for medical reasons will be charged a daily tuition rate for each day enrolled.
- Withdrawal for medical reasons must be accompanied by a statement from the Student Health Services at Virginia Tech indicating the student is unable to continue in school due to medical reasons.

ROOM AND BOARD REFUNDS

Students holding a residence hall contract or a board plan who leave the university during the first week of class will forfeit $100 of their residence hall fee and $100 of their board fee. Thereafter, the semester room and board charge, less $100, will be apportioned over the first six weeks of the semester. The student will be charged a weekly rate for each week enrolled, plus $100. A student who withdraws after the beginning of the seventh week of the semester will be charged the full room and board rate.

Students who purchase a declining balance meal plan will be charged a forfeiture fee of $100 during the first week. Beginning in week two and throughout the remainder of the semester, students will forfeit the base cost and will be refunded any unused dollars in the declining balance account.

Unused cash Dining Dollar deposits will be refunded in total for meal plan holders. Students who have only Dining Dollar accounts and not a meal plan will receive the balance of all cash deposits minus $15. Questions concerning adjustments to room charges should be directed to Residential and Dining Programs at 231-6201. Questions concerning adjustments to meal plan charges should be directed to the Hokie Passport Office at 231- 5121.

COLLECTION OF PAST DUE RECEIVABLES FOR STUDENTS

Any amount owed to the university including, but not limited to, tuition, fees, room, board, loans, notes receivable, and amounts due for goods and services provided is considered a receivable to the university. A receivable becomes past due if payment is not received by the payment due date. At ninety days past due, the receivable becomes delinquent.

For currently enrolled students, the primary collection tool is the placement of a “HOLD” by the Office of the University Bursar on a student’s record. This “HOLD” restricts certain student activities such as the ability to add or drop classes, receive grade transcripts, and to register for future academic terms. Once established, the “HOLD” remains in place until the debt is paid in full. Once a student is no longer enrolled, the collection procedures utilized for other “non-student” receivables are implemented.

Individuals who do not pay all fees and charges owed are responsible, in the event of their default or the return of a check for payment of said fees and charges, to pay a penalty fee, to pay interest at the highest rate allowed by law, and for all reasonable administrative costs, collections costs, and attorney’s fees incurred in the collection of funds due the University.

Addresses must be kept current on **HOKIE SPA** in order for the university to send statements in a timely manner. Students, faculty and staff can change their address on the HOKIE SPA. Non-receipt of statements is not a valid defense for non-payment; it is the responsibility of the individual who has incurred the debt to see that the debt is discharged.

For non-students, a dunning message is included on each month's statement alerting the customer to the next collection steps that will be taken. If payment is not forthcoming within the stated period, the account and all pertinent information are forwarded to an outside collection agency or the State Attorney General's Office, as appropriate, for collection. In the event the collection agency is unable to collect, the account is reported to a national credit bureau, thus affecting the debtor's credit rating.

In addition to the above measures, the university also lists the account with the Virginia Department of Taxation for set-off debt collection procedures. This means that any state income tax refund due the debtor will be reduced by the amount of the receivable owed by the debtor.

Virginia Polytechnic Institute and State University is in full compliance with the Virginia Debt Collection Act and all regulations promulgated by the State Department of Accounts and the Office of the Attorney General.

OFFICE OF THE UNIVERSITY BURSAR
150 Student Services Building
540/231-6277
Fax: 540/231-3238
E-mail: *bursar@vt.edu*
Web: *www.bursar.vt.edu*

FULL-TIME ENROLLMENT STATUS

Certification of full-time student status, for most purposes, U.S. Department of Veterans Affairs (V.A.) educational benefits, Social Security benefits, loans, scholarships, and grants, is based on the following enrollment information: official graduate enrollment for each regular semester must be 9 or more credit hours. All courses must be in the A/F option, P/F option, or equivalent credit. Please note that courses taken under the audit option do not count toward the enrollment status. Participation in the International Student Exchange program reflects full-time enrollment. Certification of enrollment for V.A. educational benefits will reflect only those hours considered to be progress toward the degree or educational objective.

FINANCIAL AID

Virginia Tech awards financial aid to qualified students in the form of grants, loans, and employment. Sources of aid come from federal agencies, university academic departments, and private foundations and corporations. Interested applicants should inquire about fellowships and teaching and research assistantships through the university academic department in which they will be enrolled. Additionally, all students should submit the Free Application for Federal Student Aid (FAFSA) to the federal processor by March 11 to be considered for priority awarding. FAFSA forms and information are available after January 1 on the web at http://www.fafsa.ed.gov

Applicants for financial aid must list Virginia Tech's institutional code number, 003754, and/or the official name of the university (Virginia Polytechnic Institute and State University, or VPI&SU) on the FAFSA in order to have the analysis of their FAFSA sent to the university's Office of Scholarships and Financial Aid. Students must complete and submit a new FAFSA to federal processor each year to be considered for aid at Virginia Tech.

All offers of financial aid are contingent upon receipt of anticipated federal and state funds by the university. Awards may be reduced or canceled if anticipated funds are not received. Offers of financial aid are subject to full-time enrollment (9 hours) and maintenance of satisfactory academic progress.

Virginia Tech administers a comprehensive financial aid program that totals $176 million for all students. Approximately 70 percent of Virginia Tech students receive some form of aid.

ELIGIBILITY REQUIREMENTS

To be eligible to receive aid from federal need-based programs, an applicant must satisfy the following eligibility requirements: meet university application requirements; be enrolled as a degree-seeking student; be a citizen or an eligible non-citizen; submit a completed FAFSA; and be making satisfactory academic progress as defined by the university policy for Title IV recipients (refer to website http://www.finaid.vt.edu/RAP.html). Full-time enrollment is required for Federal Work-Study, Perkins Loans, and some other awards. Fellowship and assistantship recipients must also enroll for at least 12 hours a term.

FEDERAL TITLE IV PROGRAMS

FEDERAL WORK-STUDY PROGRAM

This federal program provides employment opportunities to students with demonstrated financial need. All federal Work-Study positions pay at least minimum wage. Departments post positions on the jobs database at http://www.finaid.vt.edu/work/jobsearch.html

WILLIAM D. FORD FEDERAL DIRECT LOAN PROGRAM

Federal Stafford Loans are long-term, low-interest loans authorized by the federal government for the educational expenses of eligible students enrolled at least half-time. Students apply for subsidized Federal Stafford Loans (which are interest free) and Unsubsidized Federal Stafford Loans (which accrue interest) by filing the Free Application for Federal Student Aid (FAFSA). Repayment normally begins six months after the student leaves Virginia Tech or drops below half-time status.

FEDERAL PERKINS LOANS

This program provides long-term, low-interest loans from Virginia Tech to students with financial need. The interest rate to first-time borrowers is five (5) percent. Repayment of both principal and interest begins after the student leaves Virginia Tech or drops below half-time status. Repayment is made to Virginia Tech, and once funds are repaid, they are used to make loans to other Virginia Tech students.

ADDITIONAL INFORMATION

Additional information on financial aid may be obtained by writing, calling, or visiting:

Office of Scholarships and Financial Aid
200 Student Services Building (0222)
Virginia Tech
Blacksburg, VA 24061
Phone: **540/231-5179**
Fax: **540/231-9139**
E-mail: **finaid@vt.edu**
Web: **http://www.finaid.vt.edu**

All information is correct at the time of publication. Current information is available from our web site.

VETERANS AFFAIRS EDUCATIONAL BENEFITS

Applicants who wish to receive VA Educational Benefits should apply through the Office of the University Registrar, or visit their website at **http://www.registrar.vt.edu**

ASSISTANTSHIPS

Most departments at the university offer assistantships. Students should contact the academic departments to inquire about the availability of assistantships.

GRADUATE SCHOOL POLICIES & PROCEDURES

[Also available on the web: www.grads.vt.edu]

Introduction

This section sets forth policies, procedures and requirements relating to graduate study at Virginia Polytechnic Institute and State University (Virginia Tech). It is designed to assist all those involved in graduate education at the university. Interim policy changes will be noted in the minutes of the Commission on Graduate Studies and Policies of the University Council. The major responsibility for planning and executing the degree requirements rests with the graduate student. The major professor and the advisory committee help outline the student's course of study and select an appropriate research topic. The Graduate School seeks to foster quality in all phases of graduate education.

Graduate Student Responsibilities

It is the student's responsibility to satisfy all course requirements as established by the faculty teaching the courses in which the student is enrolled. It is also the student's responsibility to be aware of all graduate school and program requirements necessary to complete the plan of study. Policy changes that occur between revisions of the catalog can be found in presidential policy memoranda *(http://www.vt.edu/administration/policymemos/)*.

Changes

The university reserves the right to make changes in fees, policies, degree requirements, schedules, or courses offered.

Petitions

Exceptions to published rules may be requested of the Graduate School. Petitions must be approved by the student's advisory committee and should cite the regulation and justify the exception being requested.

Student Life Policies

The university publication, *University Policies for Student Life*, and other information about Virginia Tech are published annually.

Physical Examination

All Blacksburg campus students, admitted to the university for the first time, must complete a physical examination form and return it to Student Health Services.

Medical Insurance Coverage

The university has contracted with an insurance carrier to offer group coverage for all students at Virginia Tech. For details on levels of coverage and specific limitations, please contact the Student Medical Insurance office in the Student Services Building, 540/231–6226 or 231–6303, or visit *www.studentmedical.vt.edu*.

Medical insurance is mandatory for all international students with F–1 or J–1 visas at a minimum of $50,000 accident and sickness coverage. Medical insurance is mandatory for all College of Veterinary Medicine students at a minimum of $100,000 accident and sickness coverage. All students in these two areas must show in writing that they have equal or better coverage of the minimum levels from another insurance company, or they must purchase the university–sponsored student plan. Review of insurance policies is done by the Student Medical Insurance office.

MEDEX Overseas Evacuation Program

An overseas emergency evacuation program is available to faculty, staff, students and their families who may travel overseas either on business or pleasure. MEDEX provides emergency services outside your home country. Included are

- locating appropriate medical care
- evaluation and close monitoring of treatment – management of emergency medical evacuation and transport of mortal remains
- coordination of direct claims payments to providers
- verification of your insurance to facilitate hospital admission–continuous contact with family, physicians, and employer
- assistance with interrupted travel plans resulting from an emergency situation
- assistance replacing lost or stolen medications
- emergency message transmittal services
- emergency international transfer of funds
- assistance in locating lost or stolen passports
- multilingual language services in emergency situations
- coordination centers and phone numbers throughout the world

MEDEX is already a part of the Virginia Tech medical insurance offered to full–time students attending the university. For further information on MEDEX services or the student medical insurance program, contact Risk Management by telephone 540/231–7439, fax 540/231–5064, or e–mail to alene@vt.edu

Automobiles

Motor vehicles owned and operated by students who drive them on campus must be registered with the University Parking Services Office when the vehicle is brought on campus. Parking and operating regulations are issued at the time of registration.

Application and Admission

Applications and all related materials for admission should reach the Graduate School Office at least eight weeks before the beginning of the semester in which enrollment is requested. For financial assistance information, visit *www.finaid.vt.edu*. Admission to the Graduate School is contingent upon receipt of a bachelor of science/arts degree from an accredited college or university and the presentation of evidence of potential to pursue graduate work. Applications for admission should be made on–line at ***http://www.grads.vt.edu***.

CREDENTIALS

Applicants for admission should apply on-line at *www.grads.vt.edu*. If this is not possible, a printable application is also available. An official transcript should be sent to both the Virginia Tech Graduate School and to the academic department. Individual departments may require applicants to submit the results of the Graduate Record Examination (GRE). For applicants to the Pamplin College of Business, the Graduate Management Admissions Test (GMAT) is required. Please request that GRE or GMAT scores, if applicable, be sent to Virginia Tech. The Educational Testing Service Institution Code for Virginia Tech is 005859. All reference letters should be sent directly to the academic department. Please visit academic department websites for other departmental requirements such as resumes, vitas, portfolios, etc. All credentials submitted in support of an application become the property of the university. The application fee is $45.00 ($25.00 for Visiting Graduate Students) and is non-refundable. Applicants using a paper application must pay the fee with a check or money order drawn on a U.S. bank; cash is not acceptable. Checks should be made payable to Virginia Tech Treasurer. Applications will not be processed without the application fee.

International students are subject to the usual departmental review process required of all graduate students. The results of the Test of English as a Foreign Language (TOEFL) are required for international applicants except those who graduate from an accredited university where English is the language of instruction in the following countries/regions: Canada, United Kindom (England, Wales, Scotland, Northern Ireland), Ireland, Australia, New Zealand, Virgin Islands, Guam, Jamaica, British West Indies, Belize, Trinidad & Tobago, South Africa, and Liberia. A TOEFL score of 550 paper/213 computer based is required for consideration of the application, and some departments require higher TOEFL scores.

BASIC REQUIREMENTS

Requirements for each degree are different. Prior to applying, verify that you meet all the requirements and have taken all required tests. A list of degrees and their requirements are available for each Virginia Tech campus at this website:

http://www.grads.vt.edu/prospective/admissions_reqs.htm

ADMISSION CATEGORIES AND GRADUATE STUDENT CLASSIFICATIONS

Students are admitted or classified in one of the following categories. Changes from one status to another–for example from provisional to regular–are made when the student meets the qualifications for the change and only upon the request of the graduate program.

1. **REGULAR STUDENT**–For an applicant who meets the required grade point average (GPA) on the last 60 semester hours (or equivalent) and whose academic background meets established requirements and is relevant and current. The Graduate School requires a GPA of 3.0 or higher for this status. International students residing outside the U.S. are only considered for regular admission.

2. **PROVISIONAL STUDENT (MASTER'S ONLY)**–For an applicant whose GPA is between 2.75 and 2.99 and/or whose academic background is deficient or not current. Upon completion of 9 credit hours of course work, the student's graduate committee may recommend that the student be admitted to regular status. Provisional student status is allowed for no more than the equivalent of one semester (12 credit hours of course work is equivalent to one semester) during which time the provisional student must earn a GPA of at least 3.0.

   NOTE: International students are not eligible for consideration for admission as provisional students.

3. **NON-DEGREE STUDENT**–For an applicant with a bachelor's or higher degree, who qualifies for admission to the Graduate School as a regular student but who does not wish to or cannot be listed as a degree candidate for one of the following reasons: a) does not currently desire to work toward a graduate degree; b) desires to transfer the credits for use toward a graduate degree at another institution; or c) there currently is no higher degree available at the university other than the one the applicant currently holds in the department or field of study. The university places no limits on the total number of hours that may be taken as a non-degree student. "Non-degree" graduate students are not eligible for graduate assistantships.

   Credits earned by students in either the provisional or non-degree status may be used in meeting degree requirements if recommended by the student's advisory committee and department head and approved by the Graduate School. All students in these admission categories should seek faculty counsel before any course work is taken.

4. **COMMONWEALTH CAMPUS STUDENT**–Qualified students who wish to enroll in selected graduate courses may do so in the Commonwealth Campus program. Examples of students who seek admission into the Commonwealth Campus program include in- or out-of-state students who a) may qualify for regular admission but do not currently wish to work for a graduate degree; b) do not qualify for admission because of a poor undergraduate record but who have several years of appropriate professional experience and wish to improve their credentials; c) require graduate courses for professional certification; or d) are not U.S. citizens and are in a visa status that does not prohibit enrollment. This classification is open to individuals who hold an earned baccalaureate or higher degree from an accredited postsecondary institution. Students may take up to 12 hours of course work if they remain in good academic standing (students may petition to be allowed to take more courses). Students may not earn a graduate degree while enrolled in the Commonwealth Campus program. If rejected for a degree program, applicants are not eligible for Commonwealth Campus status.

   Those students enrolled in courses as Commonwealth Campus students who later decide to pursue a graduate degree from Virginia Tech must make formal application for admission to the Graduate School. Students seeking to pursue graduate course work in the Commonwealth Campus program must complete the Application for Graduate Study and submit a transcript

(unofficial is sufficient) or a copy of their diploma for the highest degree attained.

A determination of the applicability of any courses and credits earned while enrolled as a student in the Commonwealth Campus program will be made following admission. The acceptability of any courses and credits towards a degree is at the discretion of the department. For additional information and guidelines for this program, please contact the appropriate academic department, the Graduate School, or any Virginia Tech academic center.

5. **GRADUATE CERTIFICATE STUDENTS**– Qualified students who wish to enter Virginia Tech to obtain a graduate certificate in an approved certificate program, should submit a certificate application. The Graduate School requires a minimum grade point average of 3.0 for this category. Official transcripts must be submitted. Students will only be designated in this classification if they are not also seeking a degree. Those students pursuing a degree and a certificate simultaneously are classified in their degree program. Credits used toward a certificate may be used in meeting degree requirements if recommended by the student's advisory committee and department head and approved by the Graduate School.
6. **PROFESSIONAL CERTIFICATION STUDENT**–(Departments of Teaching and Learning and Educational Leadership and Policy Studies only). Admission requirements include an accredited bachelor's degree plus appropriate professional experience. Under this admissions category, a maximum of 9 hours of courses may be taken on a pass/fail basis only, and the courses taken may not be used toward a graduate degree. This admission is a restricted admission and permits students to enter only certain approved courses in these departments. Individual instructors may reject from their courses anyone in this category who does not meet the normal prerequisites.
7. **VISITING GRADUATE STUDENT**–A graduate student in good standing at another university may be permitted to take graduate courses by submitting a Visiting Graduate Student Letter of Approval, available in the Graduate School office or at *http://www.grads.vt.edu*.

GPA

For admission purposes, certain non–academic courses are excluded from the GPA calculation.

ELIGIBILITY OF FACULTY/STAFF FOR GRADUATE DEGREES

Faculty members of the rank of assistant professor or above shall not become candidates for degree or be awarded degrees at this university. The provost's office may be requested to waive this policy for an individual following successful appeal to the Commission on Faculty Affairs.

ADMISSIONS DECISIONS

The applicant's prospective department head and/or a departmental graduate committee review all documents. Major factors taken into consideration in this evaluation are scholastic record, professional experience, recommendations, and scores on standardized tests. Individual departments may have additional admission standards beyond those set forth by the Graduate School.

UNDERGRADUATES TAKING GRADUATE COURSES

SENIORS

Students in their senior year, with a 3.0 or better GPA, may enroll in 5000–level courses satisfying undergraduate degree requirements within their department when qualified by the course instructor and the department head. Taking 5000–level courses outside the department requires Graduate School approval. Should the student become a graduate student, these courses may not be used for graduate credits.

DUAL STUDENTS

Seniors who intend to receive a bachelor's degree, are within one semester of graduation, and have a GPA of 3.0 or better, may take graduate level course work to satisfy an advanced degree program as dual registrants. Such work may only be used to satisfy graduate degree requirements when it is not used for the bachelor's degree and with the consent of the graduate advisory committee.

COMBINED STUDENT STATUS (ARCHITECTURE ONLY)

This status is reserved for qualified students in the bachelor of architecture program who: a) are within 24 semester hours of graduation; b) are proceeding toward one of the two–year master's programs in urban and regional planning or architecture; and c) have at least a 2.75 GPA for the last two years (60 credit hours) of undergraduate studies. Combined students are permitted to take graduate courses. The bachelor of architecture degree is awarded at the end of the first year of graduate studies on acceptance of 24 semester hours of work done instead of the regular fifth year in architecture. A total of 156 semester hours is required for the bachelor of architecture degree.

FIVE-YEAR BACHELOR/MASTER'S DEGREE (OPEN)

Academic units may petition the Graduate School to combine existing bachelor's and master's degree programs into new five–year bachelor/master's degree (open) programs. These programs would allow undergraduate students with a 3.2 or better GPA and the completion of 75 hours of study to enroll in the Graduate School before completion of their undergraduate requirements.

Up to 12 hours of graduate coursework may be taken before the completion of the bachelor's degree. However, a maximum of 6 such hours may be used to satisfy both bachelor's and master's degree requirements.

FIVE-YEAR BACHELOR/MASTER'S DEGREE (HONORS PROGRAM)

Undergraduate students with a 3.5 or above GPA may apply for admission to the Graduate School upon the completion of 75 hours (see department for specific information and additional requirements) of undergraduate study.

The student submits the Application for Graduate Study to the department. Upon approval of the application, the department head will attach a letter affirming the department's acceptance and recommendation of the student into the graduate program and agreement that the student can complete his or her undergraduate studies upon demonstration of 12 hours of graduate study.

The student may be required to complete the Graduate Record Examination/GMAT at the discretion of the department. During the two semesters following admission to graduate school, the student may complete up to 12 hours of graduate work, jointly enrolled in the Graduate School and undergraduate department. Successful completion of 12 hours of graduate work with no less than a "B" average will be considered completion of the last 12 hours of the undergraduate degree.

International Admissions

Legal Status

All international students must hold valid non-immigrant status to enroll at Virginia Tech. International students in F-1 and J-1 visa status are required to carry health and accident insurance approved by Virginia Tech. International students who have been admitted and showed proof of having sufficient funds to cover their educational and living expenses for at least one year are issued visa eligibility documents (I-20 or DS-2019 forms) by the Graduate School. International students currently enrolled for advanced degrees at other American universities are usually expected to complete their degree requirements prior to their admission to Virginia Tech.

Financial Certification

Prior to the issuance of certificates of eligibility to apply for the appropriate visa, all international students must submit a financial certification form, which documents that they have sufficient financial resources for their education. In departments where financial assistance is not available, students may be asked to document sufficient funds for the duration of their degree programs.

English Placement Test

All incoming international graduate students are required to take the English Placement Test (EPT) during the orientation period prior to the beginning of classes unless they have both a TOEFL score of 620/260 or higher and an Essay Writing score (Test of Written English) of 4.5 or higher. This test assesses students' writing ability in an academic setting. Those who fail the EPT are required to take and satisfactorily complete a semester-long Advanced Academic Writing course during the first semester of their enrollment at Virginia Tech, along with their full load of academic classes (9-18 credit hours). There is an additional instructional fee for this course (fee includes the textbooks), taught by the Virginia Tech Language Institute.

SPEAK Test for International Teaching Assistants

International Graduate Teaching Assistants who are assigned classroom or laboratory teaching duties must pass the SPEAK Test before they can begin their teaching duties. Those who do not pass must take English 0014, Oral Communication for International Teaching Assistants (3 hrs., 1 credit) during the semester prior to beginning their teaching assignment. The SPEAK Test is administered individually during the Orientation Period. Additionally, all international GTAs must attend the GTA Workshop for all graduate teaching assistants during the week prior to classes.

Attending at Extended-Campus Locations

International students on F-1 or J-1 visas may pursue graduate degrees in Blacksburg or at certain extended-campus locations. They may not, however, be enrolled in the Commonwealth Campus Program because it is a special non-degree admissions category.

Requirements for Assistantships and Employment

International students on F-1 or J-1 status who obtained regular admission into a degree program are eligible for consideration by the appropriate academic departments for assistantships and in-state tuition scholarships. Part-time employment on campus is subject to federal regulations governing employment of student (F-1) and exchange visitor (J-1) visa holders. Please refer to *http://www.igss.grads.vt.edu* for further information on other visa statuses that may permit enrollment and/or employment on campus.

Enrollment and Readmission Registration Procedures

1. Pre-registration for continuing students is an eight-day period in the middle of each semester during which currently enrolled students may select classes for the next semester. During spring semester, students register for summer school (if they plan to attend) and for fall semester classes. Consult the registrar's website: *www.registrar.vt.edu*.
   a. The student consults with his/her graduate advisor about courses to be taken.
   b. When a schedule is agreed upon, the student may enter course requests by accessing Hokie SPA at *http://www.vt.edu* (choose a Quicklink). Hokie SPA (**S**tudent **P**ersonal **A**ccess) is a World Wide Web application that allows students to check grades, schedules, bills, or financial aid information from any computer running Netscape or Microsoft Internet Explorer. To log in, a Personal ID (PID) is required. New students will receive information on PID creation at the time of admission. Hokie SPA is designed to provide student access to student data, the DROP/ADD process, etc. from home or residence hall; it is not set up for advisor or departmental access to student records.
   c. Overloads (19 hours or more per semester, or 6 each summer session) require permission of the graduate dean.
   d. The student's current class schedule may be printed by accessing Hokie SPA; the student is then responsible for verifying that he/she is in fact enrolled in the courses and sections he/she has been attending. Necessary adjustments are made through the student's academic dean, no later than one week after the end of registration week.

2. Approximately three weeks after the close of pre-registration week, course request results (class ticket) are available and may be printed by accessing Hokie SPA 2000 at *http://www.vt.edu* (choose a Quicklink). The web class ticket will include detailed information regarding sections which are full, conflicting, withdrawn, or restricted, and it explains why these sections were not

added to the student's schedule. See item number six (6) below for details about why a student's course selections are sometimes ignored, or why a student's schedule might be purged or held from registration.

3. Students may adjust their schedules on a space available basis using web DROP/ADD (available through Hokie SPA), an electronic schedule adjustment program.

4. A **FORCE-ADD** form permits admission to a class over the desired capacity. This transaction is done with the pink "force–add" form available in the department offering the course, and requires the instructor's (or, in some departments, departmental) permission. Force–adds are processed by the department offering the course. Caution: the force–add transaction permits enrollment in courses with conflicting times.

5. **LATE ADDS AND DROPS**–Adjustments to a student's schedule after the last date to carry out a specific transaction (see a current Timetable for deadline dates) require permission of the graduate dean. Faculty cannot add or drop students from their rolls and cannot add or drop a student by including or removing his/her name on the final grade sheet. Students enrolled for a single course must submit a resignation form in order to drop the course.

   Classes may be added or dropped after the deadlines only with the approval of the student's advisor and the dean of the Graduate School. Upon recommendation from the major advisor, a student may drop classes without a grade penalty after the deadline under the following circumstances:
   - The student has changed the plan of study and, in the judgment of the advisor and/or department/division head, the course is no longer appropriate.
   - Several class sessions have been missed due to a severe illness or injury that is documented by Health Services or a family physician.
   - The student has been called home because of a death or life threatening illness in the immediate family.
   - Registration for the academic term was incorrect due to a verifiable error. (**NOTE**: A copy of an earlier Drop/Add processed incorrectly or other similar documentation will be required.)
   - Under other extenuating circumstances as deemed appropriate by the graduate dean.

   After the end of the semester, courses may only be dropped with a recommendation from the advisor, the advisory committee and consent of the graduate dean as appropriate. Appeals should be made through the Graduate Appeals Process.

6. **PURGED AND HELD REGISTRATIONS** – Failure to pay tuition bills by a posted deadline may result in the student's schedule being purged (removed from the system). Classes may be dropped for nonpayment the second weekend after classes begin for the term. A schedule may be held (made inaccessible to terminal operators, as well as to students using DROP/ADD, thereby precluding transactions of any type) for nonpayment of tuition fees as well as miscellaneous charges (e.g., parking tickets), for Honor Code violations, for academic ineligibility (due to academic suspension), or for failure to make progress toward a degree. This last hold is imposed by the student's dean, while all other holds are imposed by other offices. The student should check with the office imposing the hold, as only that office is authorized to remove the hold. *Billing is done by the Office of the University Bursar; contact the Bursar's Office if you have questions about your bill or do not receive a bill.*

7. **RESIGNATIONS—**A student may resign without academic penalty by completing an official Virginia Tech resignation form on or before the last day of the eighth calendar week of a fall or spring semester, or equivalent time for summer sessions or special terms for intensive courses. The student can print the resignation form from the Graduate School web site *(http://www.grads.vt.edu)* or can request it from either the Office of the University Registrar or the Graduate School office. The student's grade report and permanent record will show that he/she was enrolled for the term and that he/she resigned on the specific effective date. A student who is considering resigning should view the Virginia Tech refund policy at *www.burser.vt.edu* to determine the financial consequences of a resignation.

   A student who resigns after the stated deadline without written authorization for resignation–without–penalty by the Graduate School dean will receive automatic "F" grades in all courses in which the student is enrolled. The transcript will carry the notation, "Suspended by committee action for unauthorized resignation," and the hours for which "F" grades were received will be included in the cumulative GPA for both academic eligibility and graduation requirements. In the case of authorized resignations after the deadline, grades will not be assigned, and the Graduate School dean will determine the student's academic status (whether or not he/she is eligible to return) based on the student's previous record.

CONTINUOUS ENROLLMENT

Unless on an approved leave of absence, graduate students in degree programs must be registered continuously during the academic year and pay the prescribed fees. The number of credit hours taken should reflect the extent of a student's study or research activity.

LEAVE OF ABSENCE

A student may petition for a leave of absence. A leave will be granted under conditions requiring the suspension of activities associated with the thesis/dissertation or course work. The petition must be submitted two weeks before the beginning of the semester for which the leave is requested. A student seeking a leave of absence should complete the *Request for Leave of Absence* form that can be obtained from the Graduate School office in Sandy Hall or downloaded from the Graduate School Home Page *(http://www.grads.vt.edu)* under Current Student information–forms. The leave of absence must be approved by the student's advisor and the department head (or designated representative) before submission to the dean of the Graduate School. If the dean of the Graduate School grants the petition, the registration requirement will be relaxed during the period of leave. The academic department or the Graduate School may stipulate

conditions for the student's return from the leave of absence. International students should also consult the immigration advisors in the Graduate School before taking a leave of absence.

CHANGE OF GRADUATE PROGRAM

A change of graduate program requires the approval of the department head of both the old and new programs and the dean of the Graduate School. Students wishing to change programs should work with their current departments to obtain the required approval. Once this approval is obtained, the Graduate School will forward materials to the new department. If for any reason the new department does not recommend admission, the student will be dropped from the rolls of the Graduate School.

RE-ENROLLMENT/RE-ADMISSION/CHANGE OF ADMISSION STATUS

Re–enrollment/Readmission: Students sometimes experience situations in which they cannot be continuously enrolled. The readmission form should be used when a student has not been enrolled for more than two semesters, excluding summer. This form should also be used when returning from a leave of absence.

Change of campus: Students wishing to study at a different campus, but remain in the same major, should submit a change of campus form.

Change of admission status: Students wishing to change admission status, while remaining in the same major, should submit a change of admission status form. This form can only be used if a student is remaining in the same major, has not missed more than two semesters exluding summer, and only desires an admission status change. Examples: Commonwealth Campus to Masters, Masters to Ph.D. in the same major.

GRADING SYSTEM

Assignment of grades is the responsibility of the instructor. The university has adopted the following grading system:

LETTER GRADE	NUMERICAL VALUE (GPA)
A	4.0
A–	3.7
B+	3.3
B	3.0
B–	2.7
C+	2.3
C	2.0
C–	1.7
D+	1.3
D	1.0
D–	0.7
F	0.0

Grades in all courses, including those not counted for graduate credit, are calculated into the GPA. There are in addition to the above grades: I (incomplete), P (taught on a Pass/Fail basis only), X (continuing courses), and EQ (review or equivalent credit for research credit). NR (no grade) calculates as 0.0 in computing the GPA.

THESIS/DISSERTATION/MAJOR PAPER

A grades is not given for a thesis, dissertation or major paper; however, each thesis, dissertation, or major paper is assigned equivalent credit hours assuming satisfactory progress has been made. The NR grade can be given when progress on a thesis or dissertation has not been satisfactory.

INCOMPLETE GRADES

An incomplete ("I") may be given when the requirements of a course have not been completed because of illness or extenuating circumstances.

Grades of "I" must be removed before the end of the student's next subsequent semester of enrollment. A grade of "I" for a laboratory course must be removed during the next subsequent semester of enrollment when the course is offered. Grades of "I" may be removed during a period when the student is not enrolled at the university. Incompletes not removed during the designated time will be changed to "F."

Grades of "X" are assigned initially to course work that extends over more than one semester.

PASS/FAIL

A limited pass/fail grading system is available to encourage students to explore courses outside their major. Under the pass/fail grading system, a "P" is granted for earning a "C–" or better in a course. Otherwise, an "F" is given. The "P" or "F" will be recorded on the student's transcript and credit is given if the course is passed. The GPA is unaffected by a "P," but an "F" is included in the calculation of the GPA. The pass/fail letter grade option should be declared at the time of registration and may not be changed after the last day to add classes without the signature of the instructor, student's major advisor, and the Dean of the Graduate School.

Graduate students are permitted to take courses on a pass/fail basis, if outside the department, not on their plan of study, and approved by their advisor. Such courses may not be used to satisfy minimum degree requirements. All courses on the plan of study, that satisfy degree requirements, must be taken on a letter grade (A–F) basis except for those courses offered on a pass/fail basis only. Once credit is received for a course taken on pass/fail, the course may not be repeated under the A–F grading system.

AUDITING

An audit requires approval of the instructor and the student's graduate advisor. Auditing of laboratory work is not permitted. Registration for audit may not be changed to credit, or vice versa, after the last day to add classes without the signature of the instructor, student's major advisor, and the dean of the Graduate School. At the end of the course period, the instructor will determine if an audit is "satisfactory" or "unsatisfactory" based on participation and other expectations set forth at the beginning of the course period. Audited courses do not count toward full–time enrollment. In order to follow the governance directive that unsatisfactory audits do not apear on transcripts, the Graduate School drops (on request) any NRs awarded. Therefore, the GPA is not affected. Students are assessed the same rate for tuition and fees for audting courses as for courses taken for credit.

REPEATING COURSES

All courses on the plan of study must be taken for a letter grade. Students will be required to repeat any such courses in which a grade below "C–" is earned.

Courses originally taken on the P/F option must be repeated on a P/F basis. Courses in which a "P" grade or a grade of "C–" or better is earned may not be repeated.

Graduate Credit

Students must have a recognized status with the Graduate School and be officially registered to earn graduate credit.

Correspondence Credit/Independent Study in Absentia

No credit toward graduate degrees may be obtained by correspondence study. Independent study done in absentia must have regular faculty consultation.

Transfer Credit

Up to 50% of the graded credit hours needed to satisfy requirements for a Virginia Tech graduate degree may be transferred in from an accredited institution. All such credits must have earned grades of "B" or better, have been earned while a graduate student was in good standing, and be acceptable for graduate degree credit at the "home" institution. Grades of "S" or "P" are not acceptable. All transfer courses must be acceptable to the student's advisory committee and must have been completed within the time limits prescribed for satisfying degree requirements. Credits are transferred when they are entered on the plan of study and approved by the Graduate School. Transferred courses count only as credit hours and are not included in the calculation of the GPA. Research hours may not be transferred in from another institution for Virginia Tech graduate degree requirements. Official transcripts are required for coursework transferred from other universities.

Accelerated Courses

Students may not receive more than one-half of the course credits (excluding 5994 and 7994) required for graduate degrees from courses taught in a period less than an academic semester or summer session. Not more than one accelerated and one regular course may be taken concurrently and not more than one and one-half hours of credit may be earned per week.

Independent and Special Study Courses (5974 and 5984)

All departments are authorized to offer Independent Study and Special Study courses to allow students to pursue subject matter study in areas for which there are no approved formal courses. Independent Study courses generally involve extensive reading and tutorial sessions with the faculty supervisor and also may involve written papers. The subject of Independent Study usually is a continuation in greater depth of a topic covered in a regular course, allowing students to study topics of particular individual interest.

Special study courses are designed for a group of students, rather than for a single individual. This type of course may be used to study a timely topic, one in which there is current, but not lasting, interest. It also may be used as an experimental course before incorporating it into the regular curriculum.

Independent study courses are not to be used for additional research of the type covered under 5994 (Research and Thesis) or 7994 (Research and Dissertation). If the intended independent study relates closely to a student's research problem, it is more appropriate to register for 5994 or 7994 credits than for 5974.

The use of independent study courses (hours of 4974, 5974 and 6974 combined) and special study courses (hours of 4984, 5984 and 6984 combined) on plans of study for advanced degrees is subject to the following limits:

- For master's degree programs requiring no more than 33 total hours, a maximum of 6 hours of independent study courses and a maximum of 6 hours of special study courses, with the total for both independent study and special study courses of no more than 9 hours, may be used on the plan of study;
- For master's degree programs requiring more than 33 but no more than 48 total hours, a maximum of 9 hours of independent study courses and a maximum of 9 hours of special study courses, with the total for both independent study and special study courses of no more than 12 hours, may be used on the plan of study;
- For master's degree programs requiring more than 48 total hours, a maximum of 9 hours of independent study courses and a maximum of 9 hours of special study courses, with the total for both independent study and special study courses of no more than 18 hours, may be used on the plan of study;
- For the doctoral degree, a maximum of 12 hours of independent study courses and a maximum of 12 hours of special study courses, with the total for both independent study and special study courses of no more than 18 hours, may be used on the plan of study.

The designations used for Independent Study courses are as follows:

4974: Independent Study at the Undergraduate Level**.** May not be used for graduate credit.

5974: Independent Study at the Graduate Level**.** Requires a syllabus, a title, justification, and the method of evaluation. Independent study courses may be used to satisfy degree requirements and they should meet on a regular basis. Independent study courses are offered on a pass/fail basis only. The department head and college must approve syllabi for 5974 courses. The course syllabi should contain a distinct title, not simply "Independent Study".

The designations used for Special Study courses are as follows:

4984: Special Study at the Undergraduate Level**.** Requires a syllabus and method of evaluation. Credits for 4984 courses approved for graduate credit may be used in meeting degree requirements.

5984: Special Study at the Graduate Level**.** Requires a syllabus and method of evaluation. Credits may be used in meeting degree requirements. They are not to be offered on a recurring basis but they may be courses that are being tested before being proposed as regular courses.

Syllabi for 4984 and 5984 courses should be submitted to the Graduate School office at least 10 days before the end of the semester preceding the semester the course is to be offered. All 4984 and 5984 syllabi must be approved by the department head and the college before being submitted to the Graduate School. The course syllabi should contain a distinctive title, not simply "Special Study."

GRADUATE ASSISTANTSHIPS

Assistantships may be offered to graduate students admitted on a "Regular" or "Provisional" (GPA of 2.75–2.99) basis. To continue to be eligible, a student must be enrolled full-time (12–18 hours), maintain a GPA of 3.0 or higher and make satisfactory progress toward attainment of an advanced degree. Exact stipends depend on the work required of the student, the department, and the academic level of the student. Each department funds students according to a step system.

Graduate teaching assistants are not permitted to accept fees for tutoring students enrolled in any section of a course they are currently teaching. They are permitted to tutor for payment otherwise under university consulting policies and employment regulations.

ACADEMIC ELIGIBILITY

GRADUATE CERTIFICATE REQUIREMENTS

Certificates can be awarded to individuals who do not desire to work toward a degree. Certificate candidates must be formally accepted before taking courses. Upon successful completion of certificate requirements, academic programs will complete a *certificate completion verification form*. This form should be signed and submitted before the end of the semester in which the certificate will be awarded. Students working toward a graduate certificate should submit an *application for certificate conferral* by the published deadlines for the term in which the certificate will be awarded. This ensures that the certificate will be ordered and that the student's name will appear in the commencement bulletin.

DEGREE REQUIREMENTS

Students must obtain a 3.00 GPA, both overall and for courses on the plan of study. All courses on the approved plan, including prerequisites and supporting courses must be completed with a grade of "C" or better.

GRADUATE ASSISTANTSHIPS

Students holding a graduate assistantship must maintain a minimum 3.00 GPA on all work attempted to continue to be eligible for financial assistance. The academic department or the Graduate School may allow students one semester to remedy grade deficiencies.

PROBATION

The Graduate School does not adhere to a rigid academic eligibility schedule. However, students whose cumulative GPA falls below a "B" (3.00) average are usually placed on probation.

Enrollment for one semester of probation is normally permitted to remedy an unsatisfactory GPA. If, in the judgment of the faculty and the dean of the Graduate School, the student is incapable of making satisfactory progress, permission to continue in the graduate program will be denied, and the student will be dismissed from the university.

SATISFACTORY PROGRESS

If a student fails to make satisfactory progress toward the degree, permission may be denied to continue the program. This decision may be reached by the advisory committee, a committee in the department, or the department head, and recommended to the Graduate School. Unsatisfactory progress on the thesis or dissertation may result in NG (no grade) on 5994 or 7994.

CREDIT HOUR LOADS

EMPLOYED GRADUATE STUDENTS

The Graduate School recognizes that many students depend on part-time employment (including assistantships). University policy prescribes the following upper limits on graduate academic loads for employed students. Students on full assistantship are assumed to be 50 percent employed.

MAXIMUM STUDENT CREDIT LOAD

PERCENT EMPLOYED	ACADEMIC SEMESTER	EACH SUMMER TERM
100	6	3
75	9	3
50 or less	12–18	6–9*

* Maximum 12 hours of course work in both summer terms (maximum of 9 hours in any one term).

FELLOWSHIP RECIPIENTS

Fellowship and scholarship recipients are required to take no less than 12 credit hours each semester in which they are receiving a stipend. These hours must represent work toward satisfying minimum degree requirements. Audited courses do not qualify in satisfying this minimum.

ENROLLMENT

Full-time enrollment for graduate students consists of a minimum of 9 hours and a maximum of 18 hours per semester during the academic year. However, graduate assistants (GAs, GTAs, and GRAs) and fellowship and scholarship recipients may not enroll for fewer than 12 hours per semester. These hours must represent work toward satisfying minimum degree requirements. Audited courses do not qualify in satisfying this minimum. Graduate assistants are not required to enroll during summer sessions.

VIRGINIA TECH FACULTY AND STAFF

Full-time salaried employees, meeting admission requirements and with the approval of their department, may have waived or reimbursed twelve (12) credit hours per academic year (Fall through Summer II), not to exceed six (6) hours in a Fall, Spring, Summer I, or Summer II term. Part-time salaried employees are also eligible for tuition waiver. The maximum of twelve (12) hours will include tuition waiver, tuition reimbursement, or a combination of both. For more information, please refer to the Personnel Services website: *http://www.ps.vt.edu*.

DEGREE REQUIREMENTS

UNIVERSITY DEGREE REQUIREMENTS FOR GRADUATE STUDENTS

For graduate students, the university degree requirements are those identified in the graduate catalog effective for the academic year in which the students were admitted. The departmental requirements are those effective at the time of filing the Plan of Study. If the requirements change during the time the graduate student is enrolled, the graduate

student can choose, but is not required, to abide by the "new" requirements. For graduate students on leave status for more than one year, requirements will be reviewed on a case–by–case basis.

Requirements for Master's Degrees

Virginia Tech allows for both thesis and non–thesis master's degrees. For each degree type, the student's plan of study must meet the requirements shown below. These are minimum requirements that individual departments or advisory committees may exceed. Students are encouraged to consult individual departments for particular requirements. A course required for an undergraduate degree in a given area may not be used toward a graduate degree in the same area. Any courses listed on the plan become a part of the requirements for the degree, must be completed with a grade of "C" or better, and count toward the minimum GPA of 3.0 for fulfilling degree requirements.

Second Master's Degree

The requirements for a second master's degree are the same as for the first master's degree: an additional 30–54 hours, depending upon the degree sought. A student working on a second master's degree may transfer up to 50% of appropriate courses (see the section entitled 'Transfer Credit').

Certificate of Advanced Graduate Study (CAGS)

The Center for Public Administration and Policy CAGS program affords the student the opportunity to develop an advanced level of post–master's specialization in a public policy field (e.g., energy, human resources, or environmental policies) or a public management field (e.g., finance or personnel). This program recognizes the successful completion of 60 hours of doctoral level work, including the Preliminary Examination. Students with master's degrees who can profit from doctoral coursework but do not need or wish to write the dissertation are invited to apply. For more information, please see: *www.cpap.vt.edu*.

Students applying for the CAGS must initiate a clearance form through their course advisor and send it to the Graduate School. Also, an "Application for Degree" must be submitted to the Graduate School.

Education Specialist Degree

The Education Specialist Degree is a planned 30–credit (minimum) post–master's program. In this program, candidates are expected to attain a broad and systematic understanding of professional education, a definitive knowledge of a particular field of specialization and the ability to integrate and apply theoretical concepts of education in an actual educational context. This program is designed for the accomplished, experienced practitioner with special professional aspirations. It is not designed for those who wish to pursue a research emphasis as a prelude to a doctoral study.

The Ed.S. degree may be pursued in the following areas: Administration and Supervision of Special Ed., Curriculum and Instruction, Educational Leadership and Policy Studies–Educational Leadership (K–12) and Higher Education and Student Affairs–and Career and Technical Education.

Requirements for Doctoral Degrees

Doctor of Philosophy (Ph.D.)

Credits: Each doctoral student must complete a minimum of 90 semester hours of graduate study and a dissertation. The plan of study must meet the following requirements. These are minimum requirements and individual plans may be exceeded as required by a department or an individual's advisory committee. Courses numbered lower than 4000, or 4000–level courses other than those permitted by footnote 4 below, should be listed on the plan as supporting courses. A course required for an undergraduate degree in a given area may not be used toward a graduate degree in the same area, except through an approved departmental exception. Any courses listed on the plan become a part of the requirements for the degree, must be completed with a grade of C– or better, and count toward the minimum GPA of 3.0 for fulfilling degree requirements.

Requirements for Master's Degree

	Minimum Total Graduate Credits	Minimum Graded Graduate Credits	Minimum Research Hours
Thesis	30	20[1] (12 credits of 5000–level or higher)	6
Non–Thesis	30	24[2] (15 credits of 5000–level or higher)	

[1] A maximum of 12 credits in 4000-level courses (approved for graduate credit) and 6 credits total in 5974, 5984, and 6984 courses.

[2] A maximum of 9 credits in 4000-level courses (approved for graduate credit) and 9 credits total in 5974, 5984, and 6984 courses.

DOCTORAL DEGREE REQUIREMENTS

	SEMESTER CREDIT HOURS[1]	
	MINIMUM	MAXIMUM
Research and Dissertation (5994 and 7994)	30	–
Courses numbered 5000 or higher [2]	27[1]	–
4000–level courses [3]	0	–
Seminars (subject matter unstructured) [4]	0	4
Courses numbered 5974, 5984, and 6984[5]	–	18

[1] Departments may petition the Commission on Graduate Studies and Policies for permission to reduce the minimum number of graded course credits required for a specific degree program. The petition must provide clear justification and rationale for the requested reduction in requirements.

[2] Courses numbered 5000 or above may not be taken on a pass/fail basis except when offered P/F only.

[3] A maximum of 6 credit hours may be in 4000–level courses that are not approved for graduate credit provided that the courses are outside the student's major field and are of a level warranting graduate credit for the area in which the student is receiving the degree or if judged to be appropriate by the student's advisory committee, e.g., where significant differences in areas of concentration or departmental undergraduate requirements exist in other colleges or universities or in fields where students are likely to change majors at the time of admission to graduate school. The advisory committee must explain why the departmental exception applies to each student. Any number of 4000–level courses approved for graduate credit may be counted toward the 90 hour total, provided that all other requirements are met.

[4] Seminars may be taken on a pass/fail basis, and may be used toward meeting the minimum requirements in courses numbered 5000 or higher.

[5] Courses numbered 5974, 5984, and 6984 may be used in meeting minimum requirements in courses numbered 5000 or higher. Special study courses subsequently approved as regular courses do not count toward the maximum permitted special study credit hours, except through an approved departmental exception.

Where major and minor fields are not specified, the advisory committee will develop a plan of study to meet the student's needs.

RESIDENCY REQUIREMENTS FOR PH.D. AND ED.D.

At least 24 graduate–level credit hours, including no less than 15 hours of course work (not research 7994), must be completed while in residence at the Virginia Tech Blacksburg campus. Students may receive residence credits during the summer sessions, but not during any academic year semester(s) in which they are enrolled for fewer than 6 credits or if they are employed more than one–half time (that is, a maximum obligation external to their academic program of 20 hours a week). The Graduate School may grant policy exceptions to individual degree programs and students.

The Graduate School may permit individual degree programs to allow their students to satisfy the residency requirement at non–Blacksburg locations. Requests for such alternative location residency must be made in writing to the Graduate Dean (by letter for existing programs or as part of the program proposal for new programs). Such requests must provide a discussion of how the particular program at the alternate location will achieve the residency purposes. Where the proposed alternate residency location is a commercial entity or government laboratory, the request must include an agreement between the university and the commercial entity or government laboratory. Such agreement will specifically define the research environment that will be maintained to meet the residency requirement. The Graduate School will report annually to the Commission on Graduate Studies and Policies on the success level of the alternative residency. The Graduate School retains the right to withdraw the permission for such alternate forms of residency, if deemed necessary.

The Graduate School may grant exceptions to the 20–hour external work limitation to individual students enrolled in programs with alternative location residency. Requests for changing the 20–hour work schedule must include an agreement between the university, the student's employer, and the student. The requests should define the research environment that must be maintained at the alternative location for the duration of the Ph.D. student's residency. An endorsement letter from the student's academic advisor must accompany the request.

REQUIREMENTS FOR THE DOCTOR OF EDUCATION AND DOCTOR OF PHILOSOPHY IN EDUCATION

Residency for the Ed.D. involves full–time study during two consecutive semesters (including summers, which must be of an extended nature – this also applies to the Ph.D. in educational research and evaluation.) The dissertation for the Ed.D. typically demonstrates the candidate's ability to investigate phenomena in educational institutions or service agencies to increase practitioners' understanding of practical problems and issues. The Ed.D. student and the advisory committee develop and submit a plan of study that is designed to build on the unique strengths and interests of the individual. A total of 90 graduate credits is required for the degree.

Residency for the Ph.D. involves two consecutive regular semesters (exclusive of summers) of full–time enrollment to permit a close association between the candidate and the advisor/advisory committee. The dissertation for the Ph.D. demonstrates the candidate's ability to conceptualize, conduct, describe, and defend an original investigation that makes a significant contribution to the professional literature. A total of 96 graduate credits (90 for the Ph.D. in EdRE) is required for the degree.

PURPOSES OF THE RESIDENCY REQUIREMENT FOR DOCTORAL DEGREES

The basic goals for doctoral students include the ability to understand and critically evaluate the literature of their field, to understand the issues and problems at the frontiers of knowledge in their field, and to cultivate and exercise their ability to make original contributions to knowledge in their field. These goals are not exclusive to particular career paths, but are fundamental to the level of achievement and mature scholarship that the doctorate certifies. Specific purposes of residency are based on recent recommendations of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (Reshaping Graduate Education, National Academy Press, 1995) and the residency requirement of the Southern Association of Colleges and Schools (the accrediting agency for Virginia Tech):

1. To ensure access to a wide spectrum of courses in the student's own discipline as well as related disciplines.
2. To ensure regular and substantial interaction with an adequately large pool of qualified faculty. This is important not only to support dissertation work and studies, but as a source of advice, perspective and guidance in formulating career objectives.
3. To ensure a similar level of interaction with fellow graduate students.
4. To guard students against a parochial view of their discipline, in which narrow focus in their specialty excludes experience with other disciplines.
5. To guard against over–specialization, and provide a broad range of professional development.
6. To ensure access to full–scale library and laboratory resources.
7. To provide access and exposure to a wide spectrum of seminars, professional presentations, and contact with leaders in their own discipline as well as others.
8. To ensure quality and rigor of the program through involvement with and scrutiny by peers in other disciplines.
9. To require that students transferring several course credit hours from other institutions complete a minimal amount of course work at Virginia Tech.

The traditional residency requirement addresses these objectives by bringing the student into the rich academic environment of the multidimensional university campus. The purpose of the 20–hour external work limitation in particular is to ensure that the student's involvement with the campus' culture of study and discourse is substantial. The level of fluency and accomplishment at the frontiers of one's discipline that the doctorate represents cannot be achieved if students are never involved with more than 50 percent of their effort and intellectual energy.

Second Doctoral Degree

A student seeking a second doctoral degree, regardless of whether the first was earned at this university, must earn a minimum of 48 additional semester credit hours and must satisfy additional residence requirements specified for the doctoral degree.

Plan of Study

Approval

All graduate students must submit an approved plan of study. The plan of study must meet the minimum requirements for the designated degree, and must be approved by the student's advisor or advisory committee, the department head, and the Graduate School. All courses on the plan of study, including supporting courses, will be taken on a letter grade ("A"–"F") basis except for those courses approved to be graded on a pass–fail basis only (no audit courses).

The plan of study should be submitted to the student's department to be entered and sent electronically to the Graduate School for approval, according to the following schedule.

Master's: Before completing 15 credit hours in the M.S. program (before 30 credit hours for the master of architecture or master of urban and regional planning).

Ph.D.: Before completing 15 credit hours in the Ph.D. program.

Ed.D.: No later than 30 days following the successful completion of the required qualifying examination.

Plan of Study Changes

A plan of study change form (available on line at *http://www.grads.vt.edu*) is necessary whenever the student wishes to alter the plan of study. The plan of study change must be approved by the student's department head, advisory committee and the Graduate School. Once a course on the plan of study is taken for a grade, it must remain on the plan of study.

A master's degree candidate is allowed to change from the thesis to the non–thesis option (or vice versa) once. Such action requires written approval of the department head and the major professor.

Supporting Courses

Courses numbered lower than 4000, or 4000–level courses not approved for graduate credit, should be listed on the plan of study as supporting courses. Prerequisites should be taken as supporting courses. All courses listed on the plan of study are requirements for the degree. Such courses must be completed with a grade of "C–" or better and count toward the minimum GPA of 3.0.

Courses not approved for Graduate Credit

A course required for an undergraduate degree in a given area may not normally be credited toward a graduate degree in the same area. Exceptions to this regulation are granted to specific departments by action of the Commission on Graduate Studies and Policies. In those cases, up to 3 semester hours of 4000–level courses not specifically approved for graduate credit may be included as part of a master's degree plan and 6 as part of a doctoral degree plan of study. Departmental exceptions are granted in fields where significant differences in areas of concentration or undergraduate requirements exist in other colleges or universities or in fields where students are likely to change majors at the time of admission to Graduate School. The advisory committee must explain why the departmental exception applies to each student.

Advisory Committee

Master's students must have an advisory committee of at least three faculty members. Doctoral candidates must have an advisory committee of at least four faculty members.

This advisory committee approves the plan of study, provides advice, and periodically assesses progress and accomplishments. All committee members are appointed by the Graduate School on recommendation of the department head. It is appropriate but not required that the committee includes at least one faculty member from outside the student's major department. Committee chairs must be full–time faculty or research professors affiliated with an academic program. The student should refer to the departmental policies and procedures document for specific guidelines.

Faculty are not permitted to serve as major advisor or committee member for individuals with whom they have a personal or professional conflict of interest (e.g., spouse, son, daughter, business associate, etc.).

Changes in a student's committee will be granted only on approval of all committee members, new and old, and recommended by the department head/chair. In the case that one or more members does not approve the change in the membership of the advisory committee, an appeal may be made by either the student or a faculty member to a department graduate committee. The graduate committee will make a recommendation for action to the department head and the dean of the Graduate School.

NON-FACULTY PERSONNEL

Non–faculty personnel may be recommended for inclusion on a graduate student advisory and/or examining committee, but not for committee chairs. Such personnel should meet the standards of academic training and research experience expected of faculty members serving on such committees. Approval of the inclusion of such personnel is requested by the student's major professor to the dean of the Graduate School and particular advantages of such a nomination should be cited. Non–faculty personnel shall make up no more than one–third of the total committee membership, may share thesis/dissertation supervision responsibilities, and enjoy voting rights and privileges. Non–faculty committee members will be listed by their professional titles and affiliations. Graduate students may not serve on an advisory and/or examining committee.

THESIS AND DISSERTATION

Theses and dissertations are submitted electronically (ETD). For instructions, see *http://etd.vt.edu/* and Appendix I of this catalog. For departments where the non–thesis option is available, a master's degree candidate is allowed to change from the thesis to the non–thesis option (or vice versa) once. Such action requires written approval of the department head and the major professor. A dissertation is required of all doctorate candidates.

INDEPENDENT EFFORT

Two or more students may work on the same total problem; however, each student must prepare an independent thesis or dissertation.

COMMITTEE APPROVAL

A thesis/dissertation must be evaluated by all members of a student's advisory committee. Committee members signify approval or disapproval by signing the thesis or dissertation (ETD) approval form in ink. If a committee member does not approve the thesis/dissertation, upon the faculty member's request, non–approval will be designated on the ETD. A successful candidate is allowed, at most, one negative vote.

DEADLINE FOR SUBMISSION

Final version of the thesis/dissertation/major paper (ETD) must be submitted electronically to the Graduate School no later than two weeks after the successful completion of the final examination. If this deadline cannot be met, a request (by e–mail is preferred) for an extension should be sent to the dean of the Graduate School by the advisor.

COPYRIGHTING

The Graduate School does not require students to register their copyright. For those doctoral students that elect to register their copyright, there is an arrangement with University Microfilms (UMI). The form and guidelines for payment for this optional service are included in the booklet that is provided by UMI in the student's defense packet. If a master's student wishes to register the copyright, they must apply directly through the Library of Congress Copyright Registration Office. More information concerning the requirements and cost of copyright registration can be found at *http://www.copyright.gov/register/*.

INTELLECTUAL PROPERTY

A University Intellectual Property Policy was adopted in 1986 by the university's board of visitors. The policy applies to copyrightable material, patentable inventions, and other creations conceived by any faculty member, staff member, or student employee when substantial university resources, such as money or equipment, are used in connection with the conception and/or development of the creation. All such creations are the property of the university and subject to any applicable agreements with funding agencies.

If a student employee has conceived a creation, which may belong to the university pursuant to the Intellectual Property Policy, it is his or her responsibility to report promptly the creation to the university. All creations must be reported to the Office of the Vice Provost for Research. Creations must be reported before publication of the item, or before publication of information relative thereto or before disclosure to an outside firm or agency. Under the existing policy, net income to the university in the form of royalties (etc.) from the creation may be shared equally with the creator(s).

Copies of the Intellectual Property Policy and assistance in reporting creations may be obtained from the Office of the Vice Provost for Research.

MICROFILMING

All dissertations must be submitted to University Microfilms (UMI). UMI publishes the abstract in *Dissertation Abstracts*, microfilms and archives the dissertation and makes the dissertation available to users as a paper or electronic copy. Students may limit the distribution of their dissertation by UMI. A form is included in the student's defense packet to notify UMI about the student's restriction on distribution. The UMI processing fee is included in the archiving fee that is paid to the Graduate School.

EXAMINATIONS

All examinations are open to the faculty and faculty members are encouraged to attend and participate in such meetings. The student must be registered during the semester in which the required examination is taken. If a thesis, dissertation, or major paper is not required, a student may be enrolled in another institution for the final semester provided any courses that are to be transferred appear on the plan of study. Official transcripts for such work must be received by the Graduate School and transfer credit may not exceed the established minimum.

DEFENDING STUDENT STATUS

If registration is for GRAD 6864: Master's Defense or GRAD 7864: Doctoral Defense, the minimum registration is for 1 hour and the defense must occur within the first 20 class days of the term. If not, minimum registration for 3 hours is required.

Students should submit a Defending Student Status (DSS) form to the Graduate School two weeks before their defense, and if DSS is approved the Graduate School will register the student. Students should not enroll themselves in Defending Student Status.

Students enrolled as defending students will be classified as less than half–time for certification purposes. This status may not meet the minimum requirement for most student loan deferments. Students may wish to take into consideration their student loans when applying for "defending student" status. International students should consult the Graduate School concerning the visa implications of this status. Students on Defending Student Status are not eligible to hold assistantships or fellowships.

SCHEDULING EXAMINATIONS

Examinations are usually administered during regular academic semesters or sessions, i.e., between the first day of classes for a given semester or session and ending with the last official day for examinations.

Examinations required by the Graduate School (Preliminary and Final), are scheduled through the Graduate School office. Requests to schedule the examination should be received at least two weeks before the date requested. Examination cards should be obtained from the Graduate School on the day of the examination. The card should be returned to the Graduate School office as soon as possible after the examination. Requests to schedule final examinations should include the time, date, building and room number, title of dissertation, and the names of the recommended examining committee.

COMPLETION OF EXAMINATION

To pass any of the required examinations, a candidate is allowed at most one negative vote. If a student fails an examination, one full semester (a minimum of 15 weeks) must elapse before the second examination is scheduled. Not more than two opportunities to pass any one examination are allowed. Students failing any of the mandatory examinations two times will be dropped from the university.

FINAL EXAMINATION (MASTER'S)

An oral and/or written final examination is required of all master's programs (see departmental policy for specific format). Please review the preceding sections on Registration, Scheduling of Examinations, and Completion of Examinations for appropriate information. The examining committee will be composed of a minimum of three members, and it normally would be the same as the advisory committee. For some non–thesis master's programs, final exams are not structured as above. For more information about such programs consult the departmental policies and procedures document.

QUALIFYING EXAMINATION (DOCTORAL)

Certain departments require doctoral candidates to take a qualifying examination, usually given at the end of the first year of graduate study. The results are typically used to evaluate subject mastery, to determine deficiencies, and to determine whether the student should continue. The results of qualifying examinations are made part of the student's departmental record. Qualifying exams need not be scheduled through the Graduate School.

PRELIMINARY EXAMINATION (DOCTORAL)

The preliminary examination is a requirement for all doctoral students. This examination must be taken at least nine (9) months before the final examination. At least 24 hours of course work and/or research must remain to be taken, including work for which the student is currently enrolled. The examination is administered by the student's advisory committee with at least four members present in accordance with departmental and Graduate School policies, and may be oral, written, or both. The timing of the preliminary exam is within the purview of the advisory committee. An expected date (semester/year) for completing the preliminary examination must be submitted with the Plan of Study for approval by the Graduate School. The actual date of the preliminary examination may be changed in the same manner as that prescribed for changes in the Plan of Study.

Please review the preceding sections on Registration, Scheduling of Examinations, and Completion of Examinations for appropriate information. Individual departments may choose to administer the preliminary examination as a departmental examination. In this case the examination is typically administered by a committee with all members certifying the results. The results are to be reported to the Graduate School within two weeks after administration of the examination.

FINAL EXAMINATION (DOCTORAL)

All doctoral candidates must take a final written and/or oral examination, which is typically a defense of dissertation. This examination must be scheduled no earlier than nine months after successful completion of the preliminary examination. Please review the preceding sections on Registration, Scheduling of Examinations, and Completion of Examinations for appropriate information. This examination may be administered by the advisory committee (at least four members must be present) or a committee appointed by the dean of the Graduate School. To be eligible for graduation at the end of the semester, all final examinations must be completed and dissertations approved by the Graduate School at least 10 business days before the university commencement exercises.

TIME LIMITS

Academic work, including transfer credit, must meet the time limits specified below. Course work may be revalidated by written and/or oral examination upon petition to and approval by the dean of the Graduate School.

Requests for revalidation of out–of–date courses must be submitted by the advisor and include signatures of all members of the student's advisory committee. Course work that does not lie within the expertise of the committee members should be revalidated by a specialist in the area(s) involved. Revalidations are required in the following cases:

1. Course work more than five years old at the time of submission of the plan of study must be revalidated to count toward the master's or doctoral degree.

2. a) Course work on the plan of study must be completed within five years after the plan of study is approved or revalidated to count towards the master's degree.

   b) Course work on the doctoral plan of study must be completed within seven years after approval of the plan of study. Revalidation of course work is required if the preliminary exam for the doctoral degree has not been completed within seven years after approval of the plan of study.

PROCEDURES FOR GRADUATION

Students anticipating graduation must file an **APPLICATION FOR DEGREE** to have their names appear in the Commencement Bulletin and to obtain a diploma. The fee for the Application for Degree is $25. The Application for Degree should be submitted electronically through Hokie SPA in accordance with the following schedule:

COMPLETING DEGREE REQUIREMENTS IN:	APPLY ON OR BEFORE:
June	June 1
August	August 1
December	October 1
May	March 1

All applicants for degrees/certificates must submit an Application for Degree/Certificate Conferral no later than dates specified in table above.

ACADEMIC REGALIA

Infomation on master's and doctor's regalia is available from the University Bookstore, Clothing and Gifts department, 800–392–2756 or 540–231–5991, extension 147.

CLEARANCE PROCEDURES

Certain requirements and procedures relating to scheduling final examinations, payment of archiving/microfilming fees and the submission of final copy of thesis or dissertation are presented below.

SUMMARY OF PROCEDURES

The procedures for a candidate for the master's or doctorate degree, or certificate include:

1. Scheduling of final examination, two weeks before exam
2. Taking final examination
3. Application for degree (or certificate conferral), payment of fee
4. Submitting the final authorized version of the ETD within two weeks of defense
5. Submitting the completed and signed ETD approval form (http://etd.vt.edu/submit/)
6. Submitting any applicable supporting documentation for the ETD, i.e.: copyright permission letters to reproduce items, IRB approval or exemption notices, UMI form, suvey of earned doctorates
7. Payment of the archiving fee to the Graduate School (see ETD fees)
8. The ETD process is not considered complete until submission is approved by the Graduate School.

A student must be registered (as defending student or for a minimum of 3 credit hours for a semester or summer session) during the semester of the final examination (students on assistantships and fellowships must be registered for the minimum credits specified in "Credit Hour Loads"). Final examinations are usually scheduled within periods beginning with the first day of classes for a given semester or session and ending with the last official day of examinations. Examinations are not usually administered between semesters or sessions.

At least two weeks prior to the date of the final examination, "The Request to Admit Candidate to Final Examination" from the major advisor (with a copy to the department head) must be submitted to the Graduate School Office recommending the time, date, room number, building, title of thesis or dissertation, and names of the committee members.

The examination packet containing the examination card, allowing the student admission to the examination, should be obtained from the Graduate School on the day before or the day of the examination and should be returned to the Graduate School Office as soon as possible after the examination.

ETD FEES

An archiving fee is required by all students submitting an Electronic Thesis/Dissertation (ETD). The fee of $20.00 for master's students and $75.00 for doctoral students must be paid at the time of ETD submission.

COMMENCEMENT PARTICIPATION

Master's students who have completed, and those nearing completion, can participate in commencement. Summer graduates may attend either fall or spring commencement but must confirm through Hokie Spa.

Doctoral candidates must have completed all requirements for graduation by published deadlines to participate in the doctoral hooding ceremony.

DEGREE CONFERRING DATES

In addition to the traditional twice–a–year commencement, two additional "Degree–Conferring Dates" have been established each year. These dates appear on the diploma for qualified graduates. These additional degree–conferring dates fall on the last day of final examinations of First Summer Term and Second Summer Term. For a full list of degree–conferring dates, see our Dates & Deadlines web page: http://www.grads.vt.edu/common/dates_deadlines.htm. No commencement ceremonies are conducted during the summer. Students who complete degree requirements at these times may attend the next commencement; students must submit an AFD for the term they will complete, and confirm commencement attendance via Hokie Spa. All degrees conferred between commencements are listed in the next commencement program. Diplomas will be mailed to graduates by first class mail.

ACCOUNTING & INFORMATION SYSTEMS

Robert M. Brown, Head

KPMG Professor of Accounting & Information Systems: L.N. Killough
R. B. Pamplin Professor of Accounting & Information Systems: W.E. Seago
R. B. Pamplin Professor of Accounting & Information Systems: R.M. Brown
Professors: J.O. Hicks; J.J. Maher; F.M. Richardson; T.K. Sen
Associate Professors: R. Barkhi; F. Belanger; J.A. Brozovsky; S.A. Hicks; D.A. Salbador; S.D. Sheetz; D.P. Tegarden; J.A. Yardley
Assistant Professors: S. Bhattacharjee; W. Fan; L.G. Wallace; L.I. Wood
Instructors: C.M. Easterwood; M.T. Griffin; J.M. Lacoste
Career Advisor: R.M. Brown (231–6591)

E-mail: acis@vt.edu
Web: www.acis.cob.vt.edu

The accounting and information systems department offers programs of graduate study leading to the degrees of master of accounting and information systems and Ph.D. in business with a major in accounting and information systems.

No more than one grade of C and no grades less than C may be earned by candidates for graduate degrees. This includes prerequisite courses as well as courses taken toward the degree. A second grade of C, or any grade less than C, will result in automatic expulsion from the program, absent extenuating circumstances approved by the student's course advisor and the department head.

Master of Accounting and Information Systems Program

The master of accounting and information systems program provides graduate-level education for professional careers in accounting and information systems. The program also provides a substantial base for students wishing to teach in junior colleges or colleges with primarily undergraduate programs. For those planning to enter a Ph.D. program, the program offers the necessary foundation.

The program is open to students with a bachelor's degree in any discipline. Students without prior collegiate studies in accounting, information systems, and/or business administration can expect to spend additional time in the program completing prerequisites. For those who have fulfilled the background requirements, the program consists of 30 semester hours and can normally be completed in 12 to 17 months.

All master of accounting and information systems students take the following three courses:

ACIS 5214: Advanced Strategic Cost Management
ACIS 5394: Tax Impact of Management Decisions
ACIS 5514: Management of Information Systems

The additional seven courses depend on the student's choice of one of four possible career options: Financial Reporting and Assurance Services, Financial Services, Tax Accounting, or Information Systems. Additional courses for these options are as follows:

Financial Reporting and Assurance Services:

ACIS 5004: Accounting for Multinational Enterprises
ACIS 5584: Electronic Commerce Security
Four of the following five course alternatves:
ACIS 5014: Information Systems Audit and Control
ACIS 5114: Advanced Accounting
ACIS 5124: Governmental and Nonprofit Accounting
ACIS 5324: Corporate Tax
ACIS 5414: Auditing Theory
Non-ACIS elective

Financial Services:

ACIS 5004: Accounting for Multinational Enterprises
ACIS 5114: Advanced Accounting
ACIS 5194: Financial Statement Analysis
ACIS 5414: Auditing Theory
FIN 5024: Principles of Finance
FIN 5044: Asset Valuation*
FIN 5054: Options and Futures*
FIN 5064: Equity Rates*
FIN 5074: Interest Rates*
Select one course from the following:
FIN 5204: Managing Corp Capital Investments and Capital Structure**
FIN 5244: Managing Corporate Risk with Derivatives**
FIN 5264: Mergers & Acquisitions and Corporate Restructuring**
*one-hour course
**two-hour course

Tax Accounting:

ACIS 5314: Tax Planning and Research
ACIS 5324: Partnership and Corporate Tax
ACIS 5334: Advanced Corporate Tax
ACIS 5344: Tax Concepts
ACIS 5354: Family Tax Planning
ACIS 5394: Tax Impact of Management Decisions
Non-ACIS elective

Information Systems:

ACIS 5524: Advanced Database Management Systems
ACIS 5534: Information Systems Development
ACIS 5554: Applied Software Development
ACIS 5594: Web-Based Applications and Electronic Commerce
Non-ACIS elective
Free elective

Students who pursue their undergraduate degree in accounting and information systems at Virginia Tech are afforded the opportunity to complete the undergraduate and master's degrees in 152 semester hours. For this program, 3 semester hours of graduate credit count toward fulfilling course requirements of both the undergraduate and graduate degrees.

Ph.D. Program

The program leading to the Ph.D. in business with a major in accounting and information systems permits the student to pursue advanced graduate studies in preparation for a career in college and university teaching and research.

The first two or three years of the Ph.D. program are devoted to course work. The program's basic requirements include core course work in accounting and information systems and research methods, as well as course work in a supporting area and statistics. The remainder of the time is devoted to the dissertation. There is no foreign language requirement, although computer proficiency is expected.

The supporting area can be chosen from among the field options within the Pamplin College of Business or in an area outside the college, subject to approval by the student's advisory committee.

The following specific courses are required in the major field: ACIS 5974, 6004, and two of the following: 6014, 6024, and 6504. Depending on a student's background, additional ACIS courses may be required. Each candidate for the Ph.D. in business with a major in accounting and information

systems must pass the written examination at or near the completion of course work, defend a dissertation proposal before the accounting and information systems faculty, and pass a final oral examination after the dissertation is completed.

GRADUATE COURSES (ACIS)

5004: ACCOUNTING FOR MULTINATIONAL ENTERPRISES
Study of financial and managerial accounting for international business operations and taxation and auditing of transnational corporations. Includes investigation of major accounting differences among countries, the fundamental causes for these differences, and efforts toward international harmonization of accounting. Pre: 3116. (3H,3C**).**

5014: INFORMATION SYSTEMS AUDIT & CONTROL
This course explores the theories and practices of audit and control of computer–based information systems. Audit and control of information systems is examined from the viewpoint of management, systems professionals, and auditors. The rationale for controls, control theories, and audit practices are emphasized. Pre: 5514, 4415. (3H,3C**).**

5024: SEMINAR IN ACCOUNTABILITY
Introduction to concepts, applications and issues related to the subject of "accountability"; primarily from the perspectives of accounting and business, while branching into other disciplines for comparisons; history and evolution; development of a general model to explain the relationships, responsibilities and behavior of parties involved; application of the model to a variety of settings to test its validity and to gain insights into successesand failures of account–ability relationships. Pre: 5104. (3H,3C)

5104: FUNDAMENTALS OF ACCOUNTING
Fundamentals of accounting systems as they relate to decision making. Attention is directed toward accounting for the core of management control and financial reporting systems, and as integrally related to the information system. (3H,3C**).**

5114: ADVANCED ACCOUNTING
In–depth analysis of business mergers and acquisitions, consolidated financial statements, translation and remeasurement of foreign currencies, partnership accounting, financial distress, and other selected complex financial accounting and reporting topics. (3H,3C). I

5124: GOVERNMENTAL & NONPROFIT ACCOUNTING
An analysis of current governmental and nonprofit accounting, budgeting, reporting, and auditing concepts, models, and practices. Identification and evaluation of alternative concepts and models will also be emphasized. Pre: 4124. (3H,3C**).**

5194: FINANCIAL STATEMENT ANALYSIS
A comprehensive treatment of the analysis of financial statements as an aid to decision making. Primary attention is placed on investing and lending decisions as they affect the financial manager. Pre: 5104. (3H,3C**).**

5214: ADVANCED STRATEGIC COST MANAGEMENT
To provide an understanding of advanced strategic cost management methods. The areas covered include topics in cost estimation, cost–volume–profit analysis, activity based costing, costing in new manufacturing environments, performance measurement, management control, and ethical implications. Pre: 3215, BIT 2406. (3H,3C**).**

5294: MANAGEMENT CONTROL SYSTEMS
Analysis and design of control systems to facilitate short term decisions in order to allow management attention on long term strategic issues. Such systems integrate financial, marketing, production, and other business policies in accomplishing the goals and objectives of an organization. Accounting techniques are the core of management control systems, and information systems provide necessary links. Includes impact of tax planning, financial reporting, and internal and external auditing systems. Pre: 5104. (3H,3C**).**

5314: TAX PLANNING & RESEARCH
The basic concepts of tax planning and research are explored. Includes sources of tax research, communication of results of research, practice and procedure before the IRS, and tax planning using the personal tax course. Pre: 4314. (3H,3C**).**

5324: CORPORATE TAX
The course contains an in–depth analysis of the tax consequences of forming, operating, and liquidating a corporation and transactions between corporations and their shareholders. Pre: 4314. (3H,3C**).**

5334: CORPORATE & PARTNERSHIP TAX
Covers the tax aspects of corporate reorganizations, multiple corporations, consolidated returns, multi–state and multinational corporation operations. The tax laws relative to partnership income are also analyzed. Pre: 5324. (3H,3C**).**

5344: TAX CONCEPTS
Analysis of fundamental concepts of taxation applicable to all taxable entities. The course requires students to analyze the major court decisions from which the fundamental concepts and theories applied to the determination of federal taxable income were developed. Specific topics to be covered are gross income, accounting methods, assignment of income deductions, and property transactions. Pre: 4314. (3H,3C**).**

5354: FAMILY TAX PLANNING
An analysis of the impact of the federal income and transfer tax on family financial planning. Topics to be covered include the federal transfer tax on estates and gifts, income tax on estates and trusts, executive compensation, and family tax planning. Pre: 4314. (3H,3C**).**

5394: TAX IMPACT ON MANAGEMENT DECISIONS
An analysis of the impact of the federal income tax on management decisions. Designed for students who need only to recognize the important tax consequences that attach to many common business transactions, especially those in M.B.A. programs. Topics to be covered include an overview of tax concepts and terminology, selection of the form of business entity, acquisition, cost recovery and sale of property, executive compensation, investments, and family tax planning. Pre: 5294. (3H,3C**).**

5414: AUDITING THEORY
Study of competing auditing theories and the basic concepts, postulates, and general standards inherent in such theories. Includes discussion of conceptual issues facing the auditors and current trends in the auditing profession. Pre: 4415. (3H,3C**).**

5424: ADVANCED AUDITING PRACTICE
Application of theoretical concepts to complex and emerging practical problems in public accounting, internal auditing, and governmental auditing. Pre: 5414. (3H,3C**).**

5504: INFORMATION SYSTEMS DESIGN & DATABASE CONCEPTS
This course is an introduction to design methodologies in information systems. Structured systems analysis and design methodologies are discussed. An introduction to database design methodologies is also included. Topics related to different database models and their implementation is discussed. Students are also required to design and implement information systems using appropriate computer software. Pre: MBA/MACCT standing. (3H,3C**).**

5514: MANAGEMENT OF INFORMATION SYSTEMS
An analysis of theories and practices used in the management of systems that generate information and decisions to coordinate and control business operations. Both the Viewpoints of the manager and the systems professional are covered in this course. Pre: 1504. (3H,3C**).**

5524: ADVANCED DATABASE MANAGEMENT SYSTEMS
This course relates database theories and practices to concepts from other areas, such as programming languages, algorithms, data structures, and information systems. The relational, network, and hierarchical models are introduced. A major portion of the course deals with data manipulation languages for the relational model, design theory for relational databases, and query optimization. Pre: 4515. (3H,3C**).**

5534: INFORMATION SYSTEMS DEVELOPMENT
Study of theoretical and pragmatic approaches to the development of computer-based information systems. The emphasis is on the management of the systems development process. Strategies for managing the complexity of information systems are explored. The building of logical and physical models of systems through traditional nonexecutable models and executable computer prototypes. Pre: 1504 or 5514. (3H,3C**).**

5544 (BIT 5544): INFO CENTER FUNCTIONS
The information center assists in building systems by direct collaboration with users and analysts. Their interaction during this process is considered. The information center makes available hardware and software tools to enhance the quality of the system and the speed with which it is developed. These tools are examined. Pre: 5514. (3H,3C**).**

5554: APPLIED SOFTWARE DEVELOPMENT PROJECT
Application of system analysis, design, and implementation concepts, principles, and practices to a comprehensive system development project. A team approach is used to analyze, design, implement, and document realistic systems of moderate complexity. Use of project management methods, project scheduling and control techniques, formal presentations, walk throughs, and group dynamics in the solution of information systems problems. Development of a database to support the system. Pre: 5524, 5534. (3H,3C**).**

5564 (BIT 5564): ARTIFICIAL INTELLIGENCE APPLICATIONS IN BUSINESS
Study of key artificial intelligence techniques and their role in decision making in a business context. Topics will include methodologies for the representation of knowledge, algorithms for intelligent search, and techniques for display of expert decisions. Primary emphasis is on rule-based or expert systems, neural networks, fuzzy logic concepts, and genetic algorithms. Pre: 4515, CS 2604. (3H,3C**).**

5574 (BIT 5574): DESIGN STRATEGIES FOR E-BUSINESS SYSTEMS
This course focuses on the strategic business analysis and design requirements of an e-Business System. This course focuses on the design of the marketing, knowledge, and transaction processing components of a typical e-business system. The course develops skills required in doing requirements analysis for e-businesses, understanding business processes required for e-businesses, and designing effective e-business architectures. Emphasis is placed on the application of object-oriented systems design, suitable analysis and design concepts from structured analysis, business process reengineering, and design of web-enabled client-server systems. (3H,3C**).** II.

5584: ELECTRONIC COMMERCE SECURITY
An examination of the concepts, technologies, and applications of security in electronic commerce systems. Topics include the security threats against electronic commerce; tools used by intruders; computing platforms and security; encryption; securing the transaction and the server; detection and responses to attacks; and the future of electronic commerce security. Pre: 5514 or BIT 5474. (3H,3C).

5594 (BIT 5594): WEB-BASED APPLICATIONS & ELECTRONIC COMMERCE
An examination of the concepts, technologies, and applications of electronic commerce. Topics include the World Wide Web as a platform for electronic commerce; intranets; electronic data interchange; electronic banking and payment systems; security and firewalls; software agents; and the social, legal, and international issues of electronic commerce. Must have completed the first year of the MBA program and the prerequisites to the Master of Accountancy program. Pre: 5514 or BIT 5474. (3H,3C).

5604: ACCOUNTING FUNDAMENTALS
An introduction for practicing executives to financial accounting cycles and transactions, financial statement reporting, and internal managerial accounting and costing. This course is designed to give executives an understanding of accounting systems, and to illustrate and highlight potential points at which the systems could be manipulated. Executive MBA students only. (2H,2C).

5614: IMPLEMENTING MANAGEMENT CONTROLS
The management control process is designed to influence managers and other employees of an organization to implement the strategies of the organization. The activities of management control include: planning, coordinating, communicating, and evaluating. This course addresses the important role that accounting and other information play in this process. Executive MBA students only. (2H,2C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: CONCEPTS OF ACCOUNTING RESEARCH
Introduction to philosophy of science and scientific method; theoretical foundations and considerations when conducting empirical research; overview of various research methodologies in accounting; accessing secondary data resources; techniques of effective writing. Pre: 5114. (3H,3C**).**

6014: BEHAVIORAL RESEARCH IN ACCOUNTING SEMINAR
A doctoral level seminar emphasizing the design and evaluation of research conducted in the behavioral research area of accounting. The primary emphasis is on behavioral decision theory and its applications to the accounting function. Primary seminar material is selected from recent journal articles and current working papers on relevant topics. Requires development and presentation of research proposal related to behavioral research in accounting. Pre: 6004. (3H,3C)

6015-6016: ACCOUNTING SEMINAR
A doctoral seminar emphasizing the design and evaluation of research in financial and management accounting. Pre: 5114, 5214 for 6015, 5114 for 6016. (3H,3C**).**

6024: FINANCIAL CAPITAL MARKETS IN ACCOUNTING SEMINAR
A doctoral level seminar emphasizing the design and evaluation of research conducted in the financial capital markets area of accounting. Concentrates on empirical markets–based research concepts and methodologies utilized in accounting. Primary seminar material is selected from recent journal articles and current working papers on relevant topics. Requires development and presentation of research proposal related to capital markets in accounting. Pre: 6004. (3H,3C).

6504: SEMINAR IN INFORMATION SYSTEMS RESEARCH
A research seminar that focuses on contemporary topics in information systems. The course can be focused on a specific area of interest such as the philosophical foundations of information systems, cognitive issues in information systems, behavioral issues in information systems, group support systems, information systems project management, knowledge management, information visualization, or information systems development, or can be focused on a set of separate topics. Pre: permission of instructor. Pre: 6004. (3H,3C**).** II.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ACIS)

The following 4000–level courses have been approved for graduate credit:

4314: INCOME TAX
Survey of basic concepts of federal income taxation with emphasis on taxation of individuals and the impact of income taxes on corporations and partnerships. Pre: 2116. (3H,3C**).**

4324: ADVANCED INCOME TAX
Federal and state income tax laws as applied to partnerships, corporations, estates trusts, and federal transfers taxes on wealth. Pre: 4314. (3H,3C**).**

4415: AUDITING
Study of external, governmental and internal auditing, professional ethics, other attestation standards and specific companies and industries. Includes financial, operational and compliance auditing and audit risk assessments and techniques. Pre: 3115, 3504 or 3515. (3H,3C**).**

4504: ACCOUNTING APPLICATION DEVELOPMENT
Utilizes current software tools to design and develop segments of accounting systems using database management techniques. Provides an understanding of relational databases and query languages. Includes exposure to latest relevant technology and software. Provides hand–on use of commercial accounting software package. Pre: 3504, 3115, 3215. (3H,3C**).**

4554 (BIT 4554): NETWORKS & TELECOMMUNICATIONS IN BUSINESS
This course provides a survey of distributed computer networks and data communications in business. Topics include the benefits, costs, and risks of using computer networks, network design issues, and special considerations for network appliations. This course will require routine use of campus network and software to aid in network design and evaluation. Simulation and optimization will be used as tools for network design and evaluation. One semester of college–level programming experience required. Pre: 3515 or BIT 3444. (3H,3C**).**

4564 (BIT 4564): OBJECT–ORIENTED SYSTEMS DEVELOPMENT FOR BUSINESS
This course provides an in–depth introduction to computer networks and data communications in business. Topics include mechanisms for reliable data transfer, local and wide area network topologies and technologies, and a comprehensive treatment of internetworking. The benefits, costs, and security issues related to using computer
networks are discussed, along with network design issues, and methodologies for network applications. One semester of college–level programming experience required. Pre: 3515 or BIT 3444.

AEROSPACE & OCEAN ENGINEERING

UNIVERSITY EXEMPLARY DEPARTMENT *

R.W. Walters, Head
W.L. Neu, Assistant Head

Jack E. Cowling Professor: R.L. Simpson
Fred D. Durham Professor: J.A. Schetz
Professors: R.W. Barnwell[1]; A.J. Brown; W.J. Devenport; C.D. Hall; B. Grossman; Z. Gurdal[1]; O.F. Hughes; R.K. Kapania; J.F. Marchman III; W.H. Mason; R.W. Walters
Associate Professors: N. Hovakimyan; W.L. Neu; J.J. Wang
Assistant Professors: M.J. Allen; M. Patil; H. Schaub; C.A. Woolsey
Adjunct Professor: W.L. Hallauer, Jr.
Professors Emeritus: E. Cliff; W.C. Durham; A.K. Jakubowski; E.R. Johnson; F.H. Lutze; C.L. Yates

[1] Joint with Engineering Science and Mechanics

E-mail: aoe@vt.edu
Web: www.aoe.vt.edu/

This department offers graduate study leading to the M.S. (thesis or non–thesis) and M.E. (non–thesis) in both aerospace and ocean engineering, and the Ph.D. in aerospace engineering (ocean option available). There is no language requirement for either the master's or Ph.D.

Aerospace and ocean engineering is a diverse, rapidly changing field which has led humankind to the moon and beyond and continues to lead in the expansion of our frontiers deeper into space and to the ocean's depths. The major subjects in aerospace and ocean engineering are generally directed toward the analysis, research and development, and design of aerospace and ocean vehicles and structures, including aircraft, missiles, spacecraft, ships, submarines, undersea research vehicles, and space stations. Much of the fundamental aerospace science is equally applicable to the design of other transportation vehicles and systems (automobiles, high speed trains, rapid transit systems, etc.). Application of basic fluid mechanic and aerodynamic sciences to current problems in energy production by innovative methods, environmental pollution of air and water, and natural wind and water current effects on buildings and structures is also encouraged.

SPECIAL FACILITIES

Several excellent facilities are available for experimental research and study. These include a low–noise, low–turbulence intensity subsonic stability wind tunnel with 6' x 6' test section capable of dynamic testing of models; a 9" x 9" supersonic wind tunnel with a Mach number range from 2 through 4; a hypersonic wind tunnel to Mach 7; a subsonic wind tunnel with 3' x 3' x 20' test section; a 3' x 2' x 26' transient flow turbulent boundary layer wind tunnel; a 10 fps water tunnel; and a towing tank. Hot–wire and laser anemometers; Doppler–global velocimeters; advanced signal processing instrumentation; and computers are available.

Departmental computational facilities include several SGI computing servers and workstations, Sun workstations, and a lab of computers running Microsoft Windows. Each graduate student is also given a network connection in their office.

The aerospace and ocean engineering department participates in the interdepartmental graduate programs in computer science and applications, systems engineering and environmental sciences and engineering.

GRADUATE COURSES (AOE)

5024: VEHICLE STRUCTURES
Exact and approximate methods for analysis and design of aerospace and marine structures. Stresses, strains, constitutive equations, boundary value problems, and two–dimensional elasticity; torsion; variational methods; virtual work and energy principles; structural mechanics theorems; traditional approximate methods; and laminated plates. (3H,3C).

5034: VEHICLE STRUCTURAL DYNAMICS
Equations of motion for and dynamical response of continuous and multiple–degree–of–freedom vehicle structures. Review of single–degree–of–freedom free and forced vibrations. Force equilibrium, energy methods, and finite element modeling of restrained and unrestrained dynamical structures. Dynamic response of continuous and multi–degree–of–freedom systems by modal analysis and by direct integration. Random vibrations. Pre: 5024. (3H,3C).

5044 (CEE 5444): DYNAMIC STABILITY OF STRUCTURES
Modern structural stability analysis; static and dynamic instability; conservative and nonconservative systems; multiple loads; and Liapunov stability analysis. Applications to columns, rotating shafts, pipes conveying fluid, and airplane panels. Pre: ESM 4074 or AOE 3034. (3H,3C).

5054 (ESM 5454): ELASTIC STABILITY
Stability of elastic structural components under conservative loads; precise definitions of stability; energy approaches; Rayleigh–Ritz and Galerkin methods; and applications to column, arches, plates, and shells. Pre: 3124 or CEE 3404.

5064 (ESM 5064): STRUCTURAL OPTIMIZATION
Structural optimization via calculus of variations. Application of techniques of mathematical programming to optimize trusses, beams, frames, columns, and other structures. Sensitivity calculation of structural response. Approximation techniques and dual and optimality criteria methods. A background in optimization is necessary. (3H,3C).

5074: ADVANCED SHIP STRUCTURAL DESIGN
Methodology of rationally based optimum structural design of ships based on explicit calculation of failure loads. Elastic and inelastic plate bending. Elastic and inelastic buckling of columns, plates and stiffened panels. Computer programs for ultimate strength analysis and structiral design of ships. Sample applications. Pre: Graduate standing in Engineering. (3H,3C).

5084: SUBMARINE DESIGN
Application of engineering disciplines to the design of a steam turbine propelled nuclear submarine. The disciplines involved are fluid mechanics, solid state mechanics, structures, machine design, thermodynamics and heat transfer. (3H,3C).

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

5104: ADVANCED AERO & HYDRODYNAMICS
Vector analysis concepts; fluid stress and strain, kinematics of fluid flows including vorticity; dynamics of inviscid incompressible flow; and potential flow theory with applications to lifting and non–lifting bodies. (3H,3C).

5114: HIGH SPEED AERODYNAMICS
Aerothermodynamic phenomena and shock waves. Linearized subsonic and supersonic flow past planar surfaces and bodies of revolution. Theory of transonic aerodynamics including study of mixed flow. Similarity laws. Mathematical representation of inviscid compressible flows in equilibrium. Potential function, stream function, rotationality and geometrical considerations. Method of characteristics applied to hyperbolic flow fields. Discussion of techniques for solution of elliptic flow fields. Pre: 3114. (3H,3C).

5135–5136 (ME 5135–5136): VEHICLE PROPULSION
Aeothermodynamics of gas turbines and rockets: cycle analysis of turbojets, turbofans, prop fans, and turbo props. Analysis of ramjets and scramjets. Performance of inlets, combustors, and nozzles. Elementary theory of turbomachinery. Liquid and solid propellant chemical rockets. Electrostatic, electromagnetic, and electrothermal propulsion. Integrated rocket–ramjet. Fuels and propulsion systems for future transportation system. Pre: 3114, ME 3134. (3H,3C).

5144: BOUNDARY LAYER THEORY & HEAT TRANSFER
Conservation equations and constitutive relations, exact Navier Stokes solutions; boundary layer approximation and special solutions; approximate methods; compressibility and heat and mass transfer effects; and numerical methods and simple turbulence models. Pre: 5104. (3H,3C).

5214: AIRCRAFT DYNAMICS & CONTROL
General equations of aero/hydrodynamic vehicular motion including the effects of flexibility and changing mass. Consideration of buoyant, aerodynamic, gravitational and thrust forces, jet damping, thrust offset, and rotating machinery contributions. Reduction of equations to linearized form, aero/hydrodynamic stability derivatives. Stability and response characteristics. Application of classical control theory to aircraft control. Pre: 3134. (3H,3C).

5224: LINEAR OPTIMAL CONTROL SYSTEMS
State–variable and transfer function description for linear systems; relation of canonical matrices to state models; transition matrices; controllability, observability, stability, Luenberger observers, optimal linear feedback control laws, Kalman filtering, optimal solutions to deterministic and stochastic linear quadratic gaussian regulators. Pre: 5214. (3H,3C).

5234: ORBITAL MECHANICS
Lagrange's equations of motion, two–body problem, conic sections, Kepler's laws, orbit determination. Multi–body problems and integrals of motion. Fundamentals of perturbation theory, variation of parameters, and Lagrange's planetary equations. Regularization and alternative formulations of equations of motion. Pre: 4134. (3H,3C).

5244: OPTIMIZATION TECHNIQUES
Ordinary minimum problems with constraints. The classical multiplier method, descent methods, and quasi–Newton methods. Optimal control and the maximum principle. Second–order necessary conditions. Singular control. Continuous gradient methods, conjugate gradients. Pre: 3134, MATH 4564. (3H,3C).

5304: ADVANCED NAVAL ARCHITECTURE
Engineering analysis methods for evaluating the hydrostatic, hydrodynamic, and structural characteristics of surface ships and submarines. Methods employed in ship design include analytical, statistical, and experimental approaches. Both hull and propulsor analysis techniques are covered. (3H,3C).

5305–5306: MARINE ENGINEERING
In–depth analysis and design of major ship propulsion system and machinery components. 5305: Propellers, shafting and gearing. Intro. to boilers, steam and gas turbines, nuclear power plants and diesels. 5306: Advanced study of diesels and gas turbines. Internal combustion engines. Shipboard HVAC, pump and motor systems. Cost estimation. Pre: ME 3134. (3H,3C).

5314: NAVAL SHIP SYSTEM DESIGN
Overview of the ship design process, and insight into the major factors which influence the technical trade–offs governing the synthesis of a ship design. The course is directed primarily at systems engineers, equipment engineers (hull, machinery and combat systems), and technical managers who interface with the ship design community. The course is also of value to practicing naval architects who desire a broad perspective into the ship integration process. (NAVSEA site only). Undergraduate engineering degree required. (3H,3C).

5334: ADVANCED SHIP DYNAMICS
Derivation of the equations of motion of a ship; waves and wave forces on structures; description of wave statistics and spectral representation in a given sea state; ship response in regular waves; ship response in random waves. Pre: 3234, MATH 4564. (3H,3C).

5344: NONLINEAR CONTROL OF MECHANICAL SYSTEMS
Methods of nonlinear control, emphasizing techniques applicable to mechanical systems. Nonlinear system theory and stability analysis. Nonlinear controllability and observability. Input–output properties. Passive and dissipative systems and stability of interconnected systems. Common nonlinear control design techniques: feedback linearization; sliding mode control; adaptive control. Techniques for mechanical systems: potential shaping; kinetic shaping. Emphasis on applications to vehicle control. Pre 4004. (3H,3C).

5374: RATIONALLY–BASED DESIGN OF OCEAN STRUCTURES
Methodology of rationally–based optimum structural design of ships based on explicit calculation of failure loads. Torsion of thin–wall sections. Ultimate limit states of stiffened cylinders. Structural optimization of stiffened panels. Computer programs for ultimate strength analysis and structural design of ships, submarines and offshore platforms. Sample applications. Pre: 5074. (3H,3C).

5454: ADVANCED AEROSPACE & OCEAN ENGINEERING INSTRUMENTATION
An advanced treatment of the principles of measurement systems; standards, accuracy, uncertainty and statistical concepts, and signal processing. Detectors, transducers, and instruments for aerospace and ocean engineering. Hot–wire and laser anemometry. Signal conditioning systems and readout devices, digital data acquisition principles. Electronics and electrical test instruments. Case studies of practical instrumentation systems. Pre: 3014, 3034. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Discussion of current research topics in Aerospace and Ocean Engineering by local and visiting scholars. This course cannot be used to fulfill the minimum requirements of 30 hours toward the Master's Degree or 90 hours toward the Ph.D. Degree in Aerospace and Ocean Engineering. May be repeated. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6024: AEROELASTICITY
Discussion of the aeroelastic phenomena including flutter, divergence, control surface effectiveness, and lift redistribution; and introduction to traditional and modern methods of analysis and remedies for aeroelastic problems of flight vehicles. Pre: 5034, 5104, 5214. (3H,3C).

6114: TRANSONIC AERODYNAMICS
Basic features of transonic flows, similarity methods, and hodograph methods. Major emphasis on finite difference procedures including type dependent relaxation procedures for potential flows and time asymptotic Euler solutions. Grid generation methods, inverse design procedures, unsteady flow, wind tunnel/wall interference, and shock wave/boundary layer interactions. Pre: 3114, 4404, 5144. (3H,3C).

6124: HYPERSONIC AERODYNAMICS
Theory of inviscid hypersonic flows; blunt body and Newtonian aerodynamics; nonlinear small disturbance theory; and approximate methods and comparisons with experiment. Viscous hypersonic flow theory; skin friction and heat transfer on blunt and slender bodies; and vorticity, entropy layer, and viscous–inviscid inter–action effects. Pre: 5114. (3H,3C).

6145–6146: COMPUTATIONAL FLUID DYNAMICS
Computational methods for incompressible, compressible, and viscous fluid flows. Theoretical and numerical developments for wave equation, heat equation, Poissons equation, and Burgers equation. Applications to inviscid subsonic, transonic, and supersonic flows, viscous boundary layer, Navier Stokes, thin layer equations, and grid generation techniques. Pre: 3114, 4404, 5104. (3H,3C).

6154: TURBULENT SHEAR FLOW
Advanced treatment of the physical phenomena of turbulent boundary layers, jets, wakes, and duct flows; coherent structures; entrainment, bursting, vortex dynamics; and unsteady, wall, and freestream turbulence effects. Pre: 5144. (3H,3C).

6214: TOPICS IN MECHANICS & CONTROL OF FLIGHT
Special topics in important areas related to the mechanics and control of flight. Pre: 5214. (3H,3C).

6234: SPACEFLIGHT DYNAMICS
Orbital operations including transfer, intercept and rendezvous, Kepler, and Lambert (Gauss) problems, and numerical considerations. Attitude dynamics, motion about the center of mass, gravity gradient, and stability. Methods of attitude control both active and passive. Pre: 4134, 5234. (3H,3C).

6244: ADVANCED OPTIMIZATION TECHNIQUES
Neighboring optimal concept and guidance applications. Singular–perturbation techniques in optimal control. Applications to atmospheric flight; energy modelling. Elements of game theory. Pursuit/evasion games with air–combat applications. Pre: 5244. (3H,3C).

6314: DYNAMICS OF THE OCEAN
Large scale oceanic motions. Geostrophic and Ekman flows. Ocean circulation theories of Munk, Sverdrup, and Stommel. Numerical models. Linear and nonlinear surface waves, wave generation by wind, internal waves, and tides. Pre: 5104. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (AOE)
The following 4000–level courses have been approved for graduate credit:

4024 (ESM 4734): AN INTRODUCTION TO THE FINITE ELEMENT METHOD
The finite element method is introduced as a numerical method of solving the ordinary and partial differential equations arising in fluid flow, heat transfer, and solid and structural mechanics. The classes of problems considered include those described by the second–order and fourth–order ordinary differential equations and second–order partial differential equations. Both theory and applications of the method to problems in various fields of engineering and applied sciences will be studied. Pre: 2074, MATH 2224. (3H,3C).

4054 (CEE 4444) (ESM 4444): STABILITY OF STRUCTURES
Introduction to the methods of static structural stability analysis and their applications. Buckling of columns and frames. Energy method and approximate solutions. Elastic and inelastic behavior. Torsional and lateral buckling. Use of stability as a structural design criterion. Pre: 3024, (CEE 3404. (3H,3C).

4064 (CEE 4364): FLUID FLOWS IN NATURE
Course designed to build upon and broaden a basic traditional engineering knowledge of fluid flows into areas concerning a variety of natural occurrences and phenomena that involve fluid motions inimportant ways. Drag of sessil systems and motile animals, gliding and soaring, flying and swimming, internal flows in organisms, low Reynolds number flows, fluid–fluid interfaces, unsteady flows in nature and wind engineering. Pre: 3104 or CEE 3304 or ESM 3024 or ME 3404. (3H,3C).

4084 (ESM 4084): ENGINEERING DESIGN OPTIMIZATION
Use of mathematical programming methods for engineering design optimization including linear programming, penalty function methods, and gradient projection methods. Applications to minimum weight design, open–loop optimum control, machine design, and appropriate design problems from other engineering disciplines. Pre: MATH 2224. (3H,3C).

4114: APPLIED COMPUTATIONAL AERODYNAMICS
Development of computational methods for application to wing aerodynamic problems. Incompressible airfoil codes. Panel methods and vortex lattice methods. Finite difference techniques. Transonic and supersonic applications. Pre: 3044, 3114. (3H,3C).

4140: SPACECRAFT DYNAMICS AND CONTROL
Space missions and the way pointing requirements affect attitude control systems. Rotational kinematics and attitude determination algorithms. Modeling and analysis of the attitude dynamics of space vehicles. Rigid body dynamics, effects of energy dissipation. Gravity gradient, spin, and dual spin stabilization. Rotational maneuvers. Environmental torques. Impacts of attitude stabilization techniques on mission performance. Pre: 4134, 3034. (3H,3C).

4144: AIRCRAFT AUTOMATIC FLIGHT CONTROL
Introduction and history of aircraft automatic flight control. Mathematical models of linear systems elements. Bode amplitude and phase plots of longitudinal and lateral control system analysis. Inputs and system performance assessment. Multiloop flight control systems. Applications to representative aircraft. Pre: 3134, MATH 4564. (3H,3C).

4164: SPECIAL TOPICS IN VEHICLE PERFORMANCE
Three–dimensional point–mass equations of motion over flat and spherical Earth. Aerodynamic and propulsive modeling. Numerical integration of equations of motion. Analytic approximations and solutions. Energy state models. Advanced topics. Pre: 3104, 3134. (3H,3C).

4174 (ME 4174): SPACECRAFT PROPULSION
Spacecraft propulsion systems and their applications in orbital, interplanetary, and interstellar flight. Rocket propulsion fundamentals; advanced mission analysis; physics and engineering of chemical rockets, electrical thrusters, and propellantless systems (tethers and sails); spacecraft integration issues. Pre: 4234 or ME 4234. (3H,3C).

4204: OCEAN ACOUSTICS
Basic problems and techniques of underwater acoustics; sonar equations, sound propagation in the ocean, generation and detection of underwater sound, background and self noise, reverberation, target strength, applications. Pre: MATH 4564. (3H,3C).

4214: OCEAN WAVE MECHANICS
Introduction to theory of wave motion in different water depth regions, including wave generation and propagation. Description of wave statistics and spectral representation for realistic ocean conditions. Wave forces on stationary structures. Nonlinear waves, wave properties, and methods of analysis. Pre: 3014, MATH 4564. (3H,3C).

4224: PROBABILISTIC ANALYSIS OF OCEAN SYSTEMS
Representation of random phenomena for ocean systems (waves, vehicle motions, wave–induced loads). Concepts of correlation (for vector processes), power spectra, probability density, envelope processes. Responses of linear dynamic systems, statistics of responses, exceedance probability, extremes. Extension to nonlinear systems. Pre: 3234, MATH 4564. (3H,3C).

4274: COMPUTER BASED DESIGN OF OCEAN STRUCTURES
Computer–based structural models for combined finite element analysis, limit state analysis and optimization. Torsion of thin–walled structures. Buckling of stiffened panels and cylinders. Eigenvalue methods for buckling and vibration. Incremental plastic collapse; other progressive collapse. Ultimate strength of large structural modules. Pre: 3224. (3H,3C).

4334: SHIP DYNAMICS
Analysis of motions of rigid body vehicles in water, including influence of added mass and buoyancy. Seakeeping motion responses in waves, wave–induced structural loads, random response analysis via spectral analysis, and extreme response analysis. Introduction to hydroelasticity and maneuvering. Pre: 3014, 3034, 4214, MATH 4564. (3H,3C).

4404 (MATH 4404): APPLIED NUMERICAL METHODS
Interpolation and approximation, numerical integration, solution of equations, matrices and eigenvalues, systems of equations, approximate solution of ordinary and partial differential equations. Applications to physical problems. Partially duplicates 4554 and 3414. Mathematics majors or minors cannot take both 4404 and 3414. X–grade allowed. Pre: MATH 4564, ESM 2074. (3H,3C).

AGRICULTURAL & APPLIED ECONOMICS

Herbert H. Stoevener, Interim Head

Alumni Distinguished Professor: W.E. Purcell
Professors: J.R. Alwang; D.J. Bosch; M.J. Ellerbrock L.L. Geyer; G. McDowell; A.M. McGuirk; G.W. Norton; M. Norton; D.R. Orden; J. Schleich (Adjunct); D.B. Taylor
Associate Professors: B.F. Mills; J. Pease; E.B. Peterson; D.W. Reaves; S.K. Stephenson
Assistant Professors: C.E. Hilmer
Instructor: G.E. Groover

E-mail: stoevenr@vt.edu
Department Web: www.aaec.vt.edu/aaec/
Graduate Program Web: http://graduate.agecon.vt.edu/

Graduate programs in agricultural and applied economics lead to the degrees of M.S. (thesis and non–thesis) and Ph.D. The Ph.D. program is jointly administered with the economics department, leading to a Ph.D. in Economics. Within the Department of Agricultural and Applied Economics, domestic and international program concentrations are available in Resource and Environmental Economics, Development and International Economics, Markets and Industrial Organization, Public and Regional/Urban Economics, Microeconomic and Marcoeconomic Theory, and Econometrics and other Quantitative Methods. Students' programs of study are individually tailored and can include courses in agricultural economics, economics, urban affairs and planning, civil and biological engineering, forestry and wildlife, statistics, and other departments. Students are encouraged to design programs that develop skills required for solving applied economics problems in their areas of concentration. The nature of Virginia's rural and urban economies; the proximity to Washington, D.C.; and Virginia Tech's strong internatioal research and development programs offer excellent opportunities for graduate students to pursue diverse research interests.

The M.S. programs prepare students for careers as consultants in environmental economics, international trade and development, regional planning, marketing, agribusiness management, and price analysis, as well as more traditional career opportunities with private corporations, non–profit organizations, government agencies and extension services. Career opportunities for Ph.D. recipients are similar, but also include teaching and research positions at academic institutions.

Students entering the graduate program should have undergraduate training in intermediate microeconomics, intermediate macroeconomics, calculus, matrix algebra, and basic statistics. Undergraduates with majors in agricultural economics, economics, biological and physical sciences, engineering, mathematics, and statistics typically have the necessary background to perform well in this program. Students who lack the necessary prerequisites may be admitted on a provisional basis.

PROGRAM OF STUDY

At the master's level, the program includes course work in microeconomic and macroeconomic theory, mathematical

programming, and econometrics. The balance of the program consists of electives in the student's area(s) of concentration. Agribusiness students take a number of their courses in the College of Business.

Students entering the Ph.D. program take a common set of first year courses with Ph.D. students in the economics department. This set includes courses in macroeconomic and microeconomic theory, mathematical economics, econometrics, and applied economics. During the second and subsequent year, courses include macroeconomics, three courses in a major field, and two courses in a minor field. The balance of the program consists of electives chosen by the student.

AREAS OF CONCENTRATION

RESOURCE AND ENVIRONMENTAL ECONOMICS: Research in this area centers on the design and analysis of public policy options related to resource use and the environment. Research draws on methods developed in public economics, public finance, welfare economics, optimal control and dynamic programming, as well as microeconomic and macroeconomic theory. Ecosystem dynamics and biological modeling may be useful for some programs of research. At Virginia Tech, there are a wide variety of applicable courses available. These include AAEC 5144, 6424, 6454 and 6474; ECON 6044, and 6204; ENT 5214, 6254; FIW 5224, 5424, and 5614; FOR 5015, 5415, 5416, 5454, 5464, 5474, and 5494; and STAT 5594. In addition, students are encouraged to take selected courses from the Departments of Political Science, Geography, Civil and Environmental Engineering, and the Center for Public Administration and Policy.

Examples of student/faculty research in this area include:

1. Development of market-based incentive systems for solid waste management in Virginia, for non-tidal wetlands protection, and for resolving conflicts over water supplies;
2. Evaluation of taxes, quotas, and property rights changes as instruments for Chesapeake Bay fishery management
3. Design and evaluation of national and state surface and groundwater quality protection policies;
4. Economic and environmental implications of alternative land settlement forms; and
5. Value of information for targeting agricultural pollution control efforts.

DEVELOPMENT AND INTERNATIONAL ECONOMICS: This concentration includes the closely related areas of international and domestic economic development and international trade. Topics addressed in this area include economic development strategies, women in development, role of agriculture in development, population growth, institutional and technological change, trade policies, and food aid. Students pursuing research in rural, urban, and international development and trade may find the following courses useful: AAEC 5144, 5154, 5244, 6444, and 6454; ECON 6034, 6054, 6064, and 6304; GEOG 5134 and 5314; PSCI 5434; SOC 5504, 5524, and 6214; UAP 5154, 5174, 5234, 5394, 5404, 5474, and 5784.

Examples of student/faculty research in this area include:

1. Sanitary and phytosanitary regulations affecting Mexico–U.S. agricultural trade;
2. Public school financing in Virginia: Are resources adequate and equitably distributed?
3. Technical regulations as barriers to trade;
4. The differential impact of welfare reform on non-metropolitan and metropolitan counties in Virginia;
5. The role of communications infrastructure in agricultural and economic growth; and
6. Investing in agricultural extension for economic development.

MARKETS AND INDUSTRIAL ORGANIZATION: The program in Marketing and Industrial Organization places emphasis on analytical methods and has a strong policy orientation. Currently, faculty and graduate students are investigating the implications of growing concentration in food and fiber markets, and formulating policy recommendations to address the issue. Analytical frameworks appropriate for this general area of study include models of consumer behavior, derived demand, aggregate prices, price risk management, and those based on game theoretic behavior. Electives in this concentration include AAEC 5134, 6434, 6464, and 6424; and ECON 6005, 6006, 6044, 6104 and 6404.

Examples of faculty/student research in this area include:

1. An exploration of the effects of data aggregation and other factors on empirical estimates of market power;
2. Evidence of market power in the beef packing industry;
3. The competitive advantage for barley and grain sorghum in Virginia;
4. Health and convenience related reductions in demand for beef–how the beef industry should respond to boost demand;
5. Corn storage marketing strategies for Virginia; and
6. Assuring that quality differences are reflected in commodity prices.

PUBLIC POLICY AND REGIONAL/URBAN ECONOMICS: The Public Policy and Regional Economics concentration develops tools and techniques for the analysis of applied economic development issues. This includes theories of public sector expenditure and taxation, models of regional economic impact, urban spatial structure and regional labor market activity, as well as applied partial and general equilibrium analysis of economic development projects. Course electives include AAEC 5244, 6444 and 6474; and ECON 6204 and 6054.

Examples of faculty/student research in this area include:

1. Factors underlying non-metropolitan commuting decisions in Virginia;
2. Determinants of migration and employment growth in Virginia;
3. The role of employment density in spatial job search;
4. Factors affecting migrant labor hiring decisions; and
5. Economies of scale in public service provision.

MICROECONOMIC AND MACROECONOMIC THEORY: Students interested in advancing economic theory can pursue advanced study in microeconomics and macroeconomics. Electives in this concentration include: ECON 6004, 6005, 6015, 6024, 6034, and 6044.

Examples of faculty/student research include:

1. Exploring payoffs and beliefs in game theory;
2. Theory and simulations in spatial economics;

3. Social capital and conventions: A social networks perspective;
4. Nash networks and heterogeneous agents; and
5. Local interactions, learning and automata networks in games

ECONOMETRICS AND QUANTITATIVE METHODS: Students interested in advanced work in econometrics and quantitative methods may pursue research topics in econometrics and other quantitative methods. In this concentration, students are expected to master analytical methods used in a wide variety of applications and develop new methods useful for applied research. Electives in this concentration include AAEC 5024, 6424, 6454, 6464, and 6474; ECON 6004, 6005 and 6024; and ISE 5405, 5406, 5424, 6414, 6424, and 6514.

Examples of faculty/student research include:

1. Monte Carlo examination of static and dynamic student regression models;
2. Modeling exchange rate dynamics: the student's autoregressive model;
3. A comprehensive approach to misspecification testing;
4. Willingness to pay when budget constraints are nonlinear; and
5. When flexible forms fail to be Taylor series approximations.

GRADUATE COURSES (AAEC)

5004: SEMINAR
Formal presentation and discussion of current problems, programs, and research studies in agricultural economics. Presentations and discussions. Repeatable for credit. (1H,1C).

5024: MATHEMATICAL PROGRAMMING FOR ECONOMISTS
Employing economic principles to optimally achieve the goals of firms as a "whole." Linear, non-linear, and integer programming are employed to model firm decision making. Pre: 3004 or ECON 3104. (3H,3C).

5025,5026: APPLIED MICROECONOMICS
Basic economic theory of food and fiber production, food and fiber consumption, agricultural markets, and social welfare as influenced by the agricultural sector. Major emphasis placed on application of theory to current agricultural and resource problems. Pre: MATH 1526; ECON 3004 or ECON 3104 for 5025; MATH 1526, ECON 3004, ECON 3104 for 5026. (3H,3C).

5104: RESEARCH PROJECT PLANNING
Planning and executing a research project with emphasis on problem identification, formulation of hypothesis, choice of appropriate empirical technique and data sources. (1H,1C).

5114: RESEARCH METHODOLOGY
Theory and methods of scientific research in economics and related social sciences. Problem identification, formulation of hypotheses, principles of classification, and empirical techniques of analysis are studied. Emphasis on dynamic aspect of science; its capacity for acquisition of knowledge. Pre: 5025, 5026. (2H,2C).

5125–5126 (ECON 5125–5126): EMPIRICAL RESEARCH METHODS IN ECONOMICS
Extensive treatment of new techniques for economic modeling. 5125: Probability and statistical inference, linear regression and related dynamic models, specification, estimation, misspecification, respecification, identification. 5126: Simultaneous equations, dynamic systems, time series, limited dependent variable models. Permission of the Director of the Graduate Studies required. (3H,3C).

5134: AGRICULTURAL MARKETING
Concepts of technical and economic efficiency as they are related to the flow of agricultural products from farm to consumer. Major topics include: market equilibrium over time, space and form; price discovery under different market structures, and price risk management with futures and options. Pre: ECON 3104. (3H,3C).

5144: RESOURCE & ENVIRONMENTAL ECONOMICS
Economic theory and methods are applied to analysis of the uses of natural resources, environmental problems and public investment planning. The contribution of economic analysis to public policy formulation is stressed. Pre: ECON 3104. (3H,3C).

5154: INTERNATIONAL AGRICULTURAL DEVELOPMENT & TRADE
This course focuses on the role of agriculture in economic development and the effects of alternative trade policies and practices in less developed nations. Topics include agriculture in theories of development, population growth, migration, the economic organization of the peasant–household firm, technological change, institutional change, effects of trade restrictions, exchange rates, trade preferences, regional economic groupings, food aid, trade negotiations, agricultural sector marketing, and project analysis. Pre: ECON 3104. (3H,3C).

5164: AGRICULTURAL & RESOURCE POLICY
An advanced analysis of the role of agriculture in the general economy and of the economic, political and social forces which affect the development of agricultural and resource policy. Emphasis is upon reading and discussing economic policy studies. Pre: ECON 3104. (3H,3C).

5244: RURAL DEVELOPMENT
Theory and methods related to economic development of rural America. Considers the roles of agriculture, resources, human capital, and federal, state and local governments in development processes. Outlines the constraints created by resource scarcity, location and government policy. Quantitative methods in resource development, regional development and impact analysis are introduced. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: SEMINAR
Formal presentation and discussion of current problems, programs, and research studies in agricultural economics including projects employing advanced theoretical and quantitative techniques. Presentations and discussions. Repeatable for credit, up to 3 (M.S.) or 4 (Ph.D.) times. (1H,1C).

6424: RISK ANALYSIS
Issues in microeconomics model development and conceptual frameworks and research methods for incorporating risk into economic analysis. Pre: 5124 or ECON 5006. (3H,3C).

6434: MARKETS & REGULATION
Advanced theoretical and empirical issues relating to the economic analysis of agricultural markets. Majors topics include: economic performance of markets under varying competitive assumptions; quantitative methods of modeling and analyzing markets over multiple dimensions; econometric methods for testing hypotheses concerning the anti–trust and other market regulations. Odd years. Pre: ECON 5005, ECON 5006. (3H,3C).

6444 (ECON 6444): REGIONAL & URBAN ECONOMICS
An advanced study of the theory and application of regional and urban economics, with particular focus on the spatial aspects of economic activity. Topics include: nature of regional and urban areas, models of regional economies, location choice of firms and consumers, local public finance, housing, transportation, and labor markets. ECON 5005; ECON 5126 or AAEC 5126. (3H,3C).

6454: DYNAMIC ANALYSIS
Advanced treatment of the analysis and optimization of dynamic economic systems using mathematical tools and analytic concepts. Topics include: optimal control theory; dynamic programming; economics of resource allocation over time; and stochastic optimization models. Permission of course instructor required. Alternate years. Pre: 5025, 5124. (3H,3C).

6464: DEMAND & PRODUCTION ANALYSIS
Issues in microeconomic model development and estimation relating to demand and production systems. Topics include duality, separability, aggregation, flexible functional forms, selecting and estimating appropriate demand/ production models. Pre: ECON 5125 or AAEC 5125; ECON 5126 or AAEC 5126; ECON 5005, ECON 5006. (3H,3C).

6474 (ECON 6474): APPLIED GENERAL EQUILIBRIUM ANALYSIS
Theoretical and empirical issues in developing and implementing numerical general equilibrium models. Development of basic analytical framework and model properties, and study of selected applications in international trade, public finance, and resource and environmental economics. Pre: ECON 5005, ECON 5006. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (AAEC)

The following 4000–level courses may be taken for graduate credit:

4304: ENVIRONMENT & SUSTAINABLE DEVELOPMENT ECONOMICS
Economics of environment and sustainable development. Topics include economic efficiency, property rights, externalities, benefit–cost analysis, economic evaluation procedures, public and private conflicts in land use, water quality, and international growth/ development/environmental issues. Pre: 1005 or ECON 2115. (3H,3C).

4314: ENVIRONMENTAL ECONOMIC ANALYSIS & MANAGEMENT
Quantitative methods and computer–aided tools used in the economic analysis of environmental/natural resource issues. Economic concepts and analytical tools will be applied to realistic, problem–solving situations. Topics include cost effectiveness analysis, benefit–cost analysis, economic simulations, and statistical analysis. Pre: 4304, ECON 4014, FOR 3424. (3H,3C).

4344: SUSTAINABLE DEVELOPMENT ECONOMICS
Sustainable development concepts are critically explored with particular emphasis on implications for domestic and international sustainable development agriculture and for economic development. Students investigate case studies illustrating problems of sustainable development and potential policy solutions. Pre: 3004 or 4304 or ECON 4014. (3H,3C).

4404: AGRICULTURAL MANAGEMENT & PROBLEM–SOLVING
Capstone course for students interested in agribusiness management. Application of concepts, tools, and principles including management, finance marketing, economic theory, and quantitative methods to applied agricultural decisions. Application of knowledge on selected agricultural projects that enhance team–building, written, and oral communication skills. Computer spreadsheet application and senior status. Pre: (3414, 3404, 3504) or (3424, 3604). (3H,2L,4C).

4504: AGRICULTURAL PRICE & MARKET ANALYSIS
Estimation of agricultural supply, demand, and price relationships. Determination of market potential for new products. Students identify problem, collect data, estimate statistical relationship(s), interpret results, and write research report. Use of probability distribution in marketing strategy development. Pre: 3004, 3504, STAT 3006. (3H,3C).

4754: REAL ESTATE LAW
The law of real property, legal framework, law of estates in land, conveyancing, landlord–tenant and non–possessory interest in real property. Zoning, easements, restrictive covenants. Mortgages, deeds of trust, and taxation of real estate. Junior standing required. (3H,3C).

4764: REAL ESTATE APPRAISAL
Application of economic principles to the valuation and appraisal of property. Income, cost and comparable approach to value. Rural property, commercial, residential and transitional will be evaluated. Ethical and professional requirements. Variable lab credit available to meet Real Estate licensing requirements. (Course credits may vary from 3 to 5 hours.) Junior standing required. Variable credit course.

4804 (STAT 4804): ELEMENTARY ECONOMETRICS
Economic applications of mathematical and statistical techniques: regression, estimators, hypothesis testing, lagged variables, discrete variables, violations of assumptions, simultaneous equations. Pre: 1006, (STAT 3005 or STAT 3604). (3H,3C).

4984: SPECIAL STUDY
Variable credit course.

AGRICULTURAL AND EXTENSION EDUCATION

John Hillison, Head

Professors: J. Hillison; M. Lambur; P. Sobrero; D. Sutphin
Associate Professor: J. Gibson
Assistant Professors: T. Broyles; F.A. "Lex" Bruce, Jr.; C. Sutphin
Adjunct Professor: G. Anderson; T. Hamilton
Career Advisor: T. Broyles
Graduate Coordinator: J. Gibson

E-mail: hillison@vt.edu
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The Department of Agricultural and Extension Education offers graduate programs in a collaborative arrangement with the Career and Technical Education (CTE) program, Department of Teaching and Learning, and the College of Liberal Arts and Human Sciences. Graduate study in CTE with an Agricultural and Extension Education concentration is available in the following:

- **Teacher licensure, non-degree.** This program is intended for persons who already hold appropriate undergraduate degrees and who are seeking teaching licensure only. This option is the most commonly used by provisionally–licensed teachers who do not plan to complete the full master's degree.
- **Master of Science (M.S.), non-thesis.** The non–thesis master's degree program is intended as a professional degree for persons whose career goals include teaching agricultural education, working in Cooperative Extension, or employment in training or other public contact occupations in the broad industries of agriculture and natural resources. Several specializations are available in the non–thesis master's degree. An approved teacher licensure specialization is available and results in both the M.S. degree and licensure to teach agricultural education at the middle and high school levels.
- **Master of Science (M.S.), thesis.** The thesis option M.S. degree is intended for persons whose ultimate educational plans may be to include doctoral level study. The thesis typically involves research in either teaching or Extension.
- **Education Specialist (Ed.S.), non-thesis.** The Ed.S. is an advanced degree beyond the master's but below the doctorate. It is typically used by practicing teachers or school administrators to qualify for positions of greater responsibility in the school setting or to qualify for advancement on the pay scale.
- **Doctor of Education (Ed.D.).** The Ed.D. is a leadership degree for professionals whose career goals involve administration at either the local school division or state level, or in a business or industry setting. The degree requires basic grounding in research methodology and statistics. The successful candidate will design and complete a dissertation that is grounded in practice and makes a genuine contribution to the professional literature in Agricultural and Extension Education.
- **Doctor of Philosophy (Ph.D.).** The Ph.D. is a research degree for professionals whose career goals involve the generation and transmission of new knowledge. The degree requires extensive study in research methodology and statistics. The successful candidate will design and complete a dissertation that is grounded in substantive theory and makes a genuine contribution to the research and theoretical literature in Agricultural and Extension Education.

GRADUATE COURSES (AEE)

5034: TEACHING AGRICULTURAL MECHANICS
The coordination of essential elements required for an effective agricultural mechanics program. Special emphasis placed upon integrating agricultural mechanics instruction into a local agricultural education program, liability, curriculum content selection, special teaching methodologies and student assessment. (3H,3C).

5044: PROGRAM AND CURRICULUM DESIGN IN AGRICULTURAL AND EXTENSION EDUCATION
Methods involved in the organization, management, and evaluation of programs and curricula for agricultural education and cooperative extension. (This course is targeted to extension agent and agricultural teachers, but enrollement is open to all interested.) (3H,3C).

5074: FOUNDATIONS OF AGRICULTURAL AND EXTENSION EDUCATION
The history and philosophy of agricultural education and the cooperative extension service along with the inter–relationship and the common heritage of the two is included. Leaders of both agencies, along with their philosophies, are discussed. (3H,3C).

5104: RESEARCH APPLICATIONS IN AGRICULTURAL AND EXTENSION EDUCATION
Professional applications of research from the perspective of the research consumer rather than the researcher. Locating, accessing, interpreting, evaluating, applying, and communicating the results of research to the lay public in agricultural and extension education settings. Emphasis on professional and scientific research published in agricultural, applied life sciences, agricultural education, and cooperative extension outlets. (3H,3C).

5154: PARTNERSHIPS AND VOLUNTEERISM
Students will develop competencies in the development and direction of community volunteer partnerships and collaborations. Students will explore current volunteer development models, collaboration process theory, and key management areas including: visioning; organizing a partnership or collaboration; creating motivating volunteer positions; recruiting, screening, and interviewing; orientation and training; supervising; evaluation, retention and recognition; group process/facilitation; conflict resolution; risk management; and measuring program effectiveness. (3H,3C).

5754: INTERNSHIP IN AG & EXTENSION EDUCATION
Student participation in a planned clinical experience under supervision of a university faculty member in an approved, appropriate professional setting. A written Internship Agreement must be ocmpleted and approved before the internship begins. Variable credit course.

5894: FINAL EXAM
Pass/Fail only. (3H,3C).

5904: PROJECT AND REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5964: FIELD STUDY
Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH AND THESIS
Variable credit course.

6984: SPECIAL STUDY
Variable credit course.

7964: FIELD STUDIES
Pass/Fail only. Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (AEE)

The following 4000–level courses may be taken for graduate credit:

4244: METHODS OF TEACHING CAREER AND OCCUPATIONAL EDUCATION
Developing instructional plans, delivering and evaluating instruction, and evaluating learner performance for career and occupational education. The prerequisite EDCT 4234 will be waived for Agricultural Education students. Pre: EDCT 4234. (3H,3C).

4254: ADULT CAREER AND TECHNICAL EDUCATION
Theory, practices, and procedures involved in planning, developing, implementing, managing, and evaluating adult education programs in Vocational and Technical Education. Completion of, or concurrent enrollment in, courses in teaching methods and curriculum required.
(3H,3C).

4884: YOUTH PROGRAM MANAGEMENT
Organizational design of educational youth programs such as 4–H and FFA, including administrative planning, human resource development, recruitment, marketing, and budgeting. (3H,3C).

ANIMAL & POULTRY SCIENCES

UNIVERSITY EXEMPLARY DEPARTMENT *

Mark A. McCann, Head

Paul Mellon Distinguished Professor of Agriculture: D.S. Kronfeld
Professors: W.E. Beal; D.M. Denbow; E.A. Dunnington; J.W. Knight; D.R. Notter; S.H. Umberger; K.E. Webb, Jr.; E.A. Wong
Associate Professors: J.D. Eifert; M.J. Estienne; D.E. Eversole; S.P. Greiner; J.B. Hall; A.F. Harper; R.M. Lewis; E.J. Smith; M.L. Wahlberg; C.M. Wood
Assistant Professors: H. Jiang; A.P. McElroy; C.L. Novak; R.K. Splan
Instructor: T.L. McDonald
Adjunct Professor: P.A. Harris
Career Advisors: C.M. Wood; D.M. Denbow; D.E. Eversole
Graduate Coordinator: D.R. Notter

E-mail: mmccnn@vt.edu
Web: www.apsc.vt.edu/

This department offers graduate courses and research opportunities leading to the M.S. (thesis or non–thesis option) and Ph.D. Students may specialize in animal management (M.S. only), genetics, molecular biology, nutrition, physiology or product quality assurance. Students in this department may also obtain the Ph.D. in the Genetics, Bioinformatics, and Computational Biology Program or participate in the Interdepartmental Molecular Cell Biology and Biotechnology Ph.D. option.

The mission of the Department of Animal and Poultry Sciences is to provide leadership for a viable and sustainable animal agriculture through comprehensive and relevant teaching, research and extension programs involving beef cattle, broiler and layer chickens, horses, sheep, swine and turkeys. The department strives to increase the efficiency and profitability of animal–based production and recreation activities while enhancing animal well–being, food safety and environmental quality through teaching, research and the application of new technology. Graduates of the department find employment in a wide range of business, academic and public service jobs covering all aspects of animal production, management and care.

Students wishing acceptance into this program should have completed an undergraduate degree in the agricultural or biological sciences, with evidence of good scholarship and scientific aptitude. Strong preparation in biology, chemistry and mathematics is essential. Exact admission requirements vary with area of specialization, as do the specific graduate courses that are required. However, students with undergraduate majors other than Animal and (or) Poultry Science may be required to take additional background courses.

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

Fellowships and teaching and research assistantships are available to qualified students on a competitive basis. Students receiving teaching assistantships will have instructional responsibilities. All students may be required by their advisory committee to assist in teaching for at least one semester during their program.

GRADUATE COURSES (APSC) (ALS)

APSC 5004: GRADUATE SEMINAR
Students review and lead discussion of current problems and literature in Animal and Poultry Sciences. May be repeated. Pass/Fail only. (1H,1C).

ALS 5004: ANIMAL NUTRITION SEMINAR
Reports and discussion of current research in animal nutrition on an inter-departmental basis. May be repeated. (1H,1C).

ALS 5054 (HNFE 5054): METHODOLOGY IN NUTRITION RESEARCH
Use of laboratory techniques, instrumentation, and experimental design in the solution of fundamental problems in human and animal nutrition. Odd years. (2H,2C).

ALS 5064 (BCHM 5046) (BIOL 5064) (PPWS 5064): SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty, and outside speakers. Students give formal presentations of research results or current literature. May be taken on a pass-fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A-F basis. Graduate status in participating MCBB departments required. (1H,1C).

ALS 5104 (HNFE 5104): NUTRITIONAL ASPECTS OF DIGESTIVE SYSTEMS
Principles of gastrointestinal tract structure, motility, and digestive functions with emphasis on neuroendocrine and metabolic regulation of absorption and transport of carbohydrates, lipids, amino acids, minerals, and vitamins during the life cycles of food animals and humans. Pre: HNFE 3026, ALS 3204. (2H,2C).

ALS 5105-5106: POPULATION GENETICS
Principles of population genetics; gene frequency; forces that change gene frequency (migration, mutation, selection); genetic drift; biometric relationships between relatives; calculation of inbreeding and relationship; additive, dominance, and epistatic effects; estimation and use of repeatability, heritability, and genetic correlations; and formation and use of selection goals and selection criteria. PRE: (5105) BIOL 3004, STAT 5615; (5106) STAT 5615, 5616. (SH,3C).

ALS 5114 (HNFE 5114): VITAMINS & MINERALS
Study of metabolic regulation and physiologic functions of micronutrients; micronutrient functions as related to maintenance of health and prevention of disease; analytical methods, determination of micronutrient requirements and assessment of status. Odd years. Pre: 5104, BCHM 5124 or HNFE 5104. (3H,3C).

ALS 5124 (HNFE 5124): PROTEIN & AMINO ACID METABOLISM
Protein and amino acid metabolism in liver, muscle, kidney, and brain; effects of dietary protein on gene expression; protein turnover in tissues; protein quality evaluations; analytical problems in amino acid metabolism. Even years. BCHM 5124, ALS 5104 or HNFE 5104. (2H,2C).

ALS 5134 (HNFE 5134): CARBOHYDRATES, LIPIDS & ENERGY METABOLISM
Concepts in the utilization, metabolism and regulation of carbohydrates and lipids as related to energy metabolism in the various organs and energy balance and its control; metabolism of carbohydrates, lipids and amino acids during activity, fasting, and different disease states in the liver, brain, adipose tissue, kidney and heart; methods of assessment of carbohydrate and lipid metabolism. Odd years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (2H,2C).

ALS 5144 (HNFE 5144): MOLECULAR ASPECTS OF NUTRITION & DISEASE
The role of specific nutrients in human and animal health at a physiologic and molecular level. Emphasis is placed on the influence of nutrients on gene expression, especially with regard to pathophysiology of diseases. Physiological and molecular aspects of nutrition and immune function will also be discussed. Even years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (3H,3C).

ALS 5284: ADVANCED TOPICS IN EQUINE NUTRITION
A critical review of current research in equine nutrition is presented. Special emphasis is placed on new concepts of nutrient requirements and interrelationships, and on factors affecting nutrient intake and utilization. (1H,1C).

ALS 5304: ADVANCED PHYSIOLOGY & ANATOMY OF DOMESTIC ANIMALS
Mammalian physiology and anatomy will be evaluated in domestic animals, laboratory animals, and primates. Emphasis will be on the cardiovascular, renal, respiratory, neural, muscle, and digestive physiology. Pre: 2304. (4H,3L,5C).

ALS 5314: COMPARATIVE REPRODUCTIVE PHYSIOLOGY
Comparative mechanisms of all major aspects of male and female reproductive physiology will be examined in domestic animals, laboratory animals, and primates. Emphasis will be given to species variation in regard to reproductive function and to a detailed examination of key reproductive events in both sexes. Pre: 4304. (4H,4C).

APSC 5894: FINAL EXAMINATION
For non-thesis candidates who are required to register for their final examination and have completed their program of study. Not to be included in minimum hours required for degree. Pass/Fail only. (3H,3C).

ALS 5904: PROJECT & REPORT
Variable credit course.

APSC 5904: PROJECT & REPORT
Project for non-thesis Master of Science degree. To constitute a maximum of 6 of the 45 hours required for the degree. May be repeated. Variable credit course.

ALS 5954: STUDY ABROAD
Variable credit course.

ALS 5964: FIELD STUDY
Pass/Fail only. Variable credit course.

ALS 5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

APSC 5974: INDEPENDENT STUDY
Pass/Fail only. Cariable credit course.

ALS 5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

APSC 5984: SPECIAL STUDY
Variable credit course.

APSC 5994: RESEARCH AND THESIS
Variable credit course.

ALS 6024 (PPWS 6024): TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle assembly, and of growth and development, structure and function of polyamines and of proteases will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: BCHM 5214.

ALS 6314: ENDOCRINOLOGY
Mechanisms in endocrine control of physiological systems will be discussed. Emphasis will be on hypothalamic, pituitary, adrenal, thyroid, parathyroid, pancreatic, and reproductive systems. Pre: 5304. (2H,3L,3C).

ALS 6984: SPECIAL STUDY
Variable credit course.

ALS 7964: FIELD STUDIES
Pass/Fail only. Variable credit course.

APSC 7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ALS) (APSC)

The following 4000–level courses have been approved for graduate credit:

APSC 4154: APPLIED MEAT ANIMAL GENETICS
The application of selection and mating systems to genetic improvement of beef cattle, swine and sheep in the United States. Description of applied breeding programs from elsewhere in the world. New findings in the inheritance of biological and behavioral traits. Future issues and concerns. Pre: ALS 3104. (3H,3C).

ALS 4304: PHYSIOLOGY OF REPRODUCTION
Physiological mechanisms that control and affect reproductive processes in domestic animals, birds, humans, and selected other species. Pre: 2304. (3H,3L,4C).

APSC 4414: BEEF PRODUCTION & INDUSTRY
Detailed study of the commercial and purebred beef cattle industries. Basic principles for successful and profitable beef production. Emphasis on applied, managerial practices during laboratory. Pre: ALS 3104, ALS 3204, ALS 4304. (3H,3L,4C).

APSC 4424: HORSE PRODUCTION & MANAGEMENT
Reproduction, genetics, nutrition, health, behavior and training, economics of commercial horse farms and current issues in well–being. Pre: ALS 3104, ALS 3204, ALS 4304. (3H,3L,4C).

APSC 4434: SHEEP PRODUCTION
Current principles and methods for science–based production and management of sheep. Pre: ALS 3104, ALS 3204, ALS 4304. (3H,3L,4C).

APSC 4444: SWINE PRODUCTION
Principles for commercial and seedstock swine production; current management methods, housing and marketing. Experience in management techniques obtained during laboratory. Pre: ALS 3104, ALS 3204, ALS 4304. (3H,3L,4C).

APSC 4454: LIVESTOCK MANAGEMENT
Overview of livestock production systems; principles of nutrition, reproduction, economics, and breeding and selection of beef cattle, swine, and sheep. For non–majors. (3H,3C).

APSC 4504: POULTRY PRODUCTION SYSTEMS MANAGEMENT
Systems management of integrated poultry operations. Economic analysis and programs management used in decision–making processes. Prepares students for careers as division/company managers and decision makers. Pre: APSC 4404. (3H,3C).

ALS 4554 (BIOL 4554): NEUROCHEMICAL REGULATION
Neurochemical transmission within the vertebrate brain will be examined. Emphasis will be placed on the chemical coding underlying the control of various behaviors and how these systems can be modified by various drugs or diet. Pre: (ALS 2304 or BIOL 3404), CHEM 2535. (3H,3C).

ALS 4574 (BIOL 4574): SOCIAL BEHAVIOR OF BIRDS & MAMMALS
Animal behavior from the viewpoint of group organization during the life cycle of the organism. Emphasis is on adaptive mechanisms as they relate to the behavior–physiology–genetic interaction. Pre: BIOL 1106. (2H,2C).

APPAREL, HOUSING, AND RESOURCE MANAGEMENT

LuAnn R. Gaskill, Head

Residential Property Management Advisory Board Professor: R.C. Goss
International Textile and Apparel Association Fellow: M.J.T. Norton
Professors: J.O. Beamish; L.R. Gaskill; R.C. Goss; M.J.T. Norton; K.R. Parrott
Associate Professors: H.I. Chen–Yu; J.M. Emmel; V.L. Giddings; D.K. Kincade; I.E. Leech; R.H. Lytton; S. Schofield–Tomschin
Assistant Professors: J.M. Emmel; C.R. Hayhoe; J. Kim; A. White
Instructor: W.P. Council

Graduate Program Coordinator E-mail: jbeamish@vt.edu
Department Head E-mail: lagaskil@vt.edu
Graduate Program Secretary E-mail: sepperly@vt.edu
Web: http://www.chse.vt.edu/ahrm/

The Mission of the Department of Apparel, Housing, and Resource Management (AHRM) is to improve the quality of life for individuals, families, and the broader community by creating and extending knowledge in apparel, housing, and resource management. All programs in the department address the interaction of consumers (individuals, families, or communities) with products and services, as well as human and material resources that consumers use to achieve their goals and ultimately enhance their quality of life. Consumer, business, and design perspectives are applied in teaching and learning, research, and outreach. As a diverse academic program, interdisciplinary perspectives in graduate programming are encouraged, which allows students to be grounded in the broad fundamentals of their field and to become familiar with related studies.

The department offers graduate courses and research studies leading to the M.S. (thesis or non–thesis option) and the Ph.D. degree with a major in Apparel, Housing, and Resource Management. Diverse student needs are accommodated through three areas of specialization: Apparel, Housing, or Resource Management. Each specialization area offers a variety of graduate and undergraduate courses. Students are guided by their graduate advisory committee in developing their plans of study in core curriculum courses and concentration courses to meet individual career goals and fulfill departmental and university requirements. The following statements briefly describe each program specialization.

Apparel

Apparel focuses on apparel issues, from design through distribution, with an emphasis on consumer satisfaction. Students may choose to concentrate in one of three areas, including: Apparel Product Design and Analysis, Business and Economic Analysis of Apparel and Textiles, or Apparel and Textiles Quality Analysis.

Housing

Housing focuses on the residential environment. Areas of study include the interrelationships of consumers and housing, design of the structure and its systems, economic considerations, processes by which housing is provided, and public policy and programs relevant to housing. Students may choose to emphasize one of several aspects of research, such as housing markets, housing design, or household equipment.

Resource Management

Resource Management focuses on the principles and processes involved in recognition, creation, and allocation of human and material resources to meet goals. Students may choose to emphasize one of several research areas, such as management of human and non–human resources, consumer protection, financial counseling, or financial planning.

Admission to the Graduate Program

Students may enter graduate work in AHRM from a wide variety of backgrounds. Applicants to the graduate program must be accepted by the Graduate School and the department faculty. The department Graduate Studies Committee will review each applicant on: previous academic work, letters of reference, grade point average; Graduate Record Examination (GRE) or Graduate Management Admission Test (GMAT) scores not over five years old; TOEFL scores of international students; and professional goals and motivation.

Graduate assistantships and tuition scholarships/waivers are available to qualified graduates on a competitive basis.

Special Degree Requirements

The Ph.D. qualifying examination, required prior to completion of 12 credits, is intended to access the student's suitability for the program and asist in program planning. This examination is given only during fall and spring semesters.

Graduate Courses (AHRM)

5004: ORIENTATION TO RESEARCH
Orientation to and examination of research methods, collection and analysis of data, and research reports. Development of a research proposal. (3H,3C).

5104: ADVANCED TEXTILE EVALUATION
A study of the analytical techniques used to determine changes in the chemical and physical structures and properties of textiles resulting from processing and general use. Three credits of statistics are required. (2H,3L,3C).

5114: DESIGN PROCESS
Factors affecting product development and evaluation in apparel, including idea development, needs assessment, prototype development and wear testing. Theory, concepts, and methodology will be applied to actual research problems. Nine additional credits in AHRM are required. (2H,3L,3C).

5124: CLOTHING AND TEXTILES PRODUCT ANALYSIS
An investigation of new products and equipment used in apparel fabrication by industry and the home sewer. Emphasis will be placed on individual analysis, evaluation, and synthesis of findings applicable to clothing fabrication and design. (2H,3L,3C).

5204: CONSUMER ECONOMICS IN CLOTHING AND TEXTILES
Roles of consumers in American economy, analysis of household production and consumption with respect to clothing and textile needs, and constraints in meeting needs. (3H,3C).

5214: APPAREL MANUFACTURING: ECONOMIC AND SOCIAL ISSUES
Study of industrial production of apparel. Detailed analysis of production systems and management methods as well as economic and social issues confronting the industry. Pre: 4224, 4214. (3H,3C).

5224: SOCIAL AND PSYCHOLOGICAL ASPECTS OF DRESS
Study and analyses of social science theories as applied to dress. Three hours of statistics required. (3H,3C).

5304: FAMILY ECONOMICS
Analysis of the family as a decision–making unit within the larger economic and political systems. Relates ecoomic concepts to decisions of families by using tools of economics to anlyze the impact of economic issues upon individuals and families. Pre: ECON 2115, ECON 2116. (3H,3C).

5305,5306: ADVANCED TEXTILE EVALUATION
(2H,3L,3C)

5404: THE CONSUMER IN THE ECONOMY
Analysis of the market economy and the role of the consumer. History of the consumer movement is examined along with today's recurring consumer problems and issues. (3H,3C).

5414: DESIGN PROCESS
Factors affecting product development and evaluation in apparel including idea development, needs assessment, prototype development and wear testing. Theory, concepts, and methodology will be applied to actual research problems. Nine additional credits in AHRM are required. (2H,3L,3C).

5434: CONSUMER PROTECTION ENVIRONMENT
Examination of consumer protection activities: legal, social responsibility, and ethical issues from the viewpoint of both the consumer and the organization offering the product. Consideration of the goals, support, concerns, and issues regarding legislation and current regulatory status and trends. (3H,3C).

5604: HISTORICAL INFLUENCES ON HOUSING CHOICE
Examination of housing choice as influenced by social, economic, political, and technological trends. Analysis of federal housing policy as it relates to the production and consumption of housing and the resulting impact on households. Pre: 3604. (3H,3C).

5614: SOCIAL ISSUES IN HOUSING
A study of housing trends and issues, including the influence of demographics, sustainability, special needs, affordability, and technology. The theoretical base and policy implications of research on social issues in housing will be emphasized. Pre: 5604. (3H,3C).

5624: HOUSEHOLD EQUIPMENT: CURRENT DEVELOPMENTS
Study of current developments in the design, marketing, and use of household appliances and in related educational and research programs. May be repeated once. Pre: 2614. (3H,3C).

5904: PROJECT AND REPORT
Variable credit course.

5944: GRADUATE SEMINAR
Analysis, critique, and synthesis of literature and research pertinent to current issues in apparel, housing, and resource management. Exploration of implications for professional roles in a multicultural and changing, future–oriented society. Pass/Fail only. (3H,3C).

5964: PRACTICUM
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X–grade allowed.

5994: RESEARCH AND THESIS
Variable credit course.

6004: ADVANCED TOPICS
Rotating topics course, focusing on contemporary issues, topics of current importance, and problems in subject matter areas of the department. May be repeated for a maximum of 6 credits. Variable credit course.

6204: SEMINAR IN RESOURCE MANAGEMENT
(3H,3C).

6214: INTERNATIONAL PRODUCTION AND TRADE OF TEXTILES AND APPAREL
Patterns of international textile and apparel production and trade, analyzed through use of economic principles; examination of economic, political/legal, and technological influences. Pre: 4214. (3H,3C).

6604: HOUSING FOR AN AGING SOCIETY
Housing needs, conditions, and alternatives of older adults. Exploration of societal response to demographic trends of aging, including housing design, market, and policy solutions. Pre: 5604. (3H,3C).

6614: INTRNATIONAL TEXTILE/APPAREL TRADE
Patterns of international textile and apparel production and trade, analyzed through use of economic principles; examination of economic, political/legal, and technological influences. Pre: 4214. (3H,3C).

6704: ADVANCED TOPICS IN APPAREL, HOUSING, AND RESOURCE MANAGEMENT
Rotating topics course, focusing on contemporary issues, topics of current importance, and problems in subject matter areas of the department. May be repeated for a maximum of 6 credits. Variable credit course.

6804: ANALYSIS OF THEORIES IN RESEARCH IN APPAREL, HOUSING, AND RESOURCE MANAGEMENT
Analysis of theories in research in apparel, housing and resource management, with emphasis on theory development and application. Pre: 5004. (3H,3C)

7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (AHRM)

The following 4000–level courses may be taken for graduate credit:

4014: SENIOR STUDIO
Principles and Techniques of pattern design through the draping method. (1H,6L,3C).

4024: PORTFOLIO
The development and production of a professional design portfolio. (1H,3L,2C).

4034: HISTORY OF COSTUME
A study of costume which people of various cultures have worn throughout history. (3H,3C).

4044: PATTERN GRADING
Conceptual understanding and implementation of grading techniques, used in apparel engineering, for increasing and decreasing a standard size pattern to a range of sizes. Computer applications. Grading of an original design. (1H,4L,3C).

4204: TEXTILE EVALUATION
Analysis of the performance properties of fabrics. Importance of evaluation to product development, quality control, and specification of care requirements. (2H,3L,3C).

4214: ECONOMICS OF TEXTILE & APPAREL INDUSTRY
Study of the various segments of the textile and apparel industry. Analysis of the market structure and functioning of each segment and of factors currently affecting the industry. (3H,3C).

4224: FASHION ANALYSIS & COMMUNICATION
Analysis of factors influencing fashion change and acceptance. Application of effective promotional activities to trade, national, and retail levels of fashion merchandising. Senior standing required. (3H,3C).

4254: TEXTILE PRODUCTION PROCESSES
Analysis of textile production processes will include focus on a particular aspect of production for each individual. Field work will be conducted at textile manufacturing plants. (2H,3L,3C).

4314: DEBTOR–CREDITOR RELATIONSHIPS
Examination of legal and operational aspects of debtor–creditor relationship from the perspective of businesses and debtors. Overview of the types of credit, access to credit, factors contributing to debt problems, and alternatives available for resolution. Focus on collection processes of federal and state bankruptcy laws and regulations. (3H,3C).

4324: FINANCIAL COUNSELING
Examination of debt and budgeting problems affecting families. Utilizes a problem–solving approach. Includes financial counseling strategies for coping with financial crises and becoming proactive in family financial management. (3H,3C).

4334: FINANCIAL COUNSELING APPLICATIONS
Examination of family financial opportunities affecting individuals over their life cycle with emphasis on risk management and capital accumulation. Utilizes a case analysis approach applying the processes and procedures of family financial management planning. (3H,3C).

4404: CONSUMER PROTECTION
Analysis of the effectiveness of consumer protection efforts. Examination of government laws, regulations, and agencies at the federal, state, and local levels, as well as the effectiveness of both business and private consumer protection efforts. (3H,3C).

4414: PROFESSIONALISM IN CONSUMER AFFAIRS
Roles, functions, and responsibilities of consumer affairs professionals employed in business, government, and non–profit public/consumer interest organizations. Professional advocacy within employing organizations, managing consumer complaint handling systems, and major consumer and career issues are analyzed. (3H,3C).

4504: ADVANCED RESOURCE MANAGEMENT
Theory and principles of the systems approach to resource management. Application to family problems of special life cycle or resource situations. (3H,3C).

4604: HOUSING ENERGY & ENVIRONMENT
A study of the development and management of sustainable housing, emphasizing energy and environmental resource efficiency. (3H,3C).

4614: ADVANCED HOUSEHOLD EQUIPMENT
Measurement of household appliance performance. Emphasis is on analysis of consumer problems using the scientific method and standard measurement techniques. Students also gain experience in writing technical reports and responses to consumers. (1H,4L,3C).

4664: UNIVERSAL DESIGN
Evaluation and design of commercial and residential environments with consideration for accessibility, adaptation, safety, and support of the user(s). (1H,1L,2C).

4674: MANAGING & MARKETING HOUSING FOR LATER LIFE
Managing and marketing housing for later life, including active adult communities and assisted living facilities. AHRM 2676. (2H,2C).

4694: CONTEMPORARY ISSUES IN PROPERTY MANAGEMENT
Issues affecting the property manager, including multi–family housing design, career and professional decisions, and related decisions. The course culminates in the analysis of an apartment complex and development of a management plan. Senior standing required in Residential Property Management or graduate standing is required. (3H,3C).

SCHOOL OF ARCHITECTURE + DESIGN

Steve Thompson, Chair, Graduate Architecture Programs

Professors: S. Choudhury; R. Daniel; A. J. Davis; D. Dunay; R. Dunay; D. Egger; M. Frascari; J. Holt; R. Kemnitzer; D. Kilper; M. O'Brien; J. S. Poole; H.L. Rodriguez–Camilloni; H. Rott; R. Schubert; J. Wang
Associate Professors: K. Albright; M. Casto; E. Dorsa; D. Dugas; M. Feuerstein, S. Gartner; W. Galloway; W. Green; D. Jones; J. Jones; S. Martin; B. Parsons; S. Piedmont–Palladino; H. Pittman; H. Schnoedt; R. Schwaen; M. Setareh; G. Tew; S. Thompson; M. Vernon; F. Weiner
Assistant Professors: M. Breitschmid; M. Cortes; K. Edge; P. Emmons; M. McGrath; S. Molesky; M. Schneider; J. Wheeler; B. Whitney
Visiting Assistant Professor: D. Brothers
Instructors: R. Holt;
Adjunct Faculty: T. Brown; E. Carraher; B. Ferguson; L. Ferrari; B. Gauslin; D. Lever; M. Lutz; S. Pomajambo; R. Reuter; J. Ritter; S. Small; C. Yglesias

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The College of Architecture + Design offers programs leading to the degrees of master of architecture (M. Arch.) and master of science in architecture (M.S.).

Master of Architecture

The graduate curriculum options in architecture are structured to accommodate diverse student needs. This is accomplished by offering a combination of choices of studies available within the following program options, all of which lead to the degree of M.Arch.:

Post-Professional Degree Program

A one–calendar year advanced research and design program **(M.Arch.1)** is intended for the student who already has a professional degree (B.Arch.)in architecture. Students in this option pursue a definitive, experimental, design investigation or perform research in a design–related subject area, according to their special interests. These students may receive advanced standing, as determined by the graduate faculty, for up to 24 credit hours toward completion of the 54 credit hours required for graduation. Students may elect to conduct their studies either at the main campus in Blacksburg, as off–campus students at the Washington–Alexandria Center, or at the Center for European Studies and Architecture in Riva San Vitale, Switzerland.

First Professional Degree Programs

An Advanced Professional Studies option **(M.Arch.2)** is offered for the student who has previously obtained a four–year, pre–professional baccalaureate degree in architecture. The first year of study completes the student's professional building design education and related technical and history/theory studies. The second year is reserved for preparation of a design thesis demonstrative of the student's academic accomplishment and professional potential. Students in this program typically complete 54 (min.) credit hours, normally requiring at least two academic years (4 semesters) of study. Students in the M.Arch.2 program may elect to enroll at the Washington–Alexandria Center for all or a portion of their required studies and/or may spend a semester participating in the Europe Study Abroad Travel Program or in residence at the Center for European Studies and Architecture (CESA) in Riva San Vitale, Switzerland.

A Comprehensive Professional Studies option **(M.Arch.3)** is provided for graduate applicants with degrees in fields other than architecture. The student is presumed to have undertaken little or no concentration in architecture prior to enrollment in the program. In addition to the 54 (min.) graduate credit hours required for the degree, students in the M.Arch.3 option complete 27 credit hours of qualifying year academic work, engaging in studies to provide a foundation of environmental design experiences and to promote a basic understanding of the discipline. Upon successful completion of the qualifying year, students advance through a sequence of studies providing for development of building design skills and knowledge of building systems and the technical processes of construction. During the final year of the curriculum, students pursue individual study interests and prepare a thesis. This program usually requires at least three and one half years (three academic years, plus one required summer) of study. Students in the M.Arch.3 program may elect to enroll at the Washington–Alexandria Center for the final, thesis year and/or may spend a semester participating in the Europe Study Abroad Travel Program or in residence at the Center for European Studies and Architecture (CESA) in Riva San Vitale, Switzerland.

The M.Arch.2 and M.Arch.3 programs are fully accredited by the National Architectural Accrediting Board as first professional degree programs in architecture.

Note: *In the United States, most state registration boards require a degree from an accredited professional degree program as a prerequisite for licensure. The National Architectural Accrediting Board (NAAB), which is the sole agency authorized to accredit U.S. professional degree programs in architecture, recognizes two types of degrees: the bachelor of architecture and the master of architecture. A program may be granted a six-year, three-year, or two-year term of accreditation, depending on its degree of conformance with established educational standards.*

Master's programs may consist of a pre-professional undergraduate degree and a professional graduate degree, which, when earned sequentially, comprise an accredited professional education. However, the pre-professional degree is not, by itself, recognized as an accredited degree.

Master of Science in Architecture

The master of science in architecture program offers the opportunity for advanced study and research in specialized areas related to building design, construction, and operations over a broad range of scales, providing the basis for diverse career paths and/or entry into a Ph.D.–level program. The M.S. is not directed toward professional licensing and therefore is not accredited by the NAAB as a "first professional degree." While an undergraduate degree in architecture, construction, or related fields is not required, applicants must demonstrate relevant background and experience, and capabilities for undertaking advanced academic study.

The Master of Science program allows a student to conduct a research–based program of study which can be expected to contribute to the body of knowledge in the design and building professions, and may lead to future study in the college–wide doctoral program (see the "Envi–

ronmental Design and Planning" section of this catalog), graduate credits earned at the master's level.

Students will develop their own programs of study in cooperation with appropriate faculty and in consideration of the courses and facilities available. Faculty associated with the master of science in architecture program are actively teaching and researching in the following areas:

Building Science
Construction Management
Computing and Representation
Facilities Planning, Construction, and Operations
Industrial Design
Interior Design
Preservation and Rehabilitation Technology

The master of science degree is awarded upon satisfactory completion of an approved program of study of 36 credit hours in either a non–thesis option or including a thesis representing up to 10 hours of the total hours required. A brief description of the suggested major concentrations follows:

Building Science: Studies in the category of Building Science focus on various environmental systems issues over a broad range of scales and may concentrate on the following (or other) areas: energy and building design; mechanical systems and large buildings; lighting and daylighting; natural ventilation and air flow; indoor air quality; acoustics and theatre design; and building structure, assembly, and/or economics.

Construction Management: Studies in Construction Management will prepare graduates to assume management positions eventually leading to upper management responsibilities in both general and specialty construction firms, in design–build firms, and in owners organizations. Courses are concentrated in the management area of construction and include such topics as construction law, cost control, advanced scheduling techniques, and advanced management issues. Built into the program is a certain amount of flexibility depending upon the student's interests. This flexibility allows the student to pursue interests in such areas as developments, project management, design issues, and operational control through independent studies, special studies, and a selection of course work from related disciplines. The Construction Management option may be pursued as a non–thesis degree.

Industrial Design: This graduate program option offers students with architecture, design, and other undergraduate design experience, an opportunity to pursue a course of studies in industrial design. Its purpose is to provide a research focus for solving design problems, as well as a framework to achieve professional competency in the field. The option is concerned with the evaluation and application of human factors and environmental/behavioral research in the design and development of products and product environments for home, institutional, and transportation settings. It seeks to establish a better understanding of the critical interface between user needs, equipment and related space, and to apply this knowledge in the design of safe, efficient, and comfortable products and product environments. Students conduct independent and group research, participate in seminars and group projects of institutional, government and commercial sponsorship, or theoretical nature, and must produce a research–based thesis for graduation.

Interior Design: This concentration allows those with professional degrees in Interior Design or closely related areas the opportunity for advanced research which is expected to add to the body of knowledge in the discipline of Interior Design. Potential research areas include design practice, history of interiors, computer applications in interior design, and environmental behavioral factors related to the interior environment.

Facilities Planning, Construction, and Operation: Facilities planning graduates are prepared to evaluate, initiate, and respond to financial constraints, government regulatory requirements, and characteristics of client organizations affecting and influencing the development of real property assets–usually buildings and facilities. Students will master methods of economic and organizational analysis, capital programming and budgeting and preparation of environmental impact statements. The size and structure of the design and construction segments of the economy will be examined as factors in corporate long–range planning development.

Facilities operations graduates will be prepared to assume line and staff executive responsibilities in private and public sector organizations that own, operate, and invest in buildings and facilities intended for human occupancy and use. Students will master techniques of engineering analysis and operations research, epidemiological analysis, and public health management.

Computing and Representation: Students working in this concentration will study how the design process can be described, how we represent things to ourselves and others by various notation schemes, how computers can support a design process in designing, learning, analyzing, and programming, computer capability in representation, and what organization is required for paint, line–drawing, and spatial modeling programs. Since a large group of faculty in the college is engaged in the development of an integrated computer support system for design, there is opportunity for students in this area of concentration to be engaged directly in the development of such a system, and to participate intensively in discussions concerning its organization.

Preservation and Rehabilitation Technology: Students in this area of specialization will deal with problems affecting the deterioration of buildings through aging and other factors. The preservation technologist combines the skills of the architectural historical, architect, and scientist to effectively examine, diagnose, prescribe, and treat the material fabric of buildings necessary for extending their lifetime. The study and research focuses on the chemistry of building materials, the causes and processes of deterioration, the interaction of environmental factors, and relevant scientific testing methods.

In addition, research concentrations in Urban Design and Architectural Structures, within the Master of Science in Architecure program, are currently under development.

Graduate Courses (ARCH)

Courses (ARCH)
5015–5016: ADVANCED BUILDING ASSEMBLY
Study of complex building types and forms from a geometrical, functional, structural, and construction point of view; the effect of scale, site, environmental control, materials, assembly systems, and detail methods upon architectural design; the current state of building technologies. Pre: 4765, 4766. (3H,3C).

5024: HUMAN ENVIRONMENTAL FACTORS I
A systematic study of the theory and dynamics of environment–behavior interaction. Investigation of the characteristics and nature of behavioral settings. Research methods for environmental analysis and evaluation. Guidelines for design. Field assignments and a written case–study report. Pre: 4705, 4706. (3H,3C).

5034: HUMAN ENVIRONMENTAL FACTORS II
A systematic study of the theory and dynamics of environment–behavior interaction. Investigation of thecharacteristics and nature of behavioral settings. Research methods for environmental analysis and evaluation. Guidelines for design. Field assignments and a written case–study report. Pre: 4705, 4706. (3H,3C).

5035,5036: ADVANCED ENVIRONMENTAL CONTROLS
Advanced studies of environmental controls, the system, and its physical environmental factors, including development in building systems, urban systems, service systems, construction systems, materials and component systems, psycho–physical consideration, systems analysis, and computer technology. May be repeated for a maximum of 12 credit hours in varied options offered. Pre: 4755, 4756. (2H,3L,3C).

5044 (BC 5044): INTERNATIONAL CONSTRUCTION PRACTICES
This course contrasts aspects of the US construction industry with similar yet fundamentally different operating procedures utilized within the international construction community. Areas of concentration include participant organization and culture, project delivery methods, multi–national teams and unique operational and management activities essential in the international market. (3H,3C).

5045–5046: ENVIRONMENTAL DESIGN RESEARCH
Methods for identifying, evaluating, and enhancing the knowledge base for design decisions at scales ranging from room to region. Course emphasizes analytic and empirical approaches to characterizing attributes of the physical environments and their transformation into design variables. Sources of emerging knowledge and systems for maintaining technical currency are identified. Bachelor's Degree in Environmental Design (B.S. Arch, B. Arch, B.L. Arch) required. Co: UAP 5495 or UAP 5496 or EDAE 5300. (3H,3C).

5055,5056: ADVANCED BUILDING STRUCTURES
Study of building forms and structure systems ranging from horizontal–span structures to skyscrapers; preliminary design of masonry buildings, skeletons, tubes, soft and rigid surface structures by considering the complexity of load action that includes wind, seismic, and hidden loads. Pre: 4775, 4776. (3H,3C).

5064: COMPUTER APPLICATIONS IN DESIGN
Computer system fundamentals. Introduction to programming. Emphasis on computer graphics in 2 and 3–space geometry and graphics–related topics employing several languages. Computer usage in architectural design and production. Exploration of available hard and software through advanced design issues. May be repeated for a maximum of 12 credit hours in various options. Pre: 4716. (1H,6L,3C).

5115,5116: MEDIA AND THE ENVIRONMENT WORKSHOP
The role of various media of visual communication as tools of documentation, analysis, and creation in the designed visual environment. Skills in photography, film, video techniques, and printmaking graphics will be developed in specific relation to environmental design study and presentation. Co: 5715, 5716, 5994. (1H,6L,3C).

5124 (BC 5124): LAND DEVELOPMENT FOR CONSTRUCTED FACILITIES
This course covers how to get a piece of undeveloped real–estate from idea to the finished product. It discusses the construction management interface between site engineering and real–estate marketing. Topics covered include: market influences, working with regulatory agencies, zoning, economic considerations, developing an optimum plan, cost and schedule, engineering requirements, environmental impact, financing, and delivering a final product. Pre: 2014. (3H,3C).

5125,5126: MATERIALS PROCESSES WORKSHOP
Characteristics, properties, and uses of various materials and processes as tools of study, analysis, and presentation of the designed environment. The proportion, form, and sectional analysis of hand, wheel, and cast objects are studied. Uses of these materials and the technical process involved are emphasized. Workshop provides framework for design of small scale objects which can relate to environmental design and larger urban scale issues. Co: 5705, 5706 or 5994 Co: 5705 for 5125; 5706 for 5126. (1H,6L,3C).

5134: TOPICS IN ARCHITECTURE HISTORY AND THEORY
Study and critical evaluation of selected current and historical issues in architecture and environmental design. Materials studied will be in the form of projects and writings of key designers, interpretations by leading critics and analysis by historians. Topics will be selected from such areas as: theories of change in culture and architecture; concepts of expression, image, symbol, and form; problems of functional, rational, and social analysis; perception of space and organization. May be repeated for a maximum of 12 credit hours in varied options offered. X–grade allowed. Pre: 4705. (3H,3C).

5515,5516: ARCHITECTURE AND SYSTEMS LABORATORY
Architecture design laboratory with concentration on development of intellectual and professional skills of analysis, synthesis, and evaluation in design problem solving. Focus on the interrelatedness of the various components of building structure and enclosure, integration of building environmental controls, and the contribution of materials and methods of construction to the design process. Pre: 4716. (1H,15L,6C).

5614: THEORY OF URBAN FORM
Urban forms related to functions; analysis of socioeconomic, political, historical, geographic, and cultural forces influencing urban form. Concepts of idealized urban forms and theoretical models of urban configuration. Pre: 4705. (3H,3C).

5624 (LAR 5624) (UAP 5624): URBAN DESIGN SEMINAR
Current topics in urban design. Topics may include: theoretical, conceptual and practical concerns in the generation of urban spatial form; the roles of public and private interests in shaping urban form; the effects of urban intensification on the quality of public spaces; environmental issues in urban design; the role of public policy and regulatory mechanisms; the genesis and development of urban typologies. Pre: 5614. (3H,3C).

5634 (UAP 5634): URBAN DESIGN STUDIO
Urban design studio projects involving the translation of design and planning theory and methodology to actual form–giving proposals for the urban context. Emphasis will be on the development of urban tectonic form in response to functional and behavioral planning, symbolic and aesthetic factors. May be repeated for a maximum of 12 credit hours. Variable credit course. Pre: 4715.

5705,5706: ARCHITECTURE AND URBANISM SEMINAR
Review of contemporary concepts in architectural design in the context of the urban environment. Significant architectural works of

the twentieth century and the theories of their authors will be studied for an understanding of their contribution to the language of architecture. The attitudes and phenomena which have led to the making of the particular culture of our time will be studied for their impact on the built urban environment. X–grade allowed. Pre: 5516. (3H,3C).

5715,5716: ARCHITECTURE AND URBANISM LABORATORY
Advanced design laboratory for identifying needs, resources and operational methodologies across an expanded range of environmental scales. The scope of design includes the relation of the individual building to the environment in comprehensive terms, with particular emphasis on the complexity which exists at the urban scale. Methods for the identification of socio–cultural needs and the coordination of complex variables, information, and resources, leading to the conceptualization and development of design of the components of the built environment. (1H,15L,6C).

5755,5756: ADVANCED DESIGN LABORATORY
Complex environmental design problems related to social, cultural, and historical issues examined for contribution to developing appropriate architectural form and aesthetic. Laboratory will focus on research and development of graduate design projects at a range of scales: product, architectural, urban; based on individual interests. Variable credit course. X–grade allowed. Pre: 4716.

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT AND REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course. X–grade allowed.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course. X–grade allowed.

6014: PROJECT AND COMPANY MANAGEMENT
Study of the management of a construction project and a construction company. Project management includes finances, cash flows, cost control, project organization, and project planning. Company management includes company organization incorporation structure, procedures, finance, insurances, accounting, and operation. Case studies are emphasized. (3H,3C).

Advanced Undergraduate Courses (ARCH)

The following 4000–level courses have been approved for graduate credit:

4044 (LAR 4124): PROFESSIONAL PRACTICE
Introduction to scope and diversity of the building enterprise, addressing private and public macroeconomic, industrial, technical, professional, and regulatory institutions. Analysis of historic evaluation of professional roles and practices; emergence of new modes of practice, including innovative facilities procurement methods. (3H,3C).

4055,4056: ENVIRONMENT AND BUILDING SYSTEMS
A design oriented study of environmental forces, environmental impacts of the built environment, and related building environmental control, life safety and service systems, with concern for the human psycho–physical impacts of building form and systems performance. Pre: 2014. (3H,3C).

4304: TOPICS IN DESIGN METHODS
Topics in systematic methods of design and the nature of the design process including application of creative techniques, analogous thinking, analytic methods, computer–aided procedures, and information handling in design. Repeatable with a maximum of 6 credits. X–grade allowed. (3H,3C).

4705–4706: QUALIFYING DESIGN SEMINAR
Exploratory overview of selected theories and issues relevant to the design and use of the environment. 4705: Emphasis on history, human behavior, and evironmental context as it relates to architecture. 4706: Presentation and discussion of the nature of principal construction materials in relation to building design. Characteristics of primary structural materials: wood, steel, concrete, masonry; environmental control systems; supporting technologies. Not for credit for majors holding a first professional degree in architecture. (3H,3C)

4715–4716: QUALIFYING DESIGN LABORATORY
4715: Design laboratory in which student and faculty teams explore the nature of problems and potentials with which architecture is concerned, and experimentally develop methods and process through which existing contexts are transformed into new conditions. 4716: Provides introduction to basic concepts of building structures, materials, and enclosure systems, and appropriate site and climate responses. Not for credit for majors holding a first professional degree in architecture. X–grade allowed. (3H,18L,9C).

4755–4756: BUILDING ENVIRONMENTAL SYSTEMS
This sequence concentrates on defining different intervention techniques available to the architect to articulate the relationship between the outside and inside environment of buildings. These intervention techniques strive towards a fit between built form and the thermal, luminous, sonic, and water/waste environment. Pre: 4706. (3H,3C).

4765–4766: BUILDING TECHNOLOGY
The design of buildings as controlled by geometry, construction, assembly, materials, details, structure, function, enclosure, and finish work. Pre: 4706. (3H,3C).

4775–4776: BUILDING STRUCTURES
Building structures in steel, timber, and reinforced concrete; design of typical components: beams, slabs, columns, beam–columns, connections, and foundations; design of retaining walls; the resistance of buildings to gravity and lateral force action; building stability; floor/roof framing systems; design of simple buildings. Pre: ESM 3704. (3H,3C).

Graduate Courses (ITDS)

5104: ADVANCED INTERIOR DESIGN
Advanced studio project with an emphasis on the implications of physical and psychological factors on a proposed solution to a complex interior design problem. Pre: 4115. (6L,3C).

5114: ADVANCED RESEARCH DESIGN
Investigation of current and landmark housing and interior design research studies, as well as the execution of a short–term study which demonstrates a practical understanding of design research. (3H,3C).

5124: PRESERVATION OF HISTORIC INTERIORS
Study of restoration and preservation practices, including economic, social, and legal aspects and an introduction to historical research methodology. Pre: 4126. (3H,3C).

5134: FACILITY MANAGEMENT
Survey of the planning, implementation, and monitoring procedures for an organization's interior spaces, people functions, and financial assets. Pre: 4115. (3H,3C).

5964: PRACTICUM
Practicum experiences in departmental options under supervision. Maximum 15 percent of student's graduate program. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

ART & ART HISTORY

T. Truman Capone, Head

Professors: G.S. Bickley; C. Burch–Brown; D.F. Crane; R.J. Fields; R.H. Graham; L.B. Van Hook
Associate Professor: T. Capone
Assistant Professors: A.M. Knoblauch; J. Niewald; D.V. Odell; Y. White
Instructors: B. Bannan; S. Chandler; M. Nugent; K. Pinkerton; J. Rosenthal
Adjunct Professors: G. Bryson; D. Sim
Career Advisors: R.J. Fields, *Graphic Design* (231–6005); C. Burch–Brown *Studio* (231–6335); A.M. Knoblauch, *Art History* (231–3170)
Director, Student Advising: B. Bannan (231–1714)
Chair, Studio Art Program: C. Burch–Brown

Several courses are offered to serve the needs of graduate students majoring in other disciplines. This department does not offer a degree program. The courses listed below are available to graduate students and may complement their work in their particular fields.

GRADUATE COURSES (ART)

5974: INDEPENDENT STUDY
Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ART)

The following 4000–level courses have been approved for graduate credit:

4514: INTERARTS STUDIO
This studio course will investigate new approaches to art–making and new genres, such as performance art and site–specific installation. Interdisciplinary basis for course may incorporate traditional studio practices and media in the visual arts, music and theatre arts, and appropriate technology in computer, video, and film. May be repeated for a maximum of 6 credits with different topics. 3000–level Studio or Art History course required. (1H,5L,3C).

4524: PICTORIAL ARTS STUDIO
Rotating topics in the two dimensional arts, at an advanced level. All topics will challenge the student to develop stronger, independently generated work of portfolio quality. May be repeated for a maximum of 6 credits with different topics. 3000–level Painting or Drawing course required. (1H,5L,3C).

4534: APPLIED ART AND DESIGN STUDIO
Rotating topics about functional art and design. Students will use appropriate materials, tools, and processes in the creation of functional artworks, such as furniture, tiles, tableware, etc. Function and design aesthetics emphasized. May be repeated for a maximum of 6 credits with different topics. Pre: 2544 or 2554. (1H,5L,3C).

4554: SPATIAL ARTS STUDIO
Advanced level, rotating topics in the three dimensional arts. All topics will challenge the student to develop stronger, independently generated work of portfolio quality. May be repeated for a maximum of 6 credits with different topics. 3000–level Ceramics, Sculpture or Applied Art course required. (1H,5L,3C).

4564: EXHIBITION DESIGN & DISPLAY
This course will focus on the display and presentation of visual art, using local galleries as venues for student– designed exhibitions. Provides experience in the public art arena, and practical knowledge about planning, designing, and mounting an exhibition. 3000–level Studio or Art History course required. (1H,5L,3C).

4574: ADVANCED VISUAL COMMUNICATIONS
A further refinement of design theory and practice, and communication skills. Emphasis on the conceptual development of expanded project formats, and individual creativity. This class will provide a principal opportunity for building a viable portfolio. FEES REQUIRED. 6 credits of Art 3574 required. (1H,5L,3C).

BIOCHEMISTRY

John L. Hess, Head

Professors: J.–S. Chen; D.R. Dean; J.L. Hess; T.W. Keenan; P.J. Kennelly; T.J. Larson; W.E. Newton; M. Potts
Associate Professors: D.R. Bevan; E.M. Gregory; R.F. Helm; T.O. Sitz; Z. Tu; R.H. White
Assistant Professors: E. Dolan; G.E. Gillaspy; S. Kim
Adjunct Faculty: D.F. Berry; P. Mendes; J. Mahaney; H.P. Misra; B. Mukhopadhyay; D.T. Zallen

Web: www.biochem.vt.edu/

The department has programs leading to the Ph.D. and M.S. (thesis required). Research is considered the most important aspect of the graduate learning experience. Thesis or dissertation research problems are designed to give the student maximum opportunity to learn a variety of principles and techniques.

Opportunities for graduate education include research in: regulation of gene expression; macromolecular structure, function, biosynthesis and degradation; enzyme and coenzyme mechanisms of action; mechanisms of signal transduction; post–translational modifications of proteins; plant biochemistry; molecular genetics and enzymology of nitrogen fixation, archaea, and cyanobacteria; enzymology and regulation of the solvent–producing fermentative bacteria; and insect genomics and transposable elements.

Background in biology and chemistry, including one year of organic chemistry, one course in analytical chemistry or quantitative analysis, one year of calculus, and one year of biology are considered minimum prerequisites for initiation of graduate studies. Courses in biochemistry and physical chemistry are recommended.

Depending upon the candidate's degree of preparedness, two to three years are needed to complete requirements for the M.S. and four to five years for completion of requirements for the Ph.D.

Individual plans of study are arranged between student and major professor. Advanced courses in biochemistry and/or microbology and seminars constitute the course requirements in the major. Supporting courses can be selected in such areas as chemistry, immunology, environmental science, nutrition, entomology, anatomy and physiology, statistics, plant sciences, animal sciences, cell biology, and computer science. A minimum teaching experience of one semester is required for the Ph.D.

The program prepares graduates for careers in research and teaching in academic institutions, research in governmental laboratories in the health sciences and agriculture, and research in private or industrial laboratories concerned with biotechnology, pharmaceuticals, chemicals, or other areas where knowledge of biochemical or microbiological principles is of value.

GRADUATE COURSES (BCHM)

5004: SEMINAR IN BIOCHEMISTRY
Review and discussion of current problems and literature in biochemistry and nutrition. Student presentation of research results, faculty research, and visiting lecturers. May be repeated. Biochemistry majors only. (1H,1C).

5014: TECHNIQUES IN BIOCHEMICAL RESEARCH
Principles of basic modern biochemical research techniques applicable to protein structure and chemistry; enzymology; nucleic acid biochemistry; gene expression and organization; microbial metabolism; coenzyme biosynthesis; structure and function of membranes and subcellular organelles. Must have graduate standing in Biochemistry. (9L,3C).

5024: COMPUTATIONAL BIOCHEMISTRY FOR BIOINFORMATICS
Applications of protein structure and function, protein characterization, enzyme kinetics, and analysis of metabolic control for students with a background in computer science, mathematics, statistics, or engineering. Pre: B.S. or senior standing in computer science, mathemativcs, statistics, or engineering. Not available to life science majors for credit. (3H,3C)

5034: COMPARATIVE STUDIES OF NUCLEIC ACID
Physical properties of nucleic acids, isolation methods, principles of DNA reassociation and RNA hybridization experiments, genome complexities, recombinant DNA procedures, and nucleotide sequence analysis. Pre: 4116, BIOL 4714. (1H,3L,2C).

5044: COMPARATIVE METABOLISM OF ANAEROBIC BACTERIA
In–depth biochemistry and genetics of the major groups of strictly anaerobic bacteria with emphasis on metabolism influencing the native ecology of organisms in anaerobic habitats. Structure and function of enzymes and coenzymes unique to anaerobes, bioenergetics and regulation of fermentations and anaerobic respirations, one–carbon metabolism, methanogenesis, sulfate reduction, anoxic photosynthesis. Eco–physiology of rumen, intestinal freshwater and marine anaerobes. Pre: 4116. (2H,2C).

5054: MOLECULAR BIOLOGY OF PROKARYOTIC GENE REGULATION
An analysis of the experimental design and methodology used to elucidate molecular regulation of prokaryotic gene expression. Modern genetic technologies used to identify and characterize these regulatory mechanisms will be emphasized. Pre: 4115, 4116 or BIOL 4624. (3H,3C). Alternate years.

5064 (ALS 5064) (BIOL 5064) (PPWS 5064): SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty and outside speakers. Students give formal presentations of research results or current literature. May be taken on pass–fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A–F basis. Graduate status in participating MCBB departments required. (1H,1C).

5115–5116: PRINCIPLES OF BIOCHEMISTRY
Comprehensive presentation of principles of protein structure, enzymology, bioenergetics, and metabolism. Relationships between regulatory mechanisms and molecular biology. Current literature on these topics provides emphasis on the relationship of primary scientific literature to biochemical knowledge. Pre: CHEM 2536. (4H,4C).

5124: BIOCHEMISTRY FOR THE LIFE SCIENCES
Basic principlesof biochemistry including protein structure, enzymology, gene expression, bioenergetics, and pathways of energy metabolism. Not available to Biochemistry majors. Pre: CHEM 2536. (3H,3C).

5204: MOLECULAR BIOLOGY OF EUCARYOTIC GENE EXPRESSION
Mechanisms controlling eucaryotic gene expression. Topics include biochemistry and metabolism of DNA and RNA, gene and chromatin structure, enzymology of replication and transcription, modification and processing of RNA, recombinant DNA and molecular cloning techniques. Pre: 4116 or 5116. (3H,3C).

5214: MOLECULAR BIOLOGY OF THE CELL
Current concepts of the molecular organization of animal and plant cells the biosynthesis and assembly of cellular structures. Topics include membrane structure and function, biosynthesis of cellular organelles, cytoskeleton, extracellular matrix, chemical signaling between cells, and the production of engineered proteins in cells. Pre: 4116 or 5116 or 5124. (3H,3C).

5224: PROTEIN STRUCTURE & FUNCTION
Structure and function of proteins. Topics include special techniques in protein purification and characterization, techniques for studying protein structure, post–translational modification of proteins and selected topics to study the structure–function relationship of proteins. Pre: 4115 or 5115 or 5124. (3H,3C).

5264 (VMS 5264): ADVANCED MEDICAL BIOCHEMISTRY
Application of basic principles of biochemical events at the cellular level to study the physiological processes occurring in the whole organism. Examples of deviant biochemical processes in human and animal diseases. Emphasis on physiological regulation, lack of control manifested in patients (diagnosis), and current knowledge in regaining control (therapy). Pre: 4116 or 5116. (2H,2C).

5304: ENZYME KINETICS & REACTION MECHANISMS
Development of various enzyme rate equations, consideration of experimental methods for examining the physical, chemical, and kinetic data from enzymes, and examination of various models and reaction mechanisms for enzymic catalysis. Pre: 4116 or 5116, CHEM 4616. (3H,3C).

5344 (PPWS 5344): MOLECULAR BIOLOGY FOR THE LIFE SCIENCES
A multi–disciplinary treatment of gene organization and expression in animal and plant systems. Emphasis on the applications of molecular biology to current problems in applied biology and biotechnology. Pre: 4116 or 5124. (3H,3C).

5444: MOLECULAR MODELING OF PROTEINS AND NUCLEIC ACIDS
Theory and practice of molecular modeling as applied to biological macromolecules. Topics include molecular mechanics, molecular dynamics, homology modeling, protein ligand interactions, and rational drug design. Co: 4116, 5116, CHEM 3616, CHEM 4616. (2H,3L,3C).

5504: METABOLIC REGULATION
Detailed studies of the mechanisms of regulation of metabolism above the individual enzyme level. Inter– and intracellular messengers, regulation at genetic, whole cell and tissue levels will be discussed. Examples from procaryotic and eucaryotic systems will be used. Assumes some knowledge of enzyme regulation. Pre: (4116 or 5116 or 5124). (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: ADVANCED TOPICS IN BIOCHEMISTRY
Advanced topics of current interest selected from the current literature. May be repeated. Pre: 5116. (2H,2C).

6024 (PPWS 6024): TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle assembly, and of growth and development, structure and function of polyamines and of proteases will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: 5214.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (BCHM)

The following 4000–level courses have been approved for graduate credit:

4034 (VMS 4034): ENVIRONMENTAL HEALTH TOXICOLOGY
Health effects associated with the exposure to chemicals, identifying and managing problems of chemical exposure in work places and the environment, fundamental principles of biopharmaceutics and toxicokinetics, and risk assessment. Emphasis on conceptual understanding of chemical entry into the body, biotransformation, multiple chemical sensitivity, and chemically induced diseases. Identification of and chemically induced diseases. Indentification of nutrient interactions with environmentally induced disorders and to understand the mechanisms of such interactions and their influence on human health and welfare. Pre: 2104 or 3124, ALS 2304, BIOL 2406 or 3114 or 4115, 4116. (3H,3C).

4054: GENOMICS
A contemporary analysis of the development, utility and application of high–resolution methods for the study and manipulation of the complete genomes of organisms. The use of new techniques for genomic, metabolic and protein engineering (functional genomics), including high–throughput methods and nanotechnology, will be emphasized. Pre: 4116 or BIOL 3774. (1H,1C).

4115–4116: GENERAL BIOCHEMISTRY
Metabolism and chemistry of carbohydrates, proteins, lipids, and nucleic acids with emphasis on interactions and comparative aspects of microbial, plant, and animal forms. For students in the biochemistry curriculum and other students interested in a foundation course. (Students are required to have at least a C– in both Chem 2535 and 2536 to be admitted to BCHM 4115). Pre: CHEM 2536. 4115: (4H,4C) 4116: (3H,3C).

4224: SPECTROSCOPY OF BIOMOLECULES
Presentation of the applications of modern spectroscopic methods, including UV–visible, fluorescence, NMR, ESR, CD/ORD, and mass spectrometry, to biochemical analysis. Selected instruments and their uses will be demonstrated. Pre: BCHM 4116, CHEM 4524. (3H,3C).

BIOLOGICAL SYSTEMS ENGINEERING

Saied Mostaghimi, Head

H.E. and Elizabeth F. Alphin Professor: S. Mostaghimi
Professors: J.S. Cundiff; T.A. Dillaha; R.D. Grisso; D.H. Vaughan
Associate Professors: F.A. Agblevor; C.D. Heatwole; K. Mallikarjunan; M.L. Wolfe
Assistant Professors: B. Benham; S. Gay; C. Zhang
Instructor: S.C. Mariger
Career Advisors: T.A. Dillaha; K. Mallikarjunan
Graduate Coordinator: K. Mallikarjunan
Teaching Coordinator: D.H. Vaughan

E-mail: bse@vt.edu
Web: www.bse.vt.edu

The Department of Biological Systems Engineering offers programs of study leading to the degrees of master of engineering, master of science, and doctor of philosophy. Studies are offered in many technical fields of biological systems engineering, including energy conservation, agricultural waste management, fluid power systems, alternative energy sources, food engineering, bioprocess engineering, plant and animal environment, soil and water conservation engineering, watershed engineering, nonpoint source pollution control, geographic information system, sensors and controls in agriculture and aquaculture, TMDLs and sustainable agriculture.

Well–equipped laboratories are available for research in soil and water conservation, water quality, food engineering, physical properties of food and agricultural products, bioprocess engineering, fluid power system, sensors and controls, geographic information systems, and protein expression and purifications.

In addition, the department has an environmental laboratory with several large climate–controlled chambers and a field laboratory with fan testing, crop drying, and processing facilities. Sophisticated laboratories for such activities as spatial data analysis, and aquaculture are available to biological systems engineering students for interdisciplinary research. Many faculty members are involved in joint extension/research activities and may provide access to operating commercial facilities to allow students to obtain data under actual field conditions.

SPECIAL DEGREE REQUIREMENTS

Each student's plan of study must be approved by the student's advisory committee and the departmental graduate committee prior to completion of 12 semester credit hours. M.S. candidate's plan of study, in addition to the Graduate School requirements, must include at least 6 credit hours of math or statistics. Ph.D. candidates must complete 6 credit hours each of math and statistics. Ph.D. candidates are encouraged to gain classroom teaching experience through teaching the equivalent of at least one semester credit hour prior to their graduation. Graduate teaching and research assistantships are available to qualified students.

GRADUATE COURSES (BSE)

5114: PHYSICAL PROPERTIES OF AGRICULTURAL PRODUCTS
Theory and measurement of fundamental physical properties important to harvesting, handling, sorting, processing, and packaging of food and agricultural materials. Pre: 3504, STAT 4705. (3H,3C).

5124: PROBABILITY MODELS IN AGRICULTURAL ENGINEERING
Modeling data with probability distributions, reliability methods, Monte Carlo simulation of agricultural systems, and Markov models for agricultural related processes. Pre: STAT 4705. (3H,3C).

5134: LAND APPLICATION OF WASTES
Engineering concepts and design methods for land application of municipal, agricultural, and industrial wastes; waste utilization and recovery, surface and ground water pollution control; economic analysis of land application systems. Pre: 4304, CEE 4304, CSES 4594. (3H,3C).

5144 (CEE 5064): KNOWLEDGE–BASED EXPERT SYSTEMS
Function and concepts of knowledge–based expert systems. Knowledge representation, uncertainty management, inferencing techniques, and validation. Principles of knowledge acquisition and knowledge engineering. Focus on developing knowledge–based systems for information management and decision support in engineering and natural resource management. Program language experience required. (3H,3C).

5204: ENVIRONMENTAL CONTROL FOR ANIMALS AND PLANTS
Physiological reactions by plants and animals to environmental factors. Application of scientific and engineering principles for the design of production facilities with controlled environment and for modification of the soil–plant–atmosphere continuum for improved crop yield. Utilization of plant and animal models for predicting growth and performance. Pre: CSES 3114. (3H,3C).

5244 (CEE 5244): ADVANCED GIS IN HYDROLOGIC ANALYSIS
Advanced GIS course focusing on raster analysis with particular application to the issues associated with hydrologic analysis. Application and evaluation of algorithms for terrain analysis, watershed characterization, and hydrologic analysis and modeling as implemented in GIS. Digital evelation data sources and error assessment. Approaches to GIS/model integration and application. Pre: 4344 or CEE 5204 or GEOG 4084, BSE 3305 or CEE 4304. (2H,3L,3C).

5304: NONPOINT SOURCE POLL
Engineering principles of nonpoint source pollution control as affected by precipitation, surface runoff, soil characteristics, agronomic practices, and erosion in urban and agricultural watersheds with particular emphasis on the water quality impacts of agricultural activities. Pre: 3304. (3H,3C).

5354: NONPOINT SOURCE POLLUTION MODELING
Examination of the fundamental structure of nonpoint source pollution models, considering components, parameters and dependent variables, governing mathematical relationships; spatial variation of inputs; upland sediment and nutrient transport; and nonpoint source pollution control planning. Pre: 5304. (3H,3C).

5604: ADVANCED FOOD PROCESS ENGINEERING
Design of food processing operations including microwave cooking, frying, and extrusion. New food processing technologies including ohmic, radio frequency, high pressure, and pulsed electric field processing. Simulation of food processing systems. Procedures for optimizing formulations or processes. Odd years. Pre: 3504, 4604. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Selected presentations and discussions by graduate students and faculty. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (BSE)

The following 4000–level courses have been approved for graduate credit:

4004 (ESM 4004): INSTRUMENTATION & EXPERIMENTAL MECHANICS
Introduction to instrumentation. Data analysis: uncertainty, error and statistical concepts. Devices: digital multi–meters, oscilloscopes, power supplies, and function generators. Circuits: ballast circuits, wheatstone bridges, operational amplifiers, and transistors. Principles of data acquisition. Fourier analysis. Measurements of velocity, pressure, strain, displacement, forces and accelerations. Laboratory and design projects. Pre: (ESM 2204, ESM 2304, ESM 3015) or (ESM 3024, ECE 3054). (2H,2L,3C).

4144: BIOLOGICAL SYSTEMS SIMULATION
Study of modeling techniques and application of these techniques to reaction kinetics, crop growth, and systems analysis. Emphasis is on development of basic understanding of methods for defining and evaluating interrelationships between parameters in a biological system. Pre: 3504. (3H,3C).

4304: NONPOINT SOURCE POLLUTION MODELING AND MANAGEMENT
Concepts, principles and application of modeling and monitoring for assessment and management of nonpoint source pollution. Design and implementation of monitoring systems. Concepts of modeling agroecosystems and land use impacts on hydrologic/water quality response of upland catchments. Model selection, calibration, validation, and application for comparative analysis. Screening models using Geographic Information Systems. Case studies in current watershed management issues, with a focus on agricultural waste and nutrient management, using existing field and watershed models. Pre: 3306. (2H,3L,3C).

4314: IRRIGATION ENGINEERING
Engineering principles involved in irrigation and drainage theory and practices are presented. Emphasis is placed on measurement of soil and water properties, techniques for estimating water requirements, irrigation scheduling and design, operation and management of various irrigation systems. Requirements of surface and subsurface drainage systems also will be studied in detail. Pre: BSE 3304. (3H,3C).

4324: NONPOINT SOURCE POLLUTION
Engineering aspects of the sources and magnitudes of nonpoint source pollution, major causative factors, and control techniques. Emphasis on hydrologic factors, erosion, atmospheric deposition, adsorption and degradation of pollutants in soil, disposal of agricultural wastes, and management for the control of urban and agricultural nonpoint source pollution. Pre: 3104. (3H,3C).

4344: GEOGRAPHIC INFORMATION SYSTEMS FOR ENGINEERS
Conceptual, technical, and operational aspects of geographic information systems as a tool for storage, analysis, and presentation of spatial information. Focus on engineering applications in resource management, site selection, and network analysis. Laboratory work and senior standing required. (2H,3L,3C).

4394: WATER SUPPLY AND SANITATION IN DEVELOPING COUNTRIES Social, economic and engineering principles of water supply and sanitation in developing countries as affected by climate, cultural and sociological factors, and material and financial resources. Pre: 3104. (3H,3C).

4424 (ME 4434): FLUID POWER SYSTEMS AND CONTROLS
Design and analysis of industrial and mobile hydraulic systems. Hydrostatic transmissions. Electrohydraulic servovalve characteristics and use in precise position and speed control application. Characteristics of pumps, motors, valves, and activators illustrated in laboratory exercises. Pre: ESM 3024 or ME 3404.
(2H,3L,3C).

4504: BIOPROCESS ENGINEERING
Study of the engineering concepts for biological conversion of raw materials to food, pharmaceuticals, fuels, and chemicals. Emphasis is placed on enzyme kinetics and technology, bioreaction kinetics, analysis, and control of bioreactors and fermenters, and downstream processing of bioreaction products. Pre: (3504, BIOL 2604, CHEM 2514 or CHEM 2535, CHEM 3615 or CHEM 4615). (3H,3C).

4524: BIOLOGICAL PROCESS PLANT DESIGN
Engineering principles for design of systems for processing biological materials into primary and secondary products. Delivery, scheduling, storage requirements, economic analysis. Process control and instrumentation of bioprocessing plants. Pre: (4004, 4504, 4604). (3H,3C).

4544 (CHE 4544): PROTEIN SEPARATION ENGINEERING
Concepts, principles and applications of various unit operations used in protein separations. Properties of biological materials, such as cells and proteins, and their influences on process design. Design of processes for protein purification based on the impurities to be eliminated. Concepts and principles of scale–up of unit operations. Case studies in practical protein recovery and purification issues, with a focus on enhanced protein purification by genetic engineering. Protein purification process simulation and optimization using process simulation software. Pre: 3504 or CHE 3144. (3H,3C).

BIOLOGY

UNIVERSITY EXEMPLARY DEPARTMENT *

Robert H. Jones, Head

Distinguished Professors: A.L. Buikema; J.J. Tyson
Harold H. Bailey Endowed Chair: J.R. Walters
Professors: R.M. Andrews; E.F. Benfield; D.S. Cherry; J.R. Cowles; K.D. Elgert; A. Esen; J.O. Falkinham; K.W. Hilu; R.H. Jones; F.M.A. McNabb; M.G. McNamee; E.T. Nilsen; B.D. Opell; J. Phillips; D.M. Porter; C.L. Rutherford; S.E. Scheckler; J.R. Webster; B.S.J. Winkel
Associate Professors: J.A. Cranford; T.A. Jenssen; C.B. Lawrence; S.B. Melville; D.L. Popham; J. Sible; A.M. Stevens; B.J. Turner; M. Valett; R.A. Walker
Assistant Professors: L.K. Belden; C. Gibas; I. Lazar; I.T. Moore; J.W. Via; E. Wojcik; Z. Yang
Instructors: M.V. Lipscomb; M.S. Rosenzweig
Adjunct Faculty: K. Duca; R.S. Greenberg; M. Kowalewski; N.G. Love; R.J. Mitchell; B. Mukhopadhyay; D. Rathore

Web: www.biol.vt.edu/

The department offers programs of study leading to M.S. and Ph.D. degrees in biology. Graduates may designate one of the following subdisciplines to appear on transcripts: cellular and molecular biology; ecology and environmental biology; microbiology and immunology; genetics, systematics, and evolution; organismal biology (botany, zoology). Active research programs are being conducted in areas including behavior, cell biology, developmental biology, ecophysiology, ecotoxicology, evolutionary biology, environmental physiology, aquatic ecology, immunology, mammalogy, microbial ecology, microbial genetics, microbial physiology, molecular genetics, ornithology, paleobotany, population genetics, population and community ecology, systems ecology, and theoretical biology.

In addition to programs available within the department, we participate in the following interdepartmental graduate programs: Microbiology; Genetics, Bioinformatics, and Computational Biology; Molecular, Cell Biology, and Biotechnology; and Plant Physiology. Programs of study are developed by mutual agreement between students and their advisory committees to meet the unique academic requirements of each student. All biology graduate students must teach a minimum of one semester as a requirement for graduation.

GRADUATE COURSES (BIOL)

5024: POPULATION & COMMUNITY ECOLOGY
Population dynamics, interspecific interactions, succession, and diversity of plants and animals. Quantitative approaches emphasized. Ecology course required. (3H,3L,4C).

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

5034: ECOSYSTEM DYNAMICS
Application of a systems perspective to functional characteristics of ecosystems. Laboratory: computer simulation of ecosystem dynamics. Pre: MATH 2015, CS 1014. (3H,3L,4C).

5044: AQUATIC ECOTOXICOLOGY
Techniques for evaluating polluted aquatic ecosystems, including laboratory toxicity testing and field biological monitoring, and the development of criteria for maintaining water quality. (2H,2C).

5054: HAZARD EVALUATION OF TOXIC CHEMICALS
Discussion of philosophical issues in the development of standards for control of toxic chemicals in freshwater, including site–specific examples, application of current control methods, recovery of damaged ecosystems, and government regulations. Pre: 5044. (2H,2C).

5064 (ALS 5064) (BCHM 5064) (PPWS 5064): SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty and outside speakers. Students give formal presentations of research results or current literature. May be taken on pass–fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A–F basis. Graduate status in participating MCBB departments required. (1H,1C).

5075–5076: BIOINFORMATICS METHODS IN RESEARCH
Application of bioinformatics methods in biological research. Begins with theory and methods for analysis of proteins and protein families, and progresses to analysis of complex data sets including whole genome sequences and gene expression. Laboratory begins with basic techniques for information gathering and molecular sequence and structure analysis, and progresses to analysis of genome sequences and gene expression data sets. The laboratory component will provide experience in use of standard bioinformatics software and databases. Pre: 3774, BCHM 3114. (3H,3L,4C).

5164: BIOLOGY SEMINAR LAB
A practicum in the preparation and presentation of formal scientific seminars. Graduate standing required. (3L,1C).

5174: GRADUATE SEMINAR
Offered in the major subdisciplines of biology. Pass/Fail only. (1H,1C).

5204: CLASSIFICATION OF FLOWERING PLANTS
Evolutionary mechanisms and phylogenetic relationships of flowering plants. Recent systems of classification and their bases and biases. Pre: 3204. (2H,3L,3C).

5214: PLANT SYSTEMATICS
Analysis of plant variation and relationships, using morphology, cytogenetics, phytochemistry, molecular biology, and biogeography. Emphasis on breeding systems, polyploidy, hybridization, and speciation. Pre: 3204. (2H,3L,3C).

5224: ADVANCED MYCOLOGY
Biological role, morphogenesis, mating systems, and taxonomy of Basidiomycotina, Ascomycotina and related Deuteromycotina. Pre: 4244. (3H,3L,4C).

5234: ALGAL ECOLOGY
Morphological, physiological, and biochemical responses of algal communities to physical and chemical variables in their environment. Pre: 4234. (3H,3C).

5244: AQUATIC VASC PLANTS
Systematics, morphology, reproduction, and ecology of plants inhabiting ponds, lakes, streams, and marshes. One weekend field trip. Pre: 3204. (2H,3L,3C).

5304 (PPWS 5304): PLANT STRESS PHYSIOLOGY
Analysis of physiological responses of agricultural and native plants to environmental stresses such as extremes of temperature, availability of water and nutrients, and presence of air pollutants. Emphasis on linking stress caused changes in carbon gain, water loss, nutrient utilization, and energy balance with changes in growth. Laboratory to introduce equipment and research approaches used in greenhouse and field studies. (3H,3L,4C).

5384 (GEOL 5384): MORPHOMETRICS
Study of shape and size in fossil and modern organisms with strong focus on quantitative methods and digital image analysis. Covers analytical methods (multivariate methods, Fourier analysis, geometric morphometrics), image processing, and software training (SAS, SAS/IML, and Imaging Software). Pre: STAT 5004, GEOL 5374. (2H,3L,3C).

5514: FISH ENVIRONMENTAL PHYSIOLOGY
Physiology of fish, emphasizing their responses to natural and polluted environments. (3H,3C).

5604: PHYSIOLOGY: MICROORGANISM
Relationship between structure and function in microorganisms. Microbial growth; nature and biosynthesis of exocellular polymers, cell walls and membranes; export of proteins across membranes; transport of small molecules into bacteria; oxygen toxicity; motility and chemotaxis; emphasison fermentative and respiratory energy–producing metabolism; catabolic regulation; energy costs of biosynthesis in bacteria. Pre: BCHM 4116. (4H,4C).

5634: MICROBIAL PHYSIOLOGY
The study of the structure, function and metabolic activities of prokaryotic microorganisms. Topics covered include cell composition and growth, metabolic unity and diversity, patterns of regulation, transport mechanisms, environmental sensing and response and cellular differentialtion processes. Students will give presentations and critically analyze current literature in the field. (4H,4C).

5694 (CSES 5694): SOIL BIOCHEMISTRY
Comprehensive presentation and analysis of the biochemistry of soil humic acid formation, physicochemical properties of humic substances, and interactions of soil humic substances with toxic organics and metals. Microbial degradation of organics, including pesticides, and the fate of genetically engineered microbes in soil. Pre: 4684, 4694. (2H,3L,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: TOPICS IN ECOLOGY & SYSTEMATICS
Reading and discussion in a specific area of ecology and systematics. Topic will vary, and course may be taken for credit more than once. Background in ecology or systematics required. Variable credit course.

6014: TOPICS IN EVOLUTIONARY BIOLOGY
Readings and discussion in a specific area of evolutionary theory, ecological genetics, or molecular evolution. Topics will vary, and course may be taken for credit more than once. Background in genetics and population biology required. Variable credit course.

6024 (ALS 6024) (BCHM 6024) (PPWS 6024): TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle

assembly, and of growth and development, structure and function of polyamines and of proteases will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: BCHM 5214.

6064: TOPICS IN FRESHWATER ECOLOGY
Readings and discussion in a specific area of freshwater ecology, including species interactions, and community level functions. Topics will vary, and course may be taken for credit more than once. Variable credit course. Pre: 4004.

6404: TOPICS IN VERTERBRATE BIOLOGY
Readings and discussion in a specific area of vertebrate biology. Topic will vary, and course may be taken for credit more than once. Background in vertebrate biology required. Variable credit course.

6634: TOPICS IN MICROBIAL ECOLOGY
Readings and discussion in a specific area of microbial ecology. Topic will vary and course may be taken for credit more than once. (2H,2C).

6644: TOPICS IN MICROBIAL GENETICS
Readings and discussion in a specific area of microbial genetics, including temperate bacteriophage, insertion elements and transposons, gene function in prokaryotic microorganisms, and mechanisms of genetic recombination. Topic will vary and course may be taken for credit more than once. Pre: 4624. (3H,3C).

6654 (PPWS 6654): TOPICS IN VIROLOGY
Readings and discussion in a specific area of virology. Topic will vary and course may be taken for credit more than once. Pre: 4664, BCHM 4116. (3H,3C).

6704 (VMS 6704): TOPICS IN IMMUNOLOGY
Readings and discussion in a specific area of immunology. Topic will vary and course may be taken for credit more than once. Pre: 4704. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (BIOL)

The following 4000–level courses have been approved for graduate credit:

4004: FRESHWATER ECOLOGY
Interactions of physical, chemical, and biological properties of freshwater ecosystems. Senior standing required. Pre: 2804. (3H,3L,4C).

4014: ENVIRONMENTAL TOXICOLOGY
Discussion of ecotoxicological and philosophical issues in the development of standards for control of toxic chemicals in freshwater, including site–specific examples, application of current control methods, recovery of damaged ecosystems, and government regulations. Pre: 2804. (2H,2C).

4044 (GEOG 4044): BIOGEOGRAPHY
A survey of the field of biogeography. A study of the factors influencing the distribution of plants and animals approached from ecological, historical, and cultural perspectives. Human influence on biotic patterns, such as crop domestication, habitat alteration, species introductions and extinctions, management issues, and environmental change, is a primary force. Pre: 2804 or GEOG 1104. (3H,3C).

4104: DEVELOPMENTAL BIOLOGY
Morphological, physiological, and molecular events in embryological and developmental systems, including regulation at the level of transcription, translation, and enzyme or hormone activation. Pre: 2004. (3H,3C).

4134: EVOLUTIONARY GENETICS
Genetic variation, Hardy–Weinberg equilibrium, agents of change in gene frequencies, molecular evolution, mechanisms of speciation. Comparison of theoretical models with natural and laboratory populations. Pre: 2004. (3H,3C).

4204: DEVELOPMENTAL PLANT ANATOMY (WRITING INTENSIVE)
Microscopic structure of cells, tissues, and tissue systems of vascular plants in relation to growth, development, and physiology. Writing intensive. Even years. Pre: 2304. (2H,6L,4C).

4234: ALGAE (WRITING INTENSIVE)
Systematics, structure, reproduction, physiology, ecology, evolution of prokaryotic and eukaryotic algae. Weekend field trip required. Writing intensive. Pre: 2304. (2H,3L,3C).

4244: MYCOLOGY (WRITING INTENSIVE)
Morphology, ecology, classification and field and laboratory study of fungi: form and function, uses by man, plant and animal pathogens, and role in ecosystems. Writing intensive. Pre: 2304. (2H,6L,4C).

4314: PLANT ECOLOGY (WRITING INTENSIVE)
Introduction to ecology of terrestrial plants including major plant functional types, behavior of populations, responses of plant communities to disturbance, vegetation classification, and ordination. Laboratory covers methods for measuring and analyzing natural vegetation, and setting up field and greenhouse experiments. This is a writing intensive course. Even years. Pre: (2304 or 2804 or FOR 3314). (3H,3L,4C).

4324 (GEOS 4324): PLANT EVOLUTION (WRITING INTENSIVE)
Geological history, comparative morphology, evolution and systematics of pre–vascular and vascular plants. Focus on evolution of communities, adaptive construction of tissues and organs, and ecology of reproduction. Pre: 2304. (2H,6L,4C).

4354 (ENT 4354): AQUATIC ENTOMOLOGY
Biology and taxonomy of insects and other macroinvertebrates most commonly encountered in freshwater environments. Selected aspects of biology, such as habitat, feeding, locomotion, and life history. Identification of individual taxa, mostly at family and genus level. Significance of these organisms in aquatic ecology, pollution monitoring, and natural resource management.
Pre: (1005, 1006), (1015, 1016) or (1105, 1106, 1115, 1116). (3H,3L,4C).

4404: ORNITHOLOGY
Biology of birds, including functional anatomy, systematics, evolutionary history, behavior, and ecology. Laboratory on systematics, anatomy, and field experience in the areas of behavior and ecology. Pre: 2504. (3H,3L,4C).

4434: MAMMALOGY
Biology of mammals including evolution, systematics, anatomy, physiology, and ecology. Laboratory on systematics, morphology, zoogeography, and diversity of North American mammals. Pre: 2504. (3H,3L,4C).

4454: INVERTEBRATE ZOOLOGY
Identification, morphology, evolutionary relationships, and natural history of free–living invertebrates, excluding insects. Pre: 2504. (3H,3L,4C).

4474: ETHOLOGY
An evolutionary and ecological approach to animal behavior, drawing on behavioral genetics, endocrinology, neurophysiology, and behavioral ecology to explain how and why the behavior of an organism is adapted to its environment. Pre: 2504. (3H,3C).

4484 (ENT 4484) (FIW 4484): FRESHWATER BIOMONITORING
Concepts and practices of using macroinvertebrates and fish to monitor the environmental health of freshwater ecosystems. Effects of different types of pollution and environmental stress on assemblages of organisms and underlying ecological principles. Role of biological studies in environmental regulation. Study design, field and laboratory methods, data analysis and interpretation, verbal and written presentation of results. Pre: (2804), (4004 or 4354 or ENT 4354 or FIW 4424 or FIW 4614). (3H,3L,4C).

4504: HISTOLOGY
Microanatomy of cells, tissues, and organs and correlation of microanatomical structure with cellular function. Senior standing. (3H,6L,5C).

4524: ENVIRONMENTAL ANIMAL PHYSIOLOGY
Physiological adaptations to environmental factors, emphasizing vertebrate organ systems. Evolutionary and acclimatory processes will be considered. Must have prerequisites or instructor's permission. Writing intensive. Odd years. Pre: 3404. (3H,3C).

4534: COMPARATIVE ENDOCRINOLOGY (WRITING INTENSIVE)
Physiology of endocrine systems, emphasizing vertebrates but including invertebrates. Mechanisms of hormone action, physiologic roles of hormones, and overall integration. Must have prerequisites or instructor's permission. Pre: BIOL 3404. (3H,3C).

4554 (ALS 4554): NEUROCHEMICAL REGULATION
Neurochemical transmission within the vertebrate brain will be examined. Emphasis will be placed on the chemical coding underlying the control of various behaviors and how these systems can be modified by various drugs or diet. Pre: (3404 or ALS 2304), (CHEM 2535). (3H,3C).

4574 (ALS 4574): SOCIAL BEHAVIOR OF BIRDS AND MAMMALS
Animal behavior from the viewpoint of group organization during the life cycle of the organism. Emphasis is on adaptive mechanisms as they relate to the behavior–physiology–genetic interaction. Pre: 1106. (2H,2C).

4604 (FST 4604): FOOD MICROBIOLOGY
Role of microorganisms in foodborne illness and food quality, spoilage, and preservation. Control and destruction of microorganisms in foods. Pre: 2604, 2614. (3H,3L,4C).

4624: MICROBIAL GENETICS
Molecular genetics of bacteria and their associated plasmids and phages. Pre: 2004, 2604. (3H,3C).

4644: MICROBIAL MOLECULAR GENETICS AND PHYSIOLOGY LABORATORY
Introduction to classical and molecular methods used for the study of baterial genetics and physiology. Laboratory exercises cover analysis of patterns of gene regulation; assay of enzymatic activities; mutagenesis followed by selection, screening, and physiological characterization of mutant strains; genome database utilization; and large scale fermentation. Pre: 4624. (1H,6L,3C).

4664: VIROLOGY
Classification, structure, pathogenesis, host response, and replication strategies of viruses of bacteria, plants, and animals, stressing mechanisms elucidated by molecular biological techniques. Pre: 3774, BCHM 4116. (2H,3C).

4674: PATHOGENIC BACTERIOLOGY
Characteristics of bacteria that cause human disease, nature of infectious processes, virulence factors, epidemiology, resistance, immunization, diagnostic bacteriology. Pre: 2604, 2614. (3H,3L,4C).

4704: IMMUNOLOGY
Immunochemistry of antigens and antibodies, serological reactions, chemistry of complement, control of immunity, immune response of an intact animal. Pre: 2104 or CHEM 2536. (3H,3C).

4714: IMMUNOLOGY LABORATORY
Serological and immunobiological techniques used to interpret the consequences of an immune response. Pre: 4704. (3L,1C).

4774: MOLECULAR BIOLOGY LAB
An introduction to recombinant DNA methods, including restriction endonuclease digestion, gel electrophoresis, cloning, Southern blotting, polymerase chain reaction, sequencing and analysis of reporter gene expression in transgenic organisms. BIOL 3774 may be taken as a corequisite with 4774. Pre: 3774. (1H,6L,3C).

BIOMEDICAL ENGINEERING & SCIENCES

Elaine Scott, Interim Director (Virginia Tech)
Peter Santago, Co–Director (Wake Forest University)

Associated Faculty:

College of Engineering

Biological Systems Engineering:
Assistant Professor: C. Zhang

Chemical Engineering
W. Martin Johnson Professor: W.H. Velander
Associate Professor: K.F. Williams
Assistant Professors: A.S. Goldstein; K.E. Van Cott

Civil and Environmental Engineering
Daniel Pletta Professor: R.H. Plaut

Electrical and Computer Engineering
Professors: G. Brown; W. Davis; S. Midkiff; J. Tront
Associate Professors: M. Hsiao; D. Linder
Assistant Professor: C. Wyatt

Engineering Science & Mechanics
Frank Maher Professor: D.P. Telionis
Professors: D. Dillard; J.W. Grant
Associate Professor: K. Granata
Assistant Professors: J. Cotten; H. Dankowicz; M.L. Madigan

Industrial & Systems Engineering
Associate Professor: M.A. Nussbaun
Assistant Professors: K. Babski–Reeves; T.E. Lockhart

Materials Science & Engineering
Associate Professor: B.J. Love
Assistant Professor: S.G. Corcoran

Mechanical Engineering
Alumni Distinguished Professor: C.F. Reinholtz
Professors: E. Brown; T.E. Diller; E.P. Scott; R. Sturges
Associate Professors: J.H. Bohn; S. Duma; D. Leo; D. Tafti; R. West; A. Wicks

College of Veterinary Medicine

Associate Dean: Gerhardt Schurig

Biomedical Sciences and Pathobiology
Department Head: ***E. Ludeman***
Professors: T. Inzana; B. Jortner; J. Lee; H. Misra; J. Robertson
Associate Professors: W. Huckle; N. Sriranganathan; Y. Sukuzi

Large Animal Clinical Sciences
Assistant Professor: R. Howard

Research Compliance
Assistant Vice Provost-Research: D. Moore

Small Animal Clinical Sciences
Department Head: Don Barber
Associate Professor: J. Jeryl

Wake Forest University School of Medicine, Department of Biomedical Engineering

Chair: P. Santago
Professor: G. Holzwarth
Associate Professors: J.D. Bourland; C. Hamilton; M. Morykwas; M. Munley; D. Kim–Shapiro; P. Santago
Assistant Professors: D. Gage; R. Kraft; Jian–Ming Zhu
Resident Assistant Professor: B. Joel; D. Slice

E-mail: bmegrad@vt.edu
Virgina Tech Web: www.sbes.vt.edu
Wake Forest Web: www.rad.wfubmc.edu/me

Biomedical Engineering integrates engineering, life sciences, and medicine. It requires knowledge and understanding of the life sciences and how engineering principles can be applied to human medicine. The Virginia Tech–Wake Forest University School of Biomedical Engineering & Sciences (VT–WFU SBES) provides the mechanism in which all areas of biomedical engineering can be integrated through our graduate degree programs and the Center for Biomedical Engineering.

The formation of a joint school allows the Virginia Tech (VT) College of Engineering, the Wake Forest University (WFU) School of Medicine, and the Virginia Maryland Regional College of Veterinary Medicine (VMRCVM) to form a mutually beneficial relationship. The alliance offers M.S. and Ph.D. degree programs in Biomedical Engineering, a joint M.D./Ph.D. program through the WFU School of Medicine, and joint M.S./D.V.M. and D.V.M./Ph.D. programs through the VMRCVM.

DEGREES OFFERED

Students who enroll in the Virginia Tech–Wake Forest School of Biomedical Engineering & Sciences are offered the following graduate degree programs:

M.S. in Biomedical Engineering
Ph.D. in Biomedical Engineering
M.S./D.V.M.
D.V.M./Ph.D.
M.D./Ph.D.

Please refer to ***www.sbes.vt.edu*** for detailed degree requirements.

GRADUATE COURSES (BMES)

5004: MAMMALIAN PHYSIOLOGY
Cell biology, neurological and muscle physiology, autonomic nervous system, cardiovascular system, cardiac function & hormonal regulation, pulmonary system, renal system, endocrinology, gastrointestinal system, glucose and lipid storage for biomedical engineering students only. (4H,4C).

5124 (ESM 5224): ADVANCED MUSCULOSKELETAL BIOMECHANICS
Skeletal anatomy and mechanics. Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research. (3H,3C).

5164 (ME 5754): ADVANCED IMPACT BIOMECHANICS
A review of impact biomechanics and critical investigation of the impact response of the human body. Participants will study the dynamic response of the head, neck, chest, abdomen, upper extremities, and lower extremities. Real world examples from automobile safety, military applications, and sport biomechanics. Pre: ME 3504, ME 3614 or ESM 3054, ESM 3124. (3H,3C).

5514 (ME 5714): DIGITAL SIGNAL PROCESSING FOR MECHANICAL MEASUREMENTS
The fundamentals of digital signal processing of data experimentally obtained from mechanical systems will be covered. Attention will be given to the data acquisition, A/D conversion, aliasing, anti–aliasing filtering, sampling rates, valid frequency ranges, windowing functions, leakage, and various transform methods. Special attention will be given to random, transient, and harmonic function data processing. Various methods of estimation of the frequency response function (FRF) will be explored. The estimation methods will be assessed as to their impact on FRF estimation errors. (3H,3C).

5525–5526 (ECE 5605–5606): STOCHASTIC SIGNALS AND SYSTEMS
Engineering applications of probability theory, random variables and random processes. Time and frequency response of linear systems to random inputs using both classical transform and modern state space techniques. Pre: STAT 4714 for 5525; 5525 for 5526. (3H,3C).

5904: PROJECT AND REPORT
Variable credit course.

5944: SEMINAR
Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

6125–6126 (ESM 6225–6226): BIODYNAMICS & CONTROL
Study of human movement dynamics and neuromuscular control of multi–degree–of–freedom systems. 6225: Computational simulation of forward–dynamics and state–space linear control of human movement to investigate functional performance and neuromuscular pathology. 6226: Applied laboratory–based investigation and research design of human movement–control through state–of–the art measurement techniques. Pre: 5124 or ESM 5224 or (ESM 4204, ESM 5314). (3H,3C).

6164 (ME 6754): COMPUTATIONAL MODELING IN IMPACT BIOMECHANICS
Dynamic modeling of the human body subjected to transient impact loading. A combination of finite element analysis and multi–body simulated techniques. Utilized software packages with dynamic solvers. Applications include computer–aided design for automobile safety, sports biomechanics, and military restraint systems. Pre: 5164 or ME 5754. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

BUILDING CONSTRUCTION

Yvan J. Beliveau, Head

Georgia Anne Snyder-Falkinham Professor: Y.J. Beliveau
Associate Professors: F. L. Auchey; T.H. Mills; W.Y. Thabet
Assistant Professors: S.G. Brandenburg; G. Reichard
Adjunct Professor: R.R. Wakefield

E-mail: thabet@vt.edu
Web: www.caus.vt.edu/caus/bc

The department offers graduate courses to serve the needs of graduate students interested in construction management and building construction. The department does not offer a degree in building construction, but contributes to the construction management concentration in the Master of Science (Architecture) and the Construction and Building Science stream within the Environmental Design and Planning Doctoral Program. For details on each of these degree programs, interested students should consult the appropriate entries in this catalog.

GRADUATE COURSES (BC)

5014: MANAGEMENT OF INTERDISCIPLINARY FUNCTIONS IN CONSTRUCTION
An examination of the professional and technical management activities applicable to the building process, including the conceptual, planning, design, bud, negotiation, construction, and occupancy phases of public and private projects. Emphasis is placed on the integration of the palnning, design, and construction efforts to achievemaximum project quality and value. Pre: CEE 3014. (3H,3C).

5024: COST MANAGEMENT OF THE BUILDING PROCESS
A study of cost management procedures applicable to the building process from concept through owner operations. Cost considerations in the decision process, concepts for monitoring and controlling costs, and the determination of accountability are examined. Pre: ISE 2014 and BC 4444 or CEE 3014. (3H,3C).

5044 (ARCH 5044): INTERNATIONAL CONSTRUCTION PROCESSES
This course contrasts aspects of the U.S. construction industry with similar yet fundamentally different operating procedures utilized within the international construction community. Areas of concentration include participant organization and culture, project delivery methods, multinational teams, and unique operational and management activities essential to the international market. (3H,3C).

5124 (ARCH 5124): LAND DEVELOPMENT FOR CONSTRUCTED FACILITIES
This course examines the processes necessary to get a piece of undeveloped real estate from idea to the finished product. It discusses the construction management interface between site engineering and real estate marketing. Topics covered include: market influences, working with regulatory agencies, zoning, economic considerations, developing an optimum plan, cost and schedule, engineering requirements, environmental impact, financing, and delivering a final product to the marketplace. Pre: BC 2014. (3H,3C).

5184: TEMPORARY STRUCTURES
Introduction to the analysis, design, and selection of various temporary support structures needed in construction of building projects. Topics covered include excavation and temporary support methods, underpinning methods, dewatering systems, concrete formwork systems, selection, analysis/design, and construction. Due

consideration is given to unconventional construction methods and placement techniques. Pre: Senior status and instructor's approval or graduate standing. (3H,3C).

5224: FUNDAMENTALS OF PRESERVATION, RESTORATION AND REHAB OF EXISTING FACILITIES
The course focuses on fundamentals that guide interventions of Preservation, Restoration, Reconstruction and Rehabilitation of historic facilities in the U.S. These procedures will be studied, analyzed and related to the international agreements and explained in their historic evolution. The course addresses primarily interventions on facilities that are historic, buildings that will be historic, and buildings located in historic districts. Study of international charters, national standards and laws; historic designation; authenticity; collection of historic data and development of relevant documentation; conducting field work in terms of photographic survey; fundamentals of materials' degradation; hazardous aspects; reversibility of intervention; upgrading to current codes and standards; systems reconfiguration; maintainability; tax incentives and other economic considerations of interventions. Graduate standing is required. (3H,3C).

5244: PRACTICES OF PRESERVATION AND REHABILITATION AND FACILITIES MANAGEMENT
This course deals with the integration of Standards for the Treatment of Historic Properties of the Secretary of the Interior into the practices and management of projects dealing with historic properties including modern architecture. Development and use of technical reports; phasing of the project; role of the construction manager; diagnostics using non–destructive techniques; mitigation and consolidation of existing structures and materials; spatial reconfiguration and additions; maintenance and operation; and code compliance. Guidelines for appropriate and technically feasible solutions and economic issues related to interventions, roles and responsibilities will also be presented. Graduate standing required. Pre: 5224. (3H,3C).

5264: FUNDAMENTALS OF INDOOR AIR SCIENCES
The course focuses on the fundamentals of indoor air science. It is designed for practitioners of the building industry, such as architects, engineers, facilities managers, designers, contractors, construction managers, and building consultants. The course has six main components: introduction to building performance; evaluation criteria and indoor air quality issues; diagnostic protocols; prognostic protocols; feasible interventions using technical and managerial methods; cost–effectiveness of alternative solutions; and presentation of results in oral and written form. Pre: Graduate standing. (3H,3C).

5304: PRINCIPLES OF CONSTRUCTION LAW AND PROJECT DELIVERY SYSTEMS
The course deals with the numerous ways in which the legal system affects or controls the construction process. Course topics include contract law, the relationships between the parties to the construction process, tort and negligence law, and statuatory principles affecting construction. The major emphasis is on the principal contract relationships (Owner–Contractor, Contractor–Subcontractor, Owner–Architect/Engineer), and the problems and disputes that typically arise out of these relationships. The course also explores innovations in project delivery systems such as design–build and CM at–risk. Graduate standing is required. (3H,3C).

5514: PRINCIPLES AND PRACTICES OF CONSTRUCTION I
Using a case study approach coupled with several term projects to achieve its objectives, this course covers the principles and practices of construction means and methods for CSI divisions 1–6 with emphasis on concrete, masonry, and steel construction. The course also integrates topics in project management, including project contract types and delivery methods, bonds and insurance, conceptual and detailed cost estimating methods, planning and scheduling techniques, and resource/cost scheduling. Graduate standing required. (3H,3C).

5524: PRINCIPLES AND PRACTICES OF CONSTRUCTION II
Using a case study approach with various term projects, this course builds on concepts covered in BC 5514, focusing on the principles and practices of construction means and methods for CSI divisions 7–13. Emphasis is given to finishing works, thermal and moisture protection procedures, curtain wall construction, and special construction methods. The course integrates advanced topics in project management including schedule updating techniques, resource and cost tracking and control tools, and linear scheduling. Pre: 5514. (3H,3C).

5984: SPECIAL STUDY
Variable credit course.

6014 (ARCH/CEE 6014): PROJECT & COMPANY MANAGEMENT
Study of the general issues of project and company management. Project management includes finances, cash flows, cost control, project organization, and project planning. Company management includes company organization, incorporation structure, procedures, finace, insurances, accounting, and operation. Case studies are emphasized. Pre: BC 5014. (3H,3C).

6064: RESEARCH SEMINAR: PAST, PRESENT, AND FUTURE OF CONSTRUCTION
This course will look at an historical perspective of construction and how the Architecture, Engineering, and Construction (AEC) industry has evolved to where it is today. The course will look at the key elements that have affected these changes, including the evolutionary/evolving roles of the participants of the entire AEC industry. Topics will include the means, methods and contracts from 1945 to today. Topics of discussion will include: risk, contracts, project & production management, labor, leadership, automation, industrialization and IT. (3H,3C).

ADVANCED UNDERGRADUATE COURSES (BC)

The following 4000–level courses have been approved for graduate credit:

4024 (CEE 4014): ESTIMATING, PRODUCTION, AND COST ENGINEERING
Interpretation of plans and specifications, preparation of construction estimates, and cost control. Methods analysis, resource requirements, and resource costs in building systems, including system components and in large–scale civil engineering works such as highways, bridges, and hydraulic structures. Pre: CEE 3014. (3H,3C).

4034 (CEE 4034): CONTRACT SPECIFICATIONS
The course work provides an overview of the basics of the Project Manual (a collection of the contractual provisions of a nontechnical nature together with the technical provisions). Techniques of specification writing, interpretation of intent, and complimentary documents are studied. Pre: Senior standing required. (3H,3C).

4054 (CEE 4054): CONSTRUCTION LAW: ROLES & RESPONSIBILITIES
A study of current legal problems associated with the construction industry. Traditional roles of various industry participants are examined from a management's perspective. The entire building process, from pre–design to owner use, is covered with emphasis on claims avoidance. Pre: 4434 or CEE 3014 or ARCH 4044. (3H,3C).

4064: CONSTRUCTION PRACTICE LAB
This lab applies the business and construction practices related to the operation of a construction company to the execution of a senior capstone project. All project management concepts learned in prior courses are applied in this capstone lab experience. This course is formally designated as a writing–intensive course. Formal written and oral presentations are presented and critiqued by the BC faculty team, students, and industry professionals. Co: 4444. (3L,1C)

4164: PRODUCTION PLANNING & PROCESS DESIGN FOR CONSTRUCTION
The course deals with the planning and design of construction processes. Course topics include production systems, behavior of construction systems and workers, the relationships between subsystems in the construction process, queuing systems, process modeling and simulation. The major emphasis is on production and productivity. Production problems that typically occur in construction systems are discussed. The course also explores recent innovations in construction system design such as lean construction and agile construction. Pre: 2114, 2024, 4004, 4014. (3H,3C).

BUSINESS ADMINISTRATION

Tarun K. Sen, Associate Dean for Graduate and International Programs

The Pamplin College of Business offers the Master of Business Administration (M.B.A.) degree. The college also offers the master of science (M.S.) in business administration, the master of accounting and information systems, and the master of science in hospitality and tourism management. In addition, the doctor of philosophy (Ph.D.) in business is offered through the departments of Accounting and Information Systems; Business Information Technology; Finance, Insurance, and Business Law; Management; and Marketing. The Department of Hospitality and Tourism Management offers the doctor of philosophy in Hospitality and Tourism Management. Information specific to graduate degrees other than the M.B.A. is located under the associated department. Graduate degree programs offered by the Pamplin College of Business are fully accredited by the Association to Advance Collegiate Schools of Business (AACSB International) with the exception of the M.S. and Ph.D. in Hospitality and Tourism Management.

MASTER OF BUSINESS ADMINISTRATION

The program of study leading to the Master of Business Administration is designed to prepare individuals for positions of leadership in management in both the private and public sectors. The program seeks to provide the student with a broad background that cuts across the various functional areas of business. The core of the curriculum focuses on developing analytical and decision-making skills while providing the foundation knowledge necessary for managerial proficiency.

Applicants to the Pamplin M.B.A. must have received a Bachelor of Science or Bachelor of Arts degree from an accredited college or university. In addition, applicants must have completed previous coursework in calculus and accounting and must also have experience using computer systems. Students who lack fundamental accounting knowledge may complete ACIS 5104 "Fundamentals of Accounting" during their first semester in the program as an overload to make up for the deficiency. All students must have a personal computer and keep its hardware and software up-to-date during the program. Full-time students need wireless laptop computers. The College of Business publishes minimum computer hardware and software standards each year.

The Pamplin M.B.A. is available at the Blacksburg campus, as well as at the Northern Virginia Center and at several other locations across the state. Full-time students usually attend classes at the Blacksburg location and enroll in 12 to 16 credits per semester. Classes at the other locations are arranged to accommodate the needs of the working professional. The full-time program is cohort based–new students are admitted only in the fall semester and take the same courses for the first two semesters of the program.

All applicants, regardless of status or campus location, must submit the following: a completed application, official college transcripts, official Graduate Management Admission Test (GMAT) score, a professional resume, and the appropri-

ate application fee. Persons desiring to attend any location except the Northern Virginia Center should send these materials to the Virginia Tech Graduate School in Blacksburg. Applicants wishing to attend the Northern Virginia Center should send materials directly to that center. Detailed information about current admission and program requirements (which are subject to change) are available from the M.B.A. web site www.mba.vt.edu and at the M.B.A. and International Programs Office in the Pamplin College of Business.

The Pamplin M.B.A. requires 48 semester hours of course work and is structured so that students take only core courses during the first half of the program. The following courses are required: Dynamics of Organizational Behavior, Economics of Business Decisions, Managerial Statistics, Principles of Finance, Management Control Systems, Marketing Policy and Strategy, Operations Management in a Global Environment, and either Computer-Based Decision Support Systems or Management of Information Systems. The second half of the program consists of electives, including an international elective, and the capstone core course, Strategic Management. In addition, full-time students must complete career-serivces courses. Full-time students cannot be exempt from core courses or transfer credit for core courses to the Pamplin M.B.A. from another institution.

In addition to the M.B.A. core, students take elective courses that may lead to an area of specialization called a concentration. The following concentrations are available: Corporate Financial Management; Investment and Financial Services Management; E-Business Technology; Organizational Leadership; Global Business; Information Systems and Technology; Systems Engineering Management; Marketing; and Hospitality and Tourism Management.

CORPORATE FINANCIAL MANAGEMENT

The concentration provides a thorough training in corporate finance to MBAs who aspire to become a treasurer, controller, investment banker, or, ultimately, a chief financial officer. These positions encompass a wide range of activities, including asset valuation, managing the firm's capital investment and capital structure, raising capital, and distributing stockholder claims. Additional positions also exist in the corporate development division of firms that deal primarily with mergers and acquisitions and corporate restructuring. Courses in the finance curriculum are primarily offered as one-credit and two-credit topic-focused modules instead of the traditional semester-long three-credit courses. The only exceptions are FIN 5024: Principles of Finance, required of all MBA students, and the international finance elective, FIN 5184: Currencies and Global Finance. Students in finance concentrations are required to take four one-credit core modules that constitute the common body of knowledge required of all finance MBAs. After they have completed the one-credit modules, they are required to take four two-credit elective modules and the three-credit international finance course. Students can add a second finance concentration by taking three two-credit modules from the investment and financial services management concentration as their elective courses in their third and fourth semesters.
FIN 5044: Asset Valuation (1)
FIN 5054: Options and Futures (1)
FIN 5064: Equity Markets (1)
FIN 5074: Interest Rates (1)
FIN 5184: Currencies and Global Finance (3)
FIN 5204: Managing Corporate Capital Investment and Capital Structure (2)
FIN 5244: Managing Corporate Risk with Derivatives (2)
FIN 5234: Venture Capital and Investment Banking (2)
FIN 5264: Mergers & Acquisitions and Corporate Restructuring (2

INVESTMENT AND FINANCIAL SERVICES MANAGEMENT

Money managers are expected to have very strong analytical skills, good communication and people skills, and an understanding of financial markets. Commercial banks require stronger communication and people skills than analytical skills. Investment bankers must excel in both communication and analytical skills. Initiative and creativity are important in all jobs. Depending on individual interest and skills, MBAs completing this concentration may be employed by a money management company, a consulting organization, a commercial bank, or an investment bank. Typical titles for graduates with this concentration include portfolio analyst, investment adviser, credit analyst, bank manager, and investment banker. Students can add a second finance concentration by taking three two-credit modules from the corporate financial management concentration as their elective courses in their third and fourth semesters.
FIN 5044: Asset Valuation (1)
FIN 5054: Options and Futures (1)
FIN 5064: Equity Markets (1)
FIN 5074: Interest Rates (1)
FIN 5184: Currencies and Global Finance (3)
FIN 5204: Managing Corporate Capital Investment and Capital Structure (2)
FIN 5214: Fixed Income Securities (2)
FIN 5224: Portfolio Management (2)
FIN 5254: Financial Institution Risks and Strategies (2)

E-BUSINESS TECHNOLOGY

Courses in this concentration strike a balance between theory and practice, covering business strategy aspects as well as use of information technology. The concentration is designed to give students the knowledge and training they need to pursue careers in e-business development and security and Web marketing. The program's particular benefit is that MBAs who become systems designers will be conversant with marketing concepts, while graduates who become marketing managers will be knowledgeable about systems concepts. Both will understand the impact of Internet law on their respective areas.
ACIS/BIT 5594: Web-Based Applications and Electronic Commerce
MGT 5804: Strategic Leadership in Technology- Based Organizations
MGT 5814: Entrepreneurial Leadership
MGT 5834: Foundations of Managing Technology
MKTG 5154: Research for Marketing Decisions
BIT 5495: DSS Design and Implementation
FIN 5034: Internet Law and Policy

ORGANIZATIONAL LEADERSHIP

This concentration comprises an integrated set of courses that equip future executives with the knowledge and skills required to lead organizations at all levels and in a variety of contexts. The courses provide understanding of the history, values, skills, and theory of leadership. The recognition that leadership expertise plays a critical role in organizational success is driving employer interest in graduates with in-depth knowledge of the functions and methods of leadership. The courses offered in the leadership concentration prepare graduates to contribute to the growth and development of tomorrow's leading organizations.
MGT 5814: Entrepreneurial Leadership
MGT 5334: Managing Change through Leadership: Individual and Team Development
MGT 5384: Ethical Dimensions of Leadership
MGT 5824: Advanced Leadership: Skills and Concepts
MGT 5784: International Management

GLOBAL BUSINESS CONCENTRATION

The global business concentration offers a set of international business courses and a wide range of opportunities for international experience through internships, study-abroad programs, and partnerships with international institutions. Thus, graduates completing this concentration not only understand the concepts and

theories of global business, but also have some experience with the cultures and business environment of other countries. The Pamplin College offers a broad range of international experiences. They include experiential programs with extensive travel during the summer, in–residence programs using Pamplin and foreign faculty members, exchange programs, and courses in which student teams serve as consultants to foreign businesses or to domestic companies with plans for export. Some Pamplin MBAs also participate in the dual–degree program with Thunderbird University.

MKTG 5704: International Marketing Strategy
FIN 5184: Currencies and Global Finance
MGT 5784: International Management
ACIS 5004: Accounting for Multinational Enterprises
or
BIT 5494: International Operations and Information Technology
or
MKT 5754: International Marketing Plans
or
XXX5954: Study Abroad

INFORMATION SYSTEMS AND TECHNOLOGY

This concentration provides hands–on course work in all aspects of the design, implementation, and management of information systems. Courses in this concentration are aimed at developing and enhancing students' competency in information technology management. Consulting firms are the major employers of MBAs graduating with this concentration. The firms include Accenture, Deloitte and Touche, IBM, Booz–Allen and Hamilton, Bearing Point, and EDS.

ACIS 5504: Information Systems Design and Database Concepts
BIT 5454: Distributed Processing and Data Communications
BIT 5464: Object–Oriented Programming for Business
CS 5044: Object–Oriented Programming and Java
ACIS 5524: Advanced Database Management Systems
ACIS 5534: Information Systems Development
BIT 5495: DSS Design and Implementation

SYSTEMS ENGINEERING MANAGEMENT

This concentration provides specialized course work for qualified students who wish to prepare for managerial responsibilities in organizations engaged in the development and maintenance of complex technology–based systems. Students who complete this concentration will be better prepared to assume challenging engineering management responsibilities – including project leadership, program direction, and the supervision of supporting technical staff.

ENGR 5104: Applied Systems Engineering
ENGR 5004: The Systems Engineering Process
ISE 5174: Engineering Program and Project Management
BIT 5404: Management Science
ISE 5104: Operations Research

MARKETING

This concentration provides specialized course work for students who wish to perform marketing functions, including marketing research in any firm. The knowledge gained through this concentration will help them assume leadership positions in firms providing high–technology goods and services as well as firms with more traditional products and services that use high–technology tools, such as the Internet.

MKTG 5154: Research for Marketing Decisions
MKTG 5564: Marketing of High Technology
MKTG 5254: Product Strategy
MKTG 5304: Promotion Strategy
MKTG 5554: Business Marketing Management
MKTG 5704: International Marketing Strategy
MKTG 5754: Development of International Marketing Plans

HOSPITALITY AND TOURISM MANAGEMENT

This concentration provides specialized course work for those interested in pursuing a management career in the hospitality and tourism industry, one of the largest and fastest growing industries worldwide. Knowledge gained through this concentration will help current and future hospitality and tourism industry employees assume leadership positions. Courses also can complement current hospitality and tourism work experiences by providing more detailed academic exposure to select aspects of this industry. Elective courses within the concentration are provided as choices for those interested in gaining more expertise in a particular area.

HTM 5514: Contemporary Problems in the Hospitality Industry
HTM 5614: Current Issues in Travel and Tourism Management
HTM 5024: International Service Management
HTM 5464: Franchising in Hospitality Management

DUAL DEGREE

Students who are particularly interested in the global aspects of business can earn dual master's degrees in business administration and international management under partnerships the Pamplin College has established with Thunderbird, the Garvin School of International Management, and Institut National des Telécommunications (INT).

The programs allow students to earn an MBA from Pamplin and either a Master's of International Management from Thunderbird or a Master's of Science in International Management from INT in a shorter period of time than would be the case if the degrees were independently obtained. Students must qualify for regular admission to both Pamplin and the partner school to qualify for the dual program, which requires completion of course work at both schools.

Thunderbird, based in Glendale, Ariz., has been ranked first in the nation in the specialty of international business for four consecutive years in U.S. News & World Report surveys of graduate business schools and their specialty areas. It is the world's oldest and largest graduate school of international management, with campuses in Japan and France in addition to its main facility in Arizona.

INT, based in Evry, France, emphasizes business, engineering, and information technology. It has been working with Virginia Tech on various projects since 1995. This cooperation was formalized in 1999 when the two schools signed an agreement to benefit students and faculty on various levels.

EXECUTIVE MASTER OF BUSINESS ADMINISTRATION

The interdisciplinary curriculum is designed to provide all students with a formal core of business education in the areas of accounting, economics, organizational behavior and decision theory. The core courses are followed by courses in the more traditional functional areas of business: finance, information technology, marketing, and operations management. The program is designed using a lock–step cohort approach. It is geared towards mid to senior level executives with about eight years of work experience.

An international perspective underlies several of the advanced courses, as does a strong focus on high technology management. Entrepreneurial leadership and change management are key components of the curriculum and are designed to leverage students' leadership qualities in day–to–day business practice, irrespective of their area of specialization or job function.

The program includes a study abroad component that provides an exposure to international business issues. This international experience will be part of the course titled "International Strategy and Culture." It will provide a venue for EMBA students to meet with and learn from business executives from leading international companies as well as foreign government officials.

The following courses are required for completion of the Executive MBA program:

ACIS 5604	Accounting Fundamentals
MGT 5614	Global Organizational Behavior
FIN 5604	Financial and Economic Environment of Business
BIT 5644	Management of Information for Business Decision
BIT 5604	Production and Service Operations Management
MKTG 5604	Marketing Principles
MGT 5644	Leadership in a Technology Environment
MKTG 5624	Business Negotiation
BIT 5614	Information Technology for Business Decisions
FIN 5614	Financial Modeling and Corporate Finance
MGT 5624	Technological Innovation for Competitiveness
MGT 5674	Leadership for Change Management
MGT 5634	Strategic Business Environment
MKTG 5614	Marketing Analysis and Strategy
BIT 5634	E–Business Innovation and Implementation
BIT 5624	Program Management and Project Leadership
MGT 5654	International Strategy and Culture (10 day International Management Program)
ACIS 5614	Implementing Management Controls
MGT 5664	Business Ethics and Culture
FIN 5634	Legal and Ethical Issues in the High Technology Environment
MGT 5604	Team Development
FIN 5624	Valuation and Corporate Restructuring
MGT 5694	Seminar in Current Business Issues
MGT 5684	Global Strategic Management

DIVERSITY IN THE PAMPLIN COLLEGE

The Pamplin College of Business regards diversity as a source of strength and pride. Building upon this commitment, the Pamplin College affirms the following principles:

- All students, regardless of their background, race, color, gender, sexual orientation, disability, age, veteran status, national origin, religion, or political affiliation, deserve and are promised equal opportunity to an education in the Pamplin College of Business.
- We support an environment for students, faculty, and staff that is free from hostility and intolerance.
- In the pursuit of a supportive and diverse community that respects each individual, education requires that ideas and opinions be openly discussed.

The Pamplin College is committed to the goal of developing its students, faculty, and staff in a manner that inspires them to successful participation and effective leadership in a pluralistic society.

BUSINESS INFORMATION TECHNOLOGY

B.W. Taylor III, Head

Andersen Professor: L.P. Rees
Bank of America Professor: C. T. Ragsdale
Bell Atlantic-Virginia Professor: L.J. Moore
Lenz Professor: E.R. Clayton
R. B. Pamplin Professors: E.C. Houck; B.W. Taylor III
Houchens Professor: T.R. Rakes
Thornhill Professor: P.Y. Huang
Professors: R.D. Badinelli; P. Ghandforoush; R.S. Russell; R.E. Sorensen
Associate Professors: D.F. Cook; B.J. Hoopes; R.L. Major; L.A. Matheson; Q.J. Nottingham; C.W. Zobel
Assistant Professors: E.C. Brown; D.C. Chatfield; T.J. James; K.B. Keeling; M. Vroblefski
Instructors: L.L. Clark; P.L. Kitchin; L. Zelazny
Career Advisor: B.W. Taylor III (231–6596)

E-mail: ehouck@vt.edu
Web: http://www.bit.vt.edu/

The Department of Business Information Technology offers graduate studies leading to three advanced degrees: the M.B.A., the M.S. in business administration, and the Ph.D. in business. Although the level of specialization is dependent upon the degree option, each of these programs focuses on the application of scientific methodology to managerial decision making.

The M.B.A. program with a concentration in business information technology is a non–thesis degree. Its objective is to provide the individual seeking a career in either the private or public sector with a broad background in the functional areas of business. However, through the appropriate selection of electives, the student may obtain a more in–depth knowledge of certain business information technology topics. An opportunity for increased specialization at the master's level is provided by the department's major in the M.S. program.

The plan of study leading to the Ph.D. in business with a major in business information technology is designed to prepare an individual for a career in academia or for a position at the research level in private and public organizations. This plan provides an integrated education in business and intensive training in the broad discipline of business information technology. Areas of concentration include decision support systems, information systems, mathematical programming, production/operations management, and stochastic processes.

General requirements for the master's and Ph.D. are covered in the sections "Requirements for Master's Degrees" and "Requirements for the Doctor of Philosophy (Ph.D.)."

GRADUATE COURSES (BIT)

5404: MANAGEMENT SCIENCE
Study of selected topics in management science as they apply to managerial decision making. Topics include resource allocation using linear programming, transportation and assignment models, network models for planning and scheduling, queueing models for waiting line analysis, and an introduction to simulation modeling and analysis. Use of the computer for problem analysis and solution is emphasized. (3H,3C).

5414: PRODUCTION & OPERATIONS MANAGEMENT IN A GLOBAL ENVIRONMENT
Analysis of the role of operations management in modern organizations. Emphasis will be placed on the interaction of production and operations management with other functional systems in an organization. (3H,3C).

5434: COMPUTER SIMULATION IN BUSINESS
Investigation of computer simulation methodology and its application in the analysis of business systems. A high level simulation language will be used to develop simulation models for a variety of decision–making scenarios. Open to graduate students who have had introductory course work in computer programming and statistics. Pre: MBA students only or instructor's consent. (3H,3C).

5444: ADVANCED MANAGEMENT SCIENCE
Study of advanced topics in management science, with emphasis on topics not covered in BIT 5404. Topics presented include advanced topics in linear programming, duality and sensitivity analysis, integer programming, quadratic programming, goal programming, and dynamic programming. Emphasis is placed on use of the computer for problem analysis and solution. Term project included. Pre: 5404. (3H,3C).

5454: DISTRIBUTED PROCESSING & COMMUNICATIONS
This course surveys the field of computer networking and communications. Students will learn reasons for networking as well as the costs and potential problems. In addition to computers, the course discusses hardware for local and wide area connectivity and other specialized devices. Software coverage includes operating systems, network management tools, drivers and protocols. Students will learn the primary duties of a network administrator in the operation of a computer network and become familiar with network planning, implementation, and routine administration. MBA students only or instructor's consent. (3H,3C).

5464: OBJECT–ORIENTED PROGRAMMING
This course introduces concepts of object–oriented programming (OOP). Comparisons between competing systems will be discussed. Emphasis will be placed on the practical application of object oriented concepts to business programming problems. Use of an object–oriented language will be required. Graduate standing and competence in a high–level programming language. MBA students only or instructor's consent. (3H,3C).

5474: COMPUTER–BASED DECISION SUPPORT SYSTEMS
This course explains the characteristics, use, and development of decision support systems (DSS) within the context of other business information systems. The process of designing and implementing decision support systems in business is discussed from both theoretical and practical standpoints. Students will learn various ways of measuring the success of DSS implementation as well as the difficulties associated with all such measures. Students will learn to use common software tools to develop a simple DSS and will learn to use the Internet as a decision making and productivity tool. Graduate student standing or instructor's consent. (3H,3C).

5484: CURRENT ISSUES IN PRODUCTION & OPERATIONS MANAGEMENT
In–depth study of current production and operations management techniques. Attention is focused on the practical applications of recently developed production management systems. Cases, plant trips, industrial guest speakers, and film presentations are used extensively. Pre: 5404. (3H,3C).

5494: INTERNATIONAL OPERATIONS & INFORMATION TECHNOLOGY
This course includes concepts and issues critical in the globalization of business operations and information technology. Topics covered include the organization of global operations, cultural and national comparisons, planning global operations, facilities location, product development, technology transfer, global communication links, transborder data flow, international information systems, and other emerging operations and information technology issues. (3H,3C).

5495–5496: FOUNDATIONS OF DECISION SUPPORT SYSTEMS
Study of the design and implementation of decision support systems (DSS) using a visual environment. Topics will include methods for data access, modeling and computation in a visual language, graphical display of support material and report generation methodologies, object sharing between software components, and the deployment of support systems within distributed environments. Distributed DSS topics will include client server systems, common object model methodologies, and distribution in a web–based environment. Pre: 5474. (3H,3C).

5544 (ACIS 5544): INFORMATION CENTER FUNCTIONS
The information center assists in building systems by direct collaboration with users and analysts. Their interaction during this process is considered. The information center makes available hardware and software tools to enhance the quality of the system and the speed with which it is developed. These tools are examined. Pre: ACIS 5514. (3H,3C).

5564 (ACIS 5564): ARTIFICIAL INTELLIGENCE APPLICATIONS IN BUSINESS
Study of key artificial intelligence techniques and their role in decision making in a business context. Topics will include methodologies for the representation of knowledge, algorithms for intelligent search, and techniques for display of expert decisions. Primary emphasis is on rule–based or expert systems, neural networks, fuzzy logic concepts, and genetic algorithms. Pre: ACIS 4515, CS 2604. (3H,3C).

5574 (ACIS 5574): DESIGN STRATEGIES FOR E–BUSINESS SYSTEMS
This course focuses on the strategic business analysis and design requirements of an e–Business System. This course focuses on the design of the marketing, knowledge, and transaction processing components of a typical e–business system. The course develops skills required in doing requirements analysis for e–businesses, understanding business processes required for e–businesses, and designing effective e–business architectures. Emphasis is placed on the application of object–oriented systems design, suitable analysis and design concepts from structured analysis, business process reengineering, and design of web–enabled client–server systems. (3H,3C).

5594 (ACIS 5594): WEB–BASED APPLICATIONS & ELECTRONIC COMMERCE
An examination of the concepts, technologies, and applications of electronic commerce. Topics include the World Wide Web as a platform for electronic commerce; intranets; electronic data interchange; electronic banking and payment systems; security and firewalls; software agents; and the social, legal, and international issues of electronic commerce. Must have completed the first year of the MBA program or the prerequisites to the Master of Accountancy. Pre: 5474 or ACIS 5514. (3H,3C).

5604: PRODUCTION & SERVICE OPERATIONS MANAGEMENT
Study of competitive methods for designing and managing the production and delivery of products and services across functions, enterprises and global boundaries. Designing and managing a network of suppliers across enterprises is discussed, along with the information systems and planning issues involved. The course emphasizes the application of information technologies to operations planning and control. Executive MBA students only. (2H,2C).

5614: INFORMATION TECHNOLOGY FOR BUSINESS DECISIONS
The objective of this course is to provide an overview of the effective use of information technology to help organizations achieve their operational and strategic goals. The course will help managers understand the appropriate use of information technology in

business decision making. Topics on information systems design, databases, e–business, decision support systems, data warehousing and data mining, and knowledge management will be discussed to reflect on their importance in improving organizational decision–making capabilities. Executive MBA students only. (2H,2C).

5624: PROGRAM MANAGEMENT & PROJECT LEADERSHIP
This course introduces the fundamentals of program and project management, beginning with project definition and culminating in the post–project review. Students will learn techniques, terms, and guidelines that are used to manage cost, schedules, risk, group dynamics, and technical aspects throughout the life cycle of a project. The need for leadership as well as technical management of successful projects will be emphasized. Executive MBA students only. (1H,1C).

5634: E–BUSINESS INNOVATION & IMPLEMENTATION
This course focuses on the strategic business analysis and key technologies that provide the foundation for e–business innovation and implementation. The course focuses on the technology that underlies the Internet and how firms compete and win in the information technology age. Emphasis is placed on concepts, frameworks, and approaches that enable a corporate manager to embrace the Internet technology and to conduct online business. In addition to the study of the Web and Internet, other topics, such as formulating e–business strategy, e–business models, customer interface, and the business–to–business marketplaces will be covered. Executive MBA students only. (1H,1C).

5644: MANAGEMENT OF INFORMATION FOR BUSINESS DECISIONS
This course examines a number of techniques for converting subjective and objective information into structural models that allow for the systematic analysis and solution of many managerial problems. Emphasis is placed on the application of statistical techniques to unstructured data, as well as the use of mathematical programming methods for solving decision problems under conditions of certainty and uncertainty. Executive MBA students only. (2H,2C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6404: CORPORATE SIMULATION METHODS
Design and applications of simulation models for corporate organizations. Emphasis will be placed on projects in which simulation models are constructed, validated, and analyzed. Pre: 5434 (3H,3C).

6414: SEMINAR IN INFORMATION TECHNOLOGY
Advanced study of selected current topics in information technology emphasizing professional journal articles. Student research should lead to a publishable paper. Course may be taken multiple times. Pre: Restricted to graduate students in the Department of Business Information Technology. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (BIT)

The following 4000–level courses have been approved for graduate credit:

(ACIS 4554): NETWORKS & TELECOMMUNICATIONS IN BUSINESS
This course provides a survey of distributed computer networks and data communications in business. Topics include the benefits, costs, and risks of using computer networks, network design issues, and special considerations for network applications. This course will require routine use of the campus network and software to aid in network design and evaluation. Simulation and optimization will be used as tools for network design and evaluation. One semester of college–level programming experience in C required. Pre: 3444 or ACIS 2504. (3H,3C).

4564 (ACIS 4564): OBJECT–ORIENTED SYSTEMA DEVELOPMENT FOR BUSINESS.
The course first develops the foundations and principles of object–oriented programming, including encapsulation, inheritance, polymorphism, and abstraction. These concepts are acquired via comprehensive hands–on experience with a current OOP language (such as Java). The second portion of the course applies concepts learned to a business–oriented application, such as a web–based, e–commerce scenario. Pre: CS 1054. Co: 3444, ACIS 3515. (3H,3C).

CHEMICAL ENGINEERING

Erdogan Kiran, Head

Harry C. Wyatt Professor: D.G. Baird
Frank C. Vilbrandt Professor: Y.A. Liu
Fred W. Bull Professor: S.T. Oyama
Professors: E. Kiran
Associate Professors: D.F. Cox; R.M. Davis; E. Marand; K.F. Williams
Assistant Professors: A.S. Goldstein; A.K. Sum
Adjunct Professors: P.L. Durrill; B.E. Hanson; S. Smith
Career Advisor: E. Kiran
ChE Co-op Advisors: D.F. Cox; A.S. Goldstein

E-mail: chegrad@vt.edu
Web: www.che.vt.edu

Chemical engineering is a bridge between basic science and traditional engineering. It transforms our knowledge in chemical, physical, biological and life sciences into products and processes that benefit society. Chemical engineering plays a prominent role in all realistic solutions to national and international problems of energy, environment, and food. Progress toward solutions in these areas rests with judicious application of science. Such is the domain of the chemical engineer.

The graduate plans of study in chemical engineering are heavily oriented toward synthesis as well as the usual emphasis upon analysis. There is a strong thread of physics, mathematics, chemistry, biochemistry, and microbiology in much of the research in the department. Active research areas include polymer science and engineering, composite materials processing, colloid and surface chemistry, solid state chemistry and physics, self assembly and nanotechnology, biochemical and tissue engineering, catalysis and surface science, pollution prevention and computer–aided design, computational science, and supercritical fluid science and technology. Space does not allow a total listing, but these topics give an indication of the diversity of interests in the department.

Programs are also available for students with undergraduate degrees other than chemical engineering. Chemistry majors, especially those with thorough backgrounds in physical chemistry and mathematics, as well as graduates in biochemistry and microbiology, can re–orient their studies. The applied science nature of the research in the department facilitates this reorientation process of such students. M.S. programs to meet the needs of these students generally require two–to–three years.

Requirements for the M.S. and Ph.D. degrees include a core of 14 credits in transport phenomena, thermodynamics, kinetics, and mathematics. These courses are supplemented with electives chosen in supoort of thesis research or the student's special interests. Ph.D. students have to take additional courses as well and also must pass a qualifying exmination and defend a preliminary proposal prior to completing their dissertation. A thesis is required for all M.S. students.

Much of the research in the department requires multidisciplinary efforts, and chemical engineering students develop strong interactions with students and faculty in other departments and colleges.

GRADUATE COURSES (CHE)

REQUIRED CORE COURSES

5094: ADVANCED CHEMICAL ENGINEERING KINETICS
Fundamental principles of chemical kinetics applied to the analysis and design of chemical reactors. Pre: 3184. (3H,3C).

5125–5126: TRANSPORT PHENOMENA
Fundamentals aspects of transport of mass and chemical reaction. Application to complex chemical engineering problems. Advanced mathematical techniques, fundamental aspects of transport of mass, and chemical reaction. Application to complex chemical engineering problems. 5125: (3H,3C) 1; 5126: (2H,2C).

5144: ADVANCED THERMODYNAMICS
Fundamentals of physical and chemical equilibria, statistical thermodynamics, and applications to situations of current special interest. (3H,3C).

MATH 5496: MATHEMATICAL METHODS IN ENGINEERING II
Linear algebra and matrix theory, vector calculus, complex variables and integral transforms, ordinary and partial differential equations, special functions, integral euqations and calculus of variations. Facility with an existing math software package knowledge of senior level engineering mathematics required. (3H,3C).

ELECTIVES AND SPECIAL INTEREST COURSES

GRADUATE COURSES (CHE)

5014 (CHEM 5014) (MSE 5014): COMMUNICATION SKILLS & METHODS OF PRESENTATION
Methods and style to make effective technical and nontechnical presentations including blackboard presentations, overhead presentations, slide presentations, and research posters. Video presentations with critiques. (1H,1C).

5064: SOLIDS & SOLID SURFACES
Introduction to the theory of solids. Physical properties of bulk crystalline solids and their surfaces are discussed. Excitations accompanying the interaction of electrons and photons with solids are discussed to provide a basis for understanding a variety of experimental methods used in the characterization of solids. Methods for characterizing geometric and electronic structure are surveyed with an emphasis on techniques of ultrahigh–vacuum surface science. (3H,3C).

5084: HETEROGENEOUS CATALYSIS
Fundamental aspects of heterogeneous catalysis; absorption, surface reactions, and catalyst preparation. (3H,3C).

5094: ADVANCED CHEMICAL ENGINEERING KINETICS
Fundamental principles of chemical kinetics applied to the analysis and design of chemical reactors. Pre: 3184. (3H,3C).

5114: THE RUBBERY STATE & THE CRYSTALLINE STATE OF POLYMERS
Fundamental principles of rubbery elasticity and the rubbery state of polymers. Basic principles of the crystalline state of polymers with an emphasis on crystallization kinetics, morphology, and melting behavior. Pre: CHEM 4534. (3H,3C).

5124: RHEO–OPTICS OF POLYMERS
The use of electromagnetic radiation for characterizing the solid state structure and orientation behavior of polymers. Methods discussed include birefringence, linear dichroism, small and wide angle x–ray scattering, and light scattering. Pre: 4214 or CHEM 4634. (3H,3C).

5125–5126: TRANSPORT PHENOMENA
Fundamental aspects of transport of mass and chemica reaction. Application to complex chemical engineering problems. Advanced mathematical techniques, fundamental aspects of transport of mass, and chemical reaction. Application to complex chemical engineering problems. Pre: 3044, 3144 for 5125; 3044, 3144, 5125 for 5126. 5125: (3H,3C). 5126: (2H,2C).

5144: ADVANCED THERMODYNAMICS
Fundamentals of physical and chemical equilibria, statistical thermodynamics, and applications to situations of current special interest. Pre: 2164. (3H,3C).

5164: PROCESS DYNAMICS & SIMULATION
Advanced techniques for modeling and simulation of chemical processing systems. Pre: 5125, 5144. Co: 5094, 5126. (3H,3C).

5224: ADVANCED POLYMER PROCESSING
Basic principles of transport phenomena applied to the modeling of polymer processes. Emphasis is on the use of non–linear rheological equations of state and mathematical models. Pre: 5125, 5126, 4224, ESM 5734. (3H,3C).

5314: HAZARDOUS WASTE TREATMENT
Background on regulations and fundamentals of techniques used for treating hazardous wastes, ground water, and leachates. Pre: CHEM 2535. (3H,3C).

5564 (ESM 5564): NON–NEWTONIAN FLUID MECHANICS
Development of fluid models which describe the mechanical response of non–Newtonian fluids. Use of these models with the basic equations of continuum mechanics is emphasized. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: CHEMICAL ENGINEERING SEMINAR
This course is designed to improve a student's ability to present formal seminars concerned with technical and nontechnical information. Numerous presentations are given by each student enrolling in this class. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6094: ADVANCED MASS TRANSFER OPERATIONS
Applications of transport operation to the solution of advanced mass transfer problems. Emphasis to be placed on the development and use of mathematical methods to describe and optimize separations. Pre: 5126. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (CHE)

The following 4000–level courses have been approved for graduate credit:

4044: APPLIED MATHEMATICS IN CHEMICAL ENGINEERING
Mathematical techniques applied to the solution of chemical engineering problems. Pre: 3134, 3184. (2H,2C).

4114: CHEMICAL MICROENGINEERING
Application of principles of chemical engineering to small chemical systems. Topics include: conservation–of–species equation, linear multi–state chemical systems, unit micro–operations, rate and diffusion control, multiphase catalysis, chromatography, phase–transfer catalysis, facilitated diffusion. Pre: 3184. (3H,3C).

4134: CHEMICAL PROCESS MODELING
Mathemicatical modeling of chemical processes, application of numerical techniques to the solution of equations, use of a programming language to write programs for calling numerical subroutines, numerical solutions of problems resulting in partial differential equations. Pre: CHE 3114. Co: 3044, 3184. (2H,2C).

4214: INTRODUCTION TO POLYMER MATERIALS
Basics of polymeric materials including description and categorization of macromolecules; characterization; mechanical properties; rubbery, glassy, crystalline, and viscous flow behavior. Pre: 2164, 2536. (3H,3C).

4224: INTRODUCTION TO POLYMER PROCESSING
Basic principles of momentum and heat transfer applied to the analysis of polymer processing operations. Pre: 3044, 3144. (3H,3C).

4544 (BSE 4544): PROTEIN SEPARATION ENGINEERING
Concepts, principles and applications of various unit operations used in protein separations. Properties of biological materials, such as cells and proteins, and their influences on process design. Design of processes for protein purification based on the impurities to be eliminated. Concepts and principles of scale–up of unit operations. Case studies in practical protein recovery and purification issues, with a focus on enhanced protein purification by genetic engineering. Protein purification process simulation and optimization using process simulation software. Pre: 3144 or BSE 3504. (3H,3C).

CHEMISTRY

J. E. Merola, Chair

University Distinguished Professor: D.G.I. Kingston
University Distinguished Professor and Ethyl Corporation Professor: J.E. McGrath
Harvey W. Peters Professor: Neal Castagnoli, Jr.
Adhesive and Sealant Council Professor: T.C. Ward
Professors: J.G. Dillard; H.C. Dorn; W. Ducker; R.D. Gandour; H.W. Gibson; B.E. Hanson; T.E. Long; H. Marand; J.E. Merola; J.S. Riffle; J.M. Tanko; L.T. Taylor
Associate Professors: P.G. Amateis; M.R. Anderson; K.J. Brewer; P. Carlier; P.A. Deck; F. Etzkorn; G.L. Long; J.R. Morris; T. Long; B.M. Tissue; J.W. Viers; G. Yee
Assistant Professors: T.D. Crawford; A.R. Esker
Instructors: T.E. Bell; M. Bump; J.E. Eddleton; V. Long; C. Slebodnick
Career Advisor: J.W. Viers (231–5742)

E-mail: gradchem@vt.edu
Web: www.chem.vt.edu/

The Department of Chemistry provides programs leading to the M.S. (thesis or non–thesis) and Ph.D. The various programs revolve around the four classical sub–disciplines of chemistry: analytical, inorganic, organic and physical, as well as polymer chemistry. A large faculty directs research in a wide variety of areas, including analytical and environmental chemistry and chemical instrumentation, synthetic and theoretical inorganic and organic chemistry, medicinal chemistry, natural products chemistry, organometallic chemistry, physical and surface chemistry, polymer chemistry, quantum chemistry, and molecular dynamics. Many research programs are interdisciplinary in nature. Through such projects students and faculty maintain close ties with the various disciplines of chemistry as well as with colleagues in other departments such as biochemistry and biology, chemical, electrical, materials and mechanical engineering, geology, physics, and forestry. A profile of the current research interests of the faculty is available on our web site, *www.chem.vt.edu.*

The department is housed in two buildings, Davidson Hall and Hahn Hall, which contain laboratories and facilities well designed and equipped to carry out modern research programs. In addition to specialized laboratories for synthetic, physical, and analytical chemistry there is state–of–the–art equipment for nuclear magnetic resonance (both solution and solid–state), surface analytical chemistry (PES, Auger and SIMS), X–ray crystallography (single crystal and powder), atomic spectroscopy and chromatography (GC, LC, CZE, SFC, GC/MS and LC/MS). In addition, the department maintains a glass shop staffed by a full–time scientific glassblower and a well–equipped electronic shop staffed by four technicians.

Special Admission Requirements

Prerequisite to graduate work in the chemistry department is completion of an undergraduate program in chemistry or a related discipline such as biochemistry. Students with degrees in other scientific disciplines may be considered. All applicants are required to take the GRE test with the advanced chemistry test recommended.

Special Degree Requirements

Each student's program of study will be constructed by a graduate advisory committee according to the student's background and area of specialization. All candidates for graduate degrees in chemistry are required to satisfy a chemistry core curriculum which is designed to provide students with breadth at the graduate level across a wide spectrum of chemical fundamentals. The core courses are: Advanced Inorganic Chemistry, Principles of Organic Chemistry, Advanced Physical Chemistry, and Advanced Analytical. Before being admitted to candidacy for the Ph.D., students must perform satisfactorily on a preliminary examination. More detail can be found in the departmental brochure on the website. The M.S. is not a prerequisite for the Ph.D.

Graduate Courses (CHEM)

5014 (CHE 5014) (MSE 5014): COMMUNICATION SKILLS & METHODS OF PRESENTATION
Methods and style to make effective technical and nontechnic presentations including blackboard presentations, overhead presentations, slide presentations, and research posters. Video presentations with critiques. (1H,1C).

5045, 5046: MOL STRUCTURE DETERMINATION
Major research instrumentation used in structure determinations; emphasis is on applications of various techniques. Pre: 2536, 3616. (2H,2C).

5104: ADVANCED ANALYTICAL CHEMISTRY I
Discussion of theory and applications of separations and spectrometry in analytical chemistry. Topics include; GC, HPLC, Gel Permeation Chromatography, Electrophoresis, AAS, AES, AFS, lasers, flame, and plasma diagnostics. One year of physical chemistry required. (3H,3C).

5114: ADVANCED ANALYTICAL CHEMISTRY II
Discussion of theory and application of chemical equilibrium, reaction rate methods, and electroanalytical methods in analytical chemistry. One year of physical chemistry required. (3H,3C).

5124: ANALYTICAL SPECTROSCOPY
Principles, instrumentation, and applications of atomic and molecular spectroscopy. Theoreticscriptions of electronic and ro–vibrational energy levels, transitions, and energy dynamics. Modern spectroscopic instrumentation and applications in quantitative analyses. Prerequisite or equivalent Pre: 3616. (3H,3C).

5134: INDUSTRIAL INSTRUMENTAL ANALYSIS
Current topics in industrial instrumental analysis presented by individuals from industrial and governmental laboratories. The topics will concern innovative analytical methods not covered in other university courses, and methods uncommon to the university laboratory. Assumes a background in classical instrumental methods. (3H,3C).

5174 (ESM 5174): POLYMER VISCOELASTICITY
Constitutive models of linear viscoelastic materials, experimental aspects, polymer response to mechanical and electrical inputs, solid state NMR and microwave interactions with polymers, free volume theories, temperature and environmental effects on polymers, physical aging of glasses. Consent required. (3H,3C).

5404: ADVANCED INORGANIC CHEMISTRY
An advanced coverage of topics in inorganic chemistry: principles of bonding in compounds of the metals and non–metals, applications of group theory to bonding, ligand field theory, inorganic and

organometallic reaction mechanisms. Required core course for chemistry graduate students. One semester of undergraduate inorganic chemistry, one year undergraduate physical chemistry required. (3H,3C).

5504: PRINCIPLES OF ORGANIC CHEMISTRY
An advanced survey of topics in organic chemistry: Basic bonding principles, nomenclature, surveys of organic functional groups and their reactions. Required core course for chemistry graduate students. One year of undergraduate organic chemistry required. (3H,3C).

5505–5506: ADVANCED ORGANIC CHEMISTRY
Structure, stereochemistry, and bonding in organic compounds and their effects on organic reactivity. Ionic reactions, free radical reactions, and concerted reactions will be discussed. One year of undergraduate organic chemistry required. (3H,3C).

5524: MOLECULAR STRUCTURE DETERMINATION
Structure determination of organic compounds by spectroscopic methods, with an emphasis on mass spectrometry and nuclear magnetic resonance. Course will emphasize problem–solving skills. Includes hands–on instruction in nuclear magnetic resonance spectroscopy and other analytical spectroscopic methods. Partially duplicates 4524; students cannot receive credit for both 4524 and 5524. Pre: 2536, 3616 or 4616. (3H,3L,4C).

5535,5536: SYNTHETIC ORGANIC CHEMISTRY
Modern synthetic methods and their applications to the preparation of various classes of organic compounds. Pre: 5505. (3H,3C).

5614: ADVANCED PHYSICAL CHEMISTRY
An advanced survey of topics in thermodynamics, chemical kinetics, and bonding theory. Required core course for chemistry graduate students. One year of undergraduate physical chemistry required. (3H,3C).

5644: COLLOID & SURFACE CHEMISTRY
Characterization of interfaces including liquid/gas and liquid/liquid (spread monolayers) interfaces, nature of solid surfaces, gas/solid (thermodynamics), and liquid/solid (wetting, colloidal stability) interfaces. PRE: One year of physical chem. or consent. (3H,3C).

5654 (ESM 5654) (MATH 5654) (MSE 5654): ADHESION SCIENCE
Introduction to basic principles of adhesion science from the areas of mechanics, materials, and chemistry. Consent required. (3H,3C).

5664: CHEMICAL KINETICS
Phenomenological kinetics with emphasis on measurement techniques and the interpretation of kinetic data. Significance of rate laws, activation parameters for mechanisms, catalysis and fast reactions in gas and condensed phase are discussed. (3H,3C).

5704: SYNTHESIS & REACTIONS OF MACROMOLECULES
Advanced treatment of the kinetics, mechanisms, synthesis and reactions of macromolecules via step and chain processes. PRE: Second year grad standing in chemistry, chemical engineering, or consent. (3H,3C).

5894: FINAL EXAMINATION
For non–thesis candidates who are required to register for their final examination and have completed their program of study. Not to be included in minimum hours required for degree. Pass/Fail only. Variable credit course.

5904: PROJECT & REPORT
A detailed written report on a current topic in chemistry or interdisciplinary areas involving chemistry. Non–thesis M.S. students in chemistry are required to complete 4 credit hours of CHEM 5904. Graduate standing in chemistry required. Variable credit course.

5944: GRADUATE SEMINAR
Recent advances in various fields of chemistry are covered by means of reports carefully prepared and presented by individual students, under direction of various members of chemistry faculty. Work of each student is judged not only by report he gives but also by an intelligent discussion of reports presented by other students. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6164: CURRENT TOPICS IN ANALYTICAL CHEMISTRY
Special topics in frontier areas of analytical chemistry. Offered when appropriate. Pre: 5104, 5114. (3H,3C).

6424: CHEMISTRY OF NON–METALS
Non–metallic elements and their characteristic covalent compounds, including solvent systems, and inorganic polymers. (3H,3C).

6434: ORGANOMETALLIC CHEMISTRY
Chemistry and applications of organometallic and related compounds. (3H,3C).

6444: CHEMISTRY OF THE TRANSITION METALS
Physical properties and descriptive chemistry of the transition metals and their complexes. Chemistry of the lanthanide and actinide elements. (3H,3C).

6464: CURRENT TOPICS IN INORGANIC CHEMISTRY
Special topics in frontier areas of inorganic chemistry. Offered when appropriate. (3H,3C).

6504: CHEMISTRY OF NATURAL PRODUCTS
The structures, biosyntheses, reactions, and biomimetic syntheses of natural products, with examples from each of the major classes of polyketides, shikimates, terpenoids, alkaloids, antibiotics, and marine natural products. Pre: 5506. (3H,3C).

6514: SYNTHESIS OF NATURAL PRODUCTS
Advanced discussion of natural product chemistry. Emphasis on strategy in synthesis and methodology of such compounds as alkaloids, terpenes, macrocyclic antibiotics, and marine natural products. Pre: 5535, 5536, 6504. (3H,3C).

6524: PRINCIPLES OF MEDICINAL CHEMISTRY
Mechanism of action of various physiologically active compounds presented in terms of molecular interactions, structure, and physiochemical properties. Second year graduate standing in chemistry or consent required. (2H,2C).

6564: CURRENT TOPICS IN ORGANIC CHEMISTRY
Special topics in frontier areas of organic chemistry. Offered when appropriate. Pre: 5506. (3H,3C).

6614: ADVANCED CHEMICAL KINETICS
Unimolecular reactions, collision, and transition state theories; trajectory calculations; state–to–state chemistry; molecular beams; thermochemical kinetics. Pre: 5644. (3H,3C).

6624: CHEMICAL THERMODYNAMICS
Rigorous application of the laws of thermodynamics to real fluids, solutions, chemical equilibria, and non–equilibrium processes. (3H,3C).

6634: QUANTUM CHEMISTRY & SPECTROSCOPY
Study of basic quantum mechanics followed by some of its applications to chemistry and spectroscopy. Topics include: the variational method; perturbation theory; Hartree–Fock theory; the electronic structures of atoms and molecules; atomic spectra; and molecular rotational, vibrational, and electronic spectra. (3H,3C).

6654: STATISTICAL MECHANICS
Theory and chemical applications of ensembles and correlation functions, perturbation theory, time–dependent statistics, and linear response theory. (3H,3C).

6664: CURRENT TOPICS IN PHYSICAL CHEMISTRY
Special topics in frontier areas of physical chemistry. Offered when appropriate. (3H,3C).

6674: PHYSICAL CHEMISTRY OF POLYMERS
Quantitative treatment of polymer chemical composition, stereochemistry, molecular weight, topology, morphology, viscoelasticity, mechanical behavior. Offered every other year. Pre: 3615, 3616. (3H,1L,4C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (CHEM)

The following 4000–level courses have been approved for graduate credit:

4074 (MSE 4544): LABORATORY IN POLYMER SCIENCE
Experimental techniques used in the synthesis of various linear polymers, copolymers, and crosslinked networks. Determination of polymer molecular weights and molecular weight distribution. Methods used in the thermal, mechanical, and morphological characterization of polymeric systems. Graduate students in chemistry, P/F only. Pre: 3616, 4534. (1H,3L,2C).

4114: INSTRUMENTAL ANALYSIS
Principles of instrumental methods including data analysis, phase equilibrium, spectroscopy, and electrochemistry. Applications of modern instrumentation to chemical analyses using chromatography, electrophoresis, atomic and molecular spectroscopy, potentiometry, and voltammetry. Note: Graduate students will not be expected to take the corequisite lab 4124. Pre: 3616. Co: 4124. (3H,3C).

4404: PHYSICAL INORGANIC CHEMISTRY
A study of spectroscopic, bonding, and structural properties of inorganic compounds. Co: 3616. (3H,3C).

4414: INORGANIC CHEMISTRY LAB
Synthesis and characterization of inorganic compounds using modern laboratory techniques. Pre: 3615. Co: 3616, 4424. (6L,2C).

4424: DESCRIPTIVE INORGANIC CHEMISTRY
Application of fundamental principles in a systematic study of bonding and reactivity of the elements and their compounds. Pre: 1035, 1036, 1045, 1046. (3H,3C).

4524: IDENTIFICATION OF ORGANIC COMPOUNDS
Structure determination of organic compounds by spectroscopic methods, with an emphasis on mass spectrometry and nuclear magnetic resonance. Course will emphasize problem–solving skills. Pre: (2536 or 2566), (3616 or 4616). (3H,3C).

4534: ORGANIC CHEMISTRY OF POLYMERS
Structure, synthesis, and basic characteristics of the major classes of polymerization reactions including step–growth (condensation) and chain growth (addition), free radical, and ionic mechanisms. Pre: 2536. (3H,3C).

4554: DRUG CHEMISTRY
Structure, synthesis, and physiological effects of major classes of pharmaceutical agents including CNS depressants and stimulants, analgesics, anesthetics, cardiovascular agents, chemotherapeutic drugs, and oral contraceptives. Pre: 2536. (3H,3C).

4615–4616: PHYSICAL CHEMISTRY FOR THE LIFE SCIENCES
Principles of thermodynamics, chemical kinetics, and chemical bonding for students in the life sciences. 4615: Laws and applications of thermodynamics. 4616: Chemical kinetics and chemical bonding including spectroscopy. Partly duplicates 3615, cannot receive credit for 3615 and 4615. Pre: One year of chemistry, physics, and calculus. (3H,3C).

4634 (MSE 4534): POLYMER AND SURFACE CHEMISTRY
Physical chemical fundamentals of polymers and surfaces including adhesives and sealants. Pre: 3615 or 4615. (3H,3C).

4734 (CSES 4734) (ENSC 4734): ENVIRONMENTAL SOIL CHEMISTRY
Chemistry of inorganic and organic soil components with emphasis on environmental significance of soil solution–solid phase equilibria, sorption phenomena, ion exchange processes, reaction kinetics, redox reactions, and acidity and salinity processes. Pre: 2514, 2535, 3114, CSES 3114, CSES 3124, MATH 2015. (3H,3C).

4754 (CSES 4754) (ENSC 4754): INSTRUMENTAL ANALYSIS FOR AGRICULTURAL AND ENVIRONMENTAL SCIENCES
Theory and principles of common analytical instruments and their applications to agriculture and environmental science research. Topics include atomic absorption and emission spectroscopy, spectrophotometric methods (UV, visible, luminescence, and automation), chromatography, ion–selective electrodes, and microwave digestion. Infrared spectroscopy, atomic ratio and molecular mass spectroscopy, nuclear magnetic resonance will also be included. Provide hands–on experience with modern analytical instruments. Prerequisites or graduate standing required. Pre: (3114, 3124) or (CSES 3114, CSES 3124). (3H,3L,4C).

GRADUATE COURSES (MACR)

5015, 5016: MACROMOLECULAR FUNDAMENTALS LABORATORY I & II
This course will cover fundamentals and experimental techniques for the synthesis and characterization of polymeric materials. MACR 5015 includes statistical experimental design, step–growth and chain–growth polymerization, molecular modeling, thermal properties of polymers, molecular weight analysis, morphology, and melt and solution rheology. MACR 5016 includes static and dynamic mechanical analysis, rubber elasticity, spectroscopy, surface analysis, fracture behavior, and basic polymer processing. Must meet pre–requisites or equivalent. Pre: CHEM 4534 or CHEM 4634 or CHE 4104. (2H,3L,3C).

5024: WRITING SKILLS IN MACROMOLECULAR SCIENCE & ENGINEERING
This course focuses on methods and critiques for preparing technical abstracts, conference proceedings, technical industrial reports, refereed journal manuscripts and resumes. (2H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

CIVIL & ENVIRONMENTAL ENGINEERING

UNIVERSITY EXEMPLARY DEPARTMENT *

W.R. Knocke, Head

University Distinguished Professor: J.M. Duncan
W. Curtis English Professor: W.R. Knocke
Dan H. Pletta Professor: R.H. Plaut
Charles P. Lunsford Professor: M.A. Edwards
David H. Burrows Professor: M.C. Vorster
Montague-Betts Professor: T.M. Murray
Newport News Shipbuilding/Tenneco Professor: T.A. Dingus
Nick Prillaman Professor: J.T. Novak
Vecellio Professor: J.M. de la Garza
Charles E. Via, Jr. Professor: R.E. Weyers
Professors: G.D. Boardman; W.E. Cox; P. Diplas; W.S. Easterling; G.M. Filz; T.J. Grizzard; A.G. Hobeika; D.F. Kibler; J.C. Little; G.V. Loganathan; J.R. Martin II; D. Teodorovic; M.A. Widdowson
Associate Professors: T.L. Brandon; F.A. Charney; T.E. Cousins; A.M. Dietrich; R.L. Dymond; G.W. Flintsch; D.L. Gallagher; M.S. Gutierrez; K. L. Hancock; N.G. Love; J.C. Martinez; M. Mauldon; H.A. Rakha; K.B. Rojiani; A.D. Songer; A.A. Trani
Assistant Professors: L.C. Marr; C.L. Roberts-Wollmann; P.J. Vikesland
Research Associate Professor: A.N. Godrej
Research Assistant Professors: J.E. Dove
Professors Emeritus: D.A. Garst; S.M. Holzer; J.M. Hughes; J.K. Mitchell; C.W. Randall

E-mail: lindycra@vt.edu
Web: www.cee.vt.edu

The Charles Edward Via, Jr. Department of Civil and Environmental Engineering awards the M.S. in civil engineering (thesis/non-thesis), environmental engineering, and environmental sciences and engineering; the M.E. in civil engineering; and the Ph.D. in civil engineering. For the civil engineering degree, major emphasis may be placed in one of the following program areas: construction, civil infrastructure, environmental and water resources, geoenvironmental, geotechnical, structures and materials, and transportation infrastructure and systems. A minor may be taken in one or more of the alternate areas of civil engineering or in some allied field, such as mathematics, engineering mechanics, geology, urban and regional studies.

Construction engineering provides an interdisciplinary study program to coordinate topics in management, finance, accounting, operations research, construction management, and traditional engineering disciplines. Civil infrastructure engineering is an interdisciplinary program encompassing several specialty areas within and outside the civil engineering department that focuses on life-cycle management of environmental, transportation, and other public works systems. The environmental and water resources program encompasses a wide range of topics in the areas of water and wastewater treatment, water quality management, air resources engineering, solid and hazardous waste management, groundwater, environmental fluid mechanics, hydraulics and hydrology, ecological engineering, biotechnology, and water resources planning and management. The environmental sciences program is designed for students with undergraduate degrees in one of the natural sciences rather than engineering. Geo-environmental encompasses elements of the environmental, geotechnical, and hydrosystems programs and addresses subsurface waste disposal and containment, soil and ground water remediation, and environmental restoration. The geotechnical program offers opportunities for study and research in foundation design, earth dams, seepage and contaminant transport, soil behavior, soil and site improvement, in-situ testing, soil-structure interaction, soil dynamics, earthquake engineering, soil reinforcement, development of microcomputer programs for geotechnical applications, and a variety of special topics. Studies in structures and materials generally emphasize techniques in analysis and design, experimental testing of structural systems, and materials used in infrastructure facilities, with emphasis on evolution of new materials, materials deterioration, condition assessment, maintenance, and rehabilitation. The transportation and infrastructure systems program includes all aspects of planning, design and operation of transportation facilities. Well equipped laboratories are available for research within each civil engineering program.

These programs address the teaching, research, and public service missions of the university through a combination of on-campus activities, use of televised distance learning, and participation in the Commonwealth Graduate Engineering Program. In addition the civil engineering department offers M.S. programs in civil infrastructure engineering, environmental engineering and environmental sciences and engineering through the Northern Virginia Center in Falls Church, Virginia.

The civil and environmental engineering graduate programs prepare students to enter professional engineering practice at advanced levels and can also provide a basis for academic and research careers. The student who completes one of the programs should be able to:

- Perform advanced engineering analysis and design in one of the subdisciplinary areas of civil and environmental engineering.
- Plan and conduct research to advance the state of knowledge within a specialty area of civil and environmental engineering.
- Conduct educational and training programs.
- Assume positions of leadership in addressing societal problems such as inadequate infrastructure.
- Contribute to professional journals and other literature within the various specialty areas of civil and environmental engineering.

SPECIAL REQUIREMENTS

The master's programs have no foreign language requirement. For the Ph.D. program in civil engineering, no foreign language proficiency is required; however, the student's committee may prescribe a language requirement, computer skill, or other competency deemed necessary in the student's field of study.

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

GRADUATE COURSES (CEE)

5010: SCHEDULE IMPACT ANALYSIS
Analysis of construction scheduling principles, scheduling specifications, contract administration, construction law, construction delay claims, and of accepted methodologies for performing schedule impact analysis of delaying events. Pre: 4024. (3H,3C).

5024: CONTRACT ADMINISTRATION & CLAIMS RESOLUTION
This course provides students with a knowledge of the different types of contracts used in civil engineering construction. Contracts are viewed as documents which assign responsibilities and allocate risks and emphasis is placed on contract administration as the first step in reducing costs and easing the burden of dispute resolution. Techniques for quantifying and resolving claims are studied. (3H,3C).

5034: CONSTRUCTION SYSTEMS DESIGN & INTEGRATION
This course will study building systems, their design and how to best manage the life cycle cost of the systems. The course will have particular emphasis on systems. The course will have particular emphasis on mechanical and electrical equipment in buildings, solar design, lighting design, site orientation, value engineering and constructability of the various systems. (3H,3C).

5044: CONSTRUCTION RESEARCH PRESENTATION
This course requires that students produce a written paper and make an oral presentation based on a construction research topic of their choice. It is designed to sharpen skills in the written and oral presentation of technical material. Co: 6014. (3H,3C).

5054: CONSTRUCTION PERFORMANCE IMPROVEMENT
Skills for productivity improvement in construction, with special attention to techniques used to record and analyze operations as required to develop and implement efficient and rewarding methods. Consideration of the human factor in generating and implementing commitments to productivity improvements. Pre: 3014. (3H,3C).

5064 (BSE 5144): KNOWLEDGE-BASED EXPERT SYSTEMS
Function and concepts of knowledge-based expert systems. Knowledge representation, uncertainty management, inferencing techniques, and validation. Principles of knowledge acquisition and knowledge engineering. Focus on developing knowledge-based systems for information management and decision support in engineering and natural resource management. Program lang. experience required. (3H,3C).

5084: AUTOMATION IN THE A/E/C INDUSTRY
Computer concepts, computer technology, analyses and design of applications as well as means and concepts to guide development, implementation, and transfer of automation applications in the Architecture/Engineering/Construction (A/E/C) Industry. Pre: 5044. (3H,1L,3C).

5104: ENVIRONMENTAL CHEMISTRY
Applied, environmental aspects of physical, organic, and inorganic chemistry; including applications in sanitary engineering of the phenomena of precipitation, complexation, buffering capacity, and chemical equilibria. Review of the nomenclature and properties of organic compounds. (3H,3C).

5114: SOLID WASTE MANAGEMENT
Design of sludge handling and solid waste collection and disposal systems. Sludge and solid waste characteristics, handling, storage, dewatering, separation and recovery, and ultimate disposal. Pre: 3104. (3H,3C).

5124: FUNDAMENTALS OF ENVIRONMENTAL TOXICOLOGY
Introduction to nomenclature, principles, and scope of environmental toxicology. The fate and effects of both organic and inorganic toxicants in the environment, in animals, and in various test systems. Pre: 5104. (3H,3C).

5125,5126: ENVIRONMENTAL ENGINEERING DESIGN
5125: Design of wastewater treatment facilities for the reduction and elimination of organic and inorganic pollutants; 5126: Design of water treatment facilities for the production of potable waters from surface and groundwater systems. Pre: 3104. (3H,3C).

5134: ENGINEERING ASPECTS OF WATER QUALITY
The application of biological, chemical, and physical principles of water quality to engineering problems in surface waters. Pre: 3104. (3H,3C).

5144: UNIT OPERATIONS & PROCESSES LABORATORY
Applied science aspects of water and waste treatment; advanced research techniques in analysis and treatment of water and wastes. Pre: 5125 or 5126. (1H,6L,3C).

5154: AIR POLLUTION CONTROL ENGINEERING
Principles and practice of air pollution source control with emphasis on stationary source control and equipment operating and design parameters; economic and technical evaluation of control system design alternatives. (3H,3C).

5164: AIR QUALITY MODELING & MEASUREMENT
Air quality modeling and measurement of point, line and area sources. Considerations of micrometeorological and transport mechanisms in order to assess impact of proposed air pollution sources. Use of the computer simulation models (on the personal and/or main frame computer) for pollution impact prediction. Use of model calibration and validation procedures with measured ambient air quality levels and stack emissions. Fundamentals of stack design. (3H,3C).

5174: INDUSTRIAL & HAZARDOUS WASTES CONTROL
Contemporary methods for the management and treatment of industrial wastewaters, including in-plant reductions and reuse. Characterization and management of hazardous wastes. Design of appropriate systems. X-grade allowed. Pre: 5134. (3H,3C).

5184: TECHNIQUES FOR ENVIRONMENTAL ANALYSIS
An introductory course on techniques commonly utilized for analysis of environmental samples. Course will discuss gas and liquid chromatrography, mass spectrometry, and atomic absorption spectroscopy, focusing on analysis of complex environmental samples. Practical techniques and applications are emphasized, but sufficient theory is introduced to provide students with an understanding of the principles involved. (3H,3C).

5194: ENVIRONMENTAL ENGINEERING MICROBIOLOGY
Roles of microorganisms in wastewater treatment, anaerobic digestion of municipal sludges, stream self-purification, and degradation of water quality in drinking-water systems. Disinfection of wastewater and drinking water to remove viruses, bacteria, and protozoa that cause waterborne disease. (2H,3L,3C).

5204: GIS APPLICATIONS IN CIVIL ENGINEERING
Examination of data structures used in geographic information systems. Map projections and coordinate systems used in mapping. Database creation, maintenance, and integrity. Applications of GIS methods for solving civil engineering problems in land management and related areas. (3H,3C).

5214: ANALYSIS OF IMAGING SYSTEMS
Introduction to each of the major types of imaging systems used in remote sensing. Characteristics of image geometry and image mapping functions of airborne and space remote sensing systems. Emphasis on positional accuracy of remotely sensed data for mapping purposes. Introductory course in photogrammetry or remote sensing required. (3H,3C).

5224: ADVANCED GIS APPLICATIONS IN CIVIL & ENVIRONMENTAL ENGINEERING
This project-based course deals with both vector and raster

Geographic Information Systems (GIS), network analysis, tracking applications, hydrologic applications, spatial analysis, web databases, and linking GIS to models with programming, specifically in the civil and environmental engineering arena. Pre: any introductory GIS course, including 5204, GEOG 4084, or BSE 4344. (3H,3C).

5244 (BSE 5244): ADVANCED GIS IN HYDROLOGIC ANALYSIS
Advanced GIS course focusing on raster analysis with particular application to the issues associated with hydrologic analysis. Application and evaluation of algorithms for terrain analysis, watershed characterization, and hydrologic analysis and modeling as implemented in GIS. Digital elevation data sources and error assessment. Approaches to GIS/model integration and application. Pre: BSE 4344 or CEE 5204 or GEOG 4084, BSE 3305 or CEE 4304. (2H,3L,3C).

5245-5246: GEODESY
5245: Geometric and physical geodesy principles: ellipsoidal geodesy and coordinate systems, forward and inverse geodetic computations, astrogeodetic methods, Earth's gravity field and geoid undulations.
5246: Advanced Topics in geodesy and satellite positioning. Pre: 4244. (3H,3C).

5264: ANALYTIC PHOTOGRAMMETRY
Analytic treatment of single and multiple photograph problems in photogrammetry; image measurement refinement, resection, relative and absolute orientation. Aerotriangulation theory and methods. Least squares adjustments in photogrammetry. Pre: 4244. (3H,3C).

5304: ADVANCED HYDRAULICS
Application of the principles of fluid mechanics to the analysis of hydraulic engineering problems; ideal and viscous flow; seepage problems; water waves; turbulence modeling; diffusion processes. Pre: 3314. (3H,3C).

5314: RIVER MECHANICS & SEDIMENT TRANSPORT
Sediment properties; critical stress; bed-form regimes in alluvial streams; depth-discharge relations for rivers; bed load and suspended load movement; river stability; flow in bends; river training. Pre: 4324. (3H,3C).

5324: ADVANCED HYDROLOGY
Applications of statistics to hydrology, floods, and droughts; flow generation models; mathematical models in physical hydrology; difference methods in flow routing; kinematic wave; evapo-transpiration; infiltration; and atmospheric processes. X-grade allowed. Pre: 4304. (3H,3C).

5334: ANALYSIS OF WATER RESOURCES SYSTEMS
Systems analysis, modeling, and optimization in water management; linear, nonlinear, and dynamic programming models; chance constrained programs. Application to engineering problems in the areas of water supply, water quality, reservoir operation, and river basin development, groundwater management, simulation models, and land use planning. (3H,3C).

5344: ENVIRONMENTAL SYSTEMS OPTIMIZATION
Application of optimization techniques to environmental and hydraulic design. Use of linear, nonlinear, and dynamic programming to improve the efficiency and cost of environmental systems. Students will use existing computer programs to solve problems. Applications include wastewater treatment plant operation, sewer design, groundwater remediation, and reservoir management. Pre: 3304, 3104. (3H,3C)

5354 (GEOL 5814): NUMERICAL MODELING OF GROUNDWATER
Theory and practice of numerical techniques are developed and applied to fluid flow and transport in ground-water flow systems. Governing equations are formulated using FD and FE techniques with appropriate BC's and IC's. Additional topics include: model conceptualization and grid design in multidimensional systems; practical applications of numerical models including calibration, validation, and prediction; concepts and techniques of advective transport using particle tracking and dispersive transport. Introduction to MODFLOW, MODPATH, MT3D, and others. Pre: 4314, GEOL 4114. (3H,3C).

5364: WATER LAW
Analysis of law for allocation of surface and groundwater supplies, legal controls over water quality alteration, public rights of water use, and drainage law. Pre: 4804. (3H,3C).

5374: DYNAMICS GROUNDWATER
The theory of dynamics of fluids in porous media; fluid and matrix properties; transport equations; boundary and initial value problems; flow of immiscible fluids; dispersion. Pre: 4314. (3H,3C).

5384: TRANSPORT PROCESSES IN WATERWAYS
Physical aspects of mixing, advection, and diffusion processes in reservoirs, rivers, estuaries, and coastal waters, with emphasis on modeling techniques; hydraulic design aspects of waste disposal. Pre: 5304. (3H,3C).

5394: TRANSIENT FLOW IN HYDRAULIC SYSTEMS
Analysis of transient phenomena in open and closed conduits using momentum characteristics and impedance methods. Waterhammer, surge tank systems, and surface waves. (3H,3C).

5404: PLATE & SHELL STRUCTURES
Classical solutions of elastic plate theory; approximate methods; continuous plates; orthotropic plates. Theory of thin shells of revolution; membrane and bending actions. Pre: 3404. (3H,3C).

5414: FINITE ELEMENT ANALYSIS OF STRUCTURES
Formulation of the finite element method and application to skeletal, plate, and shell structures. Study of mesh layout and refinement, convergence characteristics, and solution accuracy. Tests of element quality. Use of commercial finite element codes such as ABAQUS. (3H,3C).

5424: COMPUTER ANALYSIS OF STRUCTURES II
Extension of matrix displacement method to skeletal space structures: space trusses, space frames, and grids. Incorporation of special features such as nonglobal constraints, assemblies of different types of elements, thermal problems, substructuring, and buckling analysis. Development of well-structured programs on the mainframe and transfer to the personal computer. Pre: 4404. (3H,3C).

5434: DESIGN OF COLD-FORMED STEEL STRUCTURES
Behavior and design of cold-formed steel members. Strength of thin plate elements; flexural members; compression members, symmetric and non-symmetric; beam-columns; welded, bolted, and screw-fastened connections. Building systems that utilize cold-formed steel members. Pre: 3434. (3H,3C).

5444 (AOE 5044) (ESM 5444): DYNAMIC STABILITY OF STRUCTURES
Modern structural stability analysis; static and dynamic instability; conservative and nonconservative systems; multiple loads; and Liapunov stability analysis. Applications to columns, rotating shafts, pipes conveying fluid, and airplane panels. Pre: AOE 3034, ESM 4074. (3H,3C).

5454 (ESM 5454): ELASTIC STABILITY
Stability of elastic structural components under conservative loads; precise definitions of stability; energy approaches; Rayleigh-Ritz and Galerkin methods; and applications to column, arches, plates, and shells. Pre: 3404 or AOE 3124. (3H,3C).

5464 (ESM 5464): STRUCTURAL DYNAMICS & EARTHQUAKE ENGINEERING
Earthquake-induced vibration of single- and multi-degree-of-freedom systems; application to frames and to shear and torsional buildings; response spectrum analysis; building codes; static and dynamic lateral force procedures; seismic resistance of steel and concrete building frames. Pre: 3424, 3434. Co: 4404. (3H,3C).

5474: ADVANCED REINFORCED CONCRETE DESIGN
Limit design concepts, yield-line methods, seismic considerations, and other advanced topics related to design of reinforced concrete structures. Pre: 3424. (3H,3C).

5484: ADVANCED BRIDGE DESIGN
Relationship of bridges to national needs; illustration of a preliminary design by case history; design of conventional bridge decks and girders; curved box-girder bridges; segmental construction; cable-stayed bridges; importance of design details on the seismic resistance of bridges. Pre: 3424, 3434. (3H,3C).

5494 (ESM 5234): RELIABILITY METHODS IN STRUCTURES & MECHANICS
Theory of structural reliability; reliability based designs, safety index, linear and nonlinear design equations, load and resistance factors, Level I, II and III formats, code formulations; systems reliability, bounds on reliability; extreme value distributions. Pre: 4614 or STAT 4706. (3H,3C).

5514: SOIL BEHAVIOR
Behavior of soil examined from a fundamental soil perspective. Review of methods of testing to define response; rationale for choosing shear strength and deformation parameters for soils for design applications. Pre: 3514. (3H,3C).

5524: ADVANCED SOIL TESTING FOR ENGINEERING PURPOSES
Methods of testing and analysis of soil for engineering properties including compressibility; strength in triaxial, simple, and direct shear; permeability; and stability. Pre: 4524. (1H,6L,3C).

5534: FOUNDATION ENGINEERING I
Behavior and design of retaining walls and shallow foundations. Earth pressures, bearing capacity, and settlement. Stress distribution and consolidation theories. Settlement of shallow foundations. Pre: 3514. (3H,3C).

5544: FOUNDATION ENGINEERING II
Behavior and design of anchored bulkheads, excavation bracing, driven piles, drilled piers and buried structures. Effects of pile driving. Response of deep foundations to vertical and horizontal loads. Pre: 5534. (3H,3C).

5554: SOIL & SITE IMPROVEMENT
Methods of soil and site improvement including design techniques for dewatering systems, grouting, reinforced earth, in-situ densification, stone columns, slurry trenches, and the use of geotextiles. Construction techniques for each system are described. Pre: 3514. (3H,3C).

5564: SEEPAGE & EARTH STRUCTURES
Soil permeability and seepage through soils. Embankment design. Compaction, earth pressures and pressures in embankments. Slope stability analysis. Settlements and horizontal movements in embankments. Landslide stabilization. Pre: 5514. (3H,3C).

5574: ENVIRONMENTAL GEOTECHNICS
Geotechnical aspects of environmental engineering projects. Fundamentals of soil behavior, site characterization, and contaminant transport; methods for geotechnical engineering practice for waste disposal, waste containment, and site remediation; waste landfills. Pre: 3104, 3514. (3H,3C).

5584: GEOTECHNICAL ASPECTS OF EARTHQUAKE ENGINEERING
Causative mechanisms of earthquake, earthquake magnitudes, ground motion, effect of local soil conditions on motions. Response of soils to seismic loading, liquefaction phenomena and analysis of pore pressure development, laboratory and in-situ testing for seismic loading. Analysis and design of slopes, embankments, foundations, and earth retaining structures for seismic loading. Pre: 4544. (3H,3C).

5594: GEOTECHNICAL LEADERSHIP STUDIO
Geotechnical engineering lectures, project work, and exercises addressing the application of geotechnical engineering principles in engineering practice, and the requirements for successful professional practice. Teamwork on geotechnical projects; written and oral communications; project cost estimates; proposals; contracts and liability; ethics; and leadership. 18 units of graduate courses in geotechnical engineering subjects required. Pass/Fail only. (3H,10L,6C).

5600: CIVIL INFRASTRUCTURE SYSTEMS ANALYSIS
Systems analysis, modeling infrastructure systems by mathematical programming, measuring infrastructure systems performances, probabilistic analysis of infrastructure systems, multiple attribute decision making in infrastructure systems. Graduate standing in engineering required. (3H,3C).

5604: TRAFFIC CHARACTERISTICS & FLOW
Driver, vehicle, and roadway characteristics; stochastic modeling of traffic processes including queueing theory, headway distributions, and gap acceptance; stream flow characteristics including car-following and multilane traffic models, roadway capacity and bottleneck analysis, network operations, and fuel consumption models. Pre: 4604. (2H,3L,3C).

5610: SOFT COMPUTING IN TRANSPORTATION ENGINEERING
Fuzzy sets, fuzzy arithmetic rules, approximate reasoning, fuzzy mathematical programming, artificial neural networks, fuzzy sets and neural networks; applications in transportation engineering include trip generation, trip distribution, modal split, route choice and traffic assignment, vehicle routing, scheduling, and dispatching, real time ground and air traffic control. Graduate standing in engineering required. (3H,3C).

5614: ANALYSIS OF AIR TRANSPORTATION SYSTEMS
Planning, design and operation of aviation systems with computer aided design tools and computer simulation models. Airline airport operations and practices and their effect in airport planning and design. Air cargo facilities planning and modeling. State-of-the-art computer simulation models used in aviation environmental planning and airspace modeling. Graduate standing in CE required. (3H,3C).

5620: TRANSPORTATION NETWORKS ANALYSIS
Optimal paths in transportation networks, transportation network design, vehicle routing and scheduling, facility location problems, traffic flows on networks, traffic assignment problems. Graduate standing in engineering required. (3H,3C).

5624: TRANSPORTATION & LAND USE
Interaction between transportation and land use variables, including modeling requirements, impacts, and data needs within the context of good community planning and economic development; elements of transportation and land use that shape the quality of life in urban areas. Pre: 3604. (3H,3C).

5630: DESIGN & OPERATION OF ADVANCED PUBLIC TRANSPORTATION SYSTEMS
An overview of the use of intelligent transportation systems (ITS), technologies and user services in design and operation of advanced public transit systems (APTS); emphasis is placed on communication, sensor application, information processing, traffic control, en-route and pre-trip information, electronic payment, and fleet management as they pertain to transit and paratransit services in large metropolitan areas as well as in small urban and rural communities. Pre: 3604. (3H,3C).

5634: ANALYSIS & PLANNING OF MASS TRANSIT SYSTEMS
An overview of mass transit systems; transit system planning including demand and cost analysis and evaluation; transit system design including route design, scheduling, and fare policy; transit networks and marketing; para transit systems; future trends in mass transit. Pre: 3604. (3H,3C).

5640: HIGHWAY TRANSPORTATION SAFETY
Identification of highway safety problems and development of solutions. User characteristics and expectations, road audits, roadside hardware systems, safety enhancing treatments, standard traffic control devices, real-time information and control systems, work zone and railroad crossing treatments, older driver design concepts, traffic calming, designs for pedestrians and bikes, delineation and lighting principles, and advanced 3D/4D design concepts. Group and individual analyses of problems. (3H,3C).

5644 (UAP 5644): TRANSPORTATION SYSTEMS PLANNING
Advanced consideration of problems dealing with transportation systems as they affect the socio-economic development of cities, regions, and nations; the travel behavior of a populace; the location of economic activity; the use of land; and the allocation of resources. Pre: 3604. (3H,3C).

5654: ADVANCED GEOMETRIC DESIGN & HIGHWAY SAFETY
Design and proportioning of geometric features of urban and rural roadways such as intersections, interchanges, ramp and speed change lanes, vertical and horizontal alignments, climbing auxiliary lanes, pavement cross-section templets, and safety devices. Pre: 4654. (3H,3C).

5664 (UAP 5664): INTERCITY TRANSPORTATION
Intercity transportation, including trucking, railroads, and aviation industries, as a vital part of the economy. Operation and logistic rules that govern the flow of shipments and dictate costs and freight rates under various regulatory policies and market environments. Pre: 3604. (3H,3C).

5674: ADVANCED PAVEMENT DESIGN
Methods used to characterize, stabilize, and specify pavement materials. Methods for rigid and flexible highway and airport pavement design and analysis. Load equivalence factor and specific design considerations related to environment and traffic characteristics. Pavement overlay design. Software for pavement design and analysis using various models. Pre: 3684, 4664. (3H,3C).

5684: REHABILITATION OF TRANSPORTATION STRUCTURES
Identification of maintenance and rehabilitation needs for transportation structures such as bridges and pavements. Cost effective maintenance and rehabilitation methods. Consideration of bridge and pavement management systems. (3H,3C).

5704: ENVIRONMENTAL CHEMISTRY LABORATORY
Laboratory course in support of 5104, Environmental Chemistry, allowing students to perform experiments related to natural environmental processes, including biological oxygen consumption, complexation, and carbonate equilibria. Consideration of laboratory procedures used to investigate and assess environmentally related materials and their contaminants. Co: 5104. (3L,1C).

5714: SURFACE WATER QUALITY MODELING
Use, analysis, and development of water quality models for lakes, rivers, and estuaries. Emphasis on model calibration, verification, and post-audit analysis. Lab portion will develop and apply a eutrophication model for an estuary using existing data. (2H,2L,3C).

5724: ENVIRONMENTAL MONITORING & SAMPLING
Experimental design and sampling techniques for environmental analysis, including environmental monitoring techniques and statistical principles for planning monitoring locations and frequencies at environmental sites such as landfills, rivers, lakes, and the atmosphere. Development of monitoring strategy; examination of sampling techniques for various sample types. Pre: STAT 2004. Co: 5104. (3H,3C).

5734: URBAN HYDROLOGY & STORMWATER MANAGEMENT
Development of methods and numerical models for computing surface runoff from developing watersheds; hydraulics of combined sewer systems; urban non-point source pollutant load calculations and best-management practices; control strategies for regional stormwater management; detention basin design for control of urban floods and non-point source pollutants. X-grade allowed. Pre: 4304. (3H,3C).

5744: TOPICS IN STRUCTURAL STEEL DESIGN
Calculation of stresses in steel members. Overall-local buckling interaction. Design of singly symmetrical and unsymmetrical columns and topics on flexural design, design of plate girders, bracing design, and design of framing connections. Pre: 3434. (3H,3C).

5754: PAVEMENT & BRIDGE INFRASTRUCTURE MANAGEMENT SYSTEMS
Management concepts used in civil infrastructure; planning, design, construction, maintenance, and rehabilitation of bridge and highway systems. Prioritization, optimization, and decision-making techniques. Life-cycle-cost prediction. Pre: 3684, 4664. (3H,3C).

5764: ASPHALT TECHNOLOGY
Origin, types and properties of bituminous materials and their use in civil engineering. Asphalt rheology. Theory behind technological processes and procedures for hot-mix asphalt including design philosophy, performance, and durability. Modern construction with bituminous materials; special mixtures, recycling, and additives. Pre: 4614. (2H,3L,3C).

5774: HAZARDOUS WASTE MANAGEMENT
Review of regulatory framework governing hazardous waste management. Characteristics of hazardous wastes. Fundamental physical, chemical, and biological principles applied to the design of treatment processes. Risk management. Case studies. Design project. Pre: 3104. Co: 5104. (3H,3C).

5784 (MSE 5784): SPECIAL TOPICS IN PORTLAND CONCRETE
Literature study and laboratory investigations of special physical and chemical durability problems associated with portland cement concrete structures including pavements, bridges, parking structures, and dams. Pre: 4614. (2H,3L,3C).

5794: ENVIRONMENTAL ENGINEERING PRINCIPLES
Examines the basic physical, chemical, and microbiological principles that provide the foundation for environmental engineering. Illustrates how these principles are applied to solve a wide range of environmental problems. Pre: 3104. Co: 5104. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Review and discussion of current literature, research, and consulting activities by student, faculty, and guest speakers. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH & THESIS
Variable credit course.

6014 (ARCH 6014) (BC 6014): PROJECT & COMPANY MANAGEMENT
Study of the management of a construction project and a construction company. Project management includes finances, cash flows, cost control, project organization, and project planning. Company management includes company organization incorporation structure, procedures, finance, insurances, accounting, and operation. Case studies are emphasized. (3H,3C).

6104: ADVANCED ENVIRONMENTAL CHEMISTRY
Advanced theories and practices in environmental engineering with special emphasis on inorganic aspects of water chemistry; application of water chemistry fundamentals for the description of aquatic systems. Pre: 5104 or CHEM 3616. (2H,2C).

6404: DYNAMICS OF STRUCTURES
Formulation of equations of motion by the finite element method. Solution by mode superposition and direct methods. Earthquake analysis and nonlinear analysis. Application to skeletal and plate structures. Development of computer programs and use of commercial programs. Pre: 5414, ESM 4074. (3H,3C).

6424: ADVANCED PRESTRESSED CONCRETE
Behavior and design of prestressed slabs, bridges, and precast building systems. Continuous prestressing; load-balancing method for slabs; torsion and shear; connections for precast members; partial prestressing. Pre: 4424. (3H,3C).

6434: ADVANCED STEEL DESIGN
Advanced topics of current interest in structural steel design research as given by recent publications and informal reports. In-depth study of selected projects. May be repeated. 12 credits of 5000-level courses in structures or solid mechanics required. Pre: 4434. (3H,3C).

6464 (ESM 6464): ADVANCED EARTHQUAKE ENGINEERING
Characteristics of earthquake motions; seismic risk analysis; design inputs – response spectra and spectral density function; multi-degree-of-freedom classically and non-classically damped linear and nonlinear structures; spatial variation of ground motion and multiple support excitations of large structures; structure-soil interaction analysis; floor response spectra, nonstructural components, and secondary systems; passive and active structural control – base isolation, energy dissipation devices, active and semi-active devices; elevators and rotating machines. Pre: 5464, ESM 5464 or ESM 5304. (3H,3C).

6504: THEORETICAL SOIL MECHANICS
Constitutive Laws for Soils, nonlinear elastic and plastic models. Consolidation, layered systems, sand drains, approximate three-dimensional theories, and Biot's poro-elastic formulation. Plastic equilibrium in soils Sokolovski's method of characteristics, applications to earth pressure, bearing capacity, and slope stability problems. Analysis of machine foundation problems, elastic waves through soils, dynamic properties of soils. Pre: 5514. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (CEE)

The following 4000-level courses have been approved for graduate credit:

4014 (BC 4024): ESTIMATING, PRODUCTION, AND COST ENGINEERING
Interpretation of plans and specifications, preparation of construction estimates, and cost control. Methods analysis, resource requirements, and resource costs in building systems, including system components, and in large-scale civil engineering works such as highways, bridges, and hydraulic structures. Pre: 3014. (3H,3C).

4024: CONSTRUCTION CONTROL TECHNIQUES
Techniques used to plan, schedule, and control the Construction Process. Emphasizes manual and computer-based approaches. Focuses on an analytical approach towards the construction process whereby good technical methodologies and solutions are converted to reality through construction practices. Pre: 4014. (3H,3C).

4034 (BC 4034): CONTRACT SPECIFICATIONS
The course work provides an overview of the basics of the Project Manual (a collection of the contractual provisions of a nontechnical nature together with the technical provisions). Techniques of specification writing, interpretation of intent, and complimentary documents are studied. Senior standing required. (3H,3C).

4054 (BC 4054): CONSTRUCTION LAW: ROLES AND RESPONSIBILITIES
A study of current legal problems associated with the construction industry. Traditional roles of the various industry participants are examined from a management's perspective. The entire building process, from pre-design to owner use, is covered with emphasis on claims avoidance. Pre: 3014, or 4434 or ARCH 4044. (3H,3C).

4074: CONSTRUCTION ENGINEERING: MEANS AND METHODS
Construction means, methods, and equipment used to transform a particular design concept into a completed usable structure or facility. Selection and optimization of individual units as well as the systems needed to produce the required work to the required quality on time and on budget. Pre: 3014. (3H,3C).

4084: GREEN ENGINEERING: ANALYSIS OF CONSTRUCTED FACILITIES
Green engineering analysis and design applied to all phases of construction; design, construction, operation, retrofit and decommissioning. Decision making techniques. Life cycle analysis. Pre: 3014. (3H,3C).

4104: WATER AND WASTEWATER TREATMENT DESIGN
Design of municipal water and wastewater treatment plants. Emphasis on characterization of water and wastewater and physical, chemical, and biological treatment methods. Sludge processing advanced treatment methods and treatment plant hydraulics are considered. Pre: 3104, 3304. (3H,3C).

4114: FUNDAMENTALS OF PUBLIC HEALTH ENGINEERING
Public health engineering principles for protection against biological and chemical health hazards. Emphasis on major communicable diseases that plague mankind, organisms that cause them, routes of transmission, and engineering methods of control. Appropriate control methods for rural areas and developing countries. Pre: 3104. (3H,3C).

4124: ENVIRONMENTAL INFORMATION MANAGEMENT
Computer applications in environmental engineering. Integration of environmental design, data management, and problem solving skills with computer tools and techniques. Optimization, data management, graphical and statistical data analysis, and geographical information systems. Pre: 3104. (3H,3C).

4144: AIR RESOURCES ENGR
Source assessment utilizing instrumentation and EPA reference methods. Calculation of source compliance status. Air quality PC modeling to acquire construction and operating permits. Design of monitoring networks as required by EPA and industry. Design calculations for determining the applicability of control equipment alternatives with emphasis on meeting emission standards in a cost effective manner. Pre: 3314. (3H,3C).

4174: SOLID AND HAZARDOUS WASTE MANAGEMENT
Introduction to the problems, regulations and techniques associated with the management of solid and hazardous waste. Composition, volume and characterization of the wastes. Design of collection and disposal systems, including landfills, solidification/stabilization and incineration. Pre: 3104. (3H,3C).

4184: ENVIRONMENTAL DESIGN OF WATER SUPPLY AND SEWERAGE SYSTEMS
Introduction to the hydraulics of water distribution systems, sewerage plant collection systems, pumping stations, and treatment

plants. Integrates effects of water and wastewater quality with hydraulic design. Pre: 3104, 3314. (3H,3C).

4274: LAND DEVELOP DESIGN
Overview of land development projects including factors, construction practices, legal issues, and government policies. Design project includes feasibility study, engineering evaluation of site, and layout design of lots, buildings, streets, sewers, etc. Interactive graphics and automated drafting. Senior standing in Civil Engineering required. (2H,3L,3C).

4304: HYDROLOGY
Precipitation, evaporation, consumptive use, infiltration; stream flow, flood routing; statistical analysis of hydrologic data, flood and drought forecasting, risk analysis, subsurface flow, well hydraulics, introduction to urban drainage design. Pre: CEE 3314. (3H,3C).

4314: GROUNDWATER RESOURCES
Fundamentals of groundwater hydrology; flow through porous media, both saturated and unsaturated; flow to wells in both confined and unconfined aquifers; analysis of recharge basin and field drains; seepage from canals into the groundwater; contaminants in groundwater. Pre: 3314. (3H,3C).

4324: OPEN CHANNEL FLOW
Mechanics of open channel flow, including uniform flow, gradually varied flow, channel transitions, unsteady flow and fundamentals of sediment transport phenomena. Pre: 3314. (3H,3C).

4334: HYDRAULIC STRUCTURES
Hydraulic analysis and design of engineering structures for water control, including reservoirs, dams, spillways, spilling basins, drainage structures, and hydraulic models. Pre: 3314. (3H,3C).

4344: WATER RESOURCES PLANNING
Analysis of the water resources planning process and the institutional framework for water resources management. Criteria and procedures for evaluating management alternatives are examined, with emphasis on assessment of economic and environmental impacts. Senior standing required. (3H,3C).

4354: ENVIRONMENTAL HYDROLOGY
Overall view of pollutants movements in surface waters, with emphasis on the role of various hydrologic processes. Natural and constructed wetlands and their use for water quality control. Fundamentals of river hydraulics. Design of flood control channels. Environmental consequences of various types of hydraulic systems. Mitigation, enhancement, and restoration techniques. Pre: 3104, 3314. (3H,3C).

4364 (AOE 4064): FLUID FLOWS IN NATURE
Course designed to build upon and broaden a basic traditional engineering knowledge of fluid flows into areas concerning a variety of natural occurrences and phenomena that involve fluid motions in important ways. Drag sessile systems and motile animals, gliding and soaring, flying and swimming, internal flows in organisms, low Reynolds number flows, fluid-fluid interfaces, unsteady flows in nature and wind engineering. Pre: 3304 or AOE 3104 or ESM 3024 or ME 3404. (3H,3C).

4404: COMPUTER ANALYSIS OF STRUCTURES I
Formulation of matrix displacement method in a form suitable for program development. Application to trusses and frames. Incorporation of special features such as symmetry, internal releases, support settlements, and influence lines. Initiation of program development. Use of existing programs on the personal computer. Pre: 3404. (3H,3C).

4424: DESIGN OF PRESTRESSED CONCRETE STRUCTURES
Principle of prestressing applied to concrete beams, slabs, and frames; design of individual elements and structural systems of prestressed concrete; precast construction and connection design. Pre: 3424. (3H,3C).

4434: DESIGN OF STEEL STRUCTURES II
Plastic design of steel beams, columns, and connections; elastic design of tension, compression, and flexural members using Load and Resistance Factor Design specifications. Pre: 3434. (2H,3L,3C).

4444 (AOE 4054) (ESM 4444): STABILITY OF STRUCTURES
Introduction to the methods of static structural stability analysis and their applications. Buckling of columns and frames. Energy method and approximate solutions. Elastic and inelastic behavior. Torsional and lateral buckling. Use of stability as a structural design criterion. Pre: 3404, AOE 3024. (3H,3C).

4454: MASONRY STRUCTURAL DESIGN
Masonry materials, material testing, material specifications. Structural behavior and design of masonry elements (walls, beams, and columns) and systems used in structures. Construction techniques and the details of masonry construction. Building codes relating to analysis and design of masonry structures. Pre: 3684, 3424. (3H,3C).

4474: REINFORCED CONCRETE STRUCTURES II
Behavior and design of continuous reinforced concrete structures subjected to gravity and lateral loads. application of computer programs to frame analysis and design of members. Biaxial bending of columns, two-way floor systems, retaining walls, and footing design problems. Comprehensive design project concludes the course. Pre: 3424. (3H,3C).

4494: COMPUTER METHODS IN STRUCTURAL DESIGN
Design of structural members in steel, concrete, and wood using computers. Design of structural systems. Development of programs for the solution of structural design problems. Senior standing in civil engineering required. (3H,3C).

4504: FINITE ELEMENT METHOD IN CIVIL ENGINEERING
Introduction to finite element method as applied to civil engineering problems. One-dimensional stress-deformation, fluid flow, and consolidation problems. Analysis of beam bending and beam-column and torsion problems. Two-dimensional plane strain, plane stress, and axisymmetric analysis of stress-deformation and fluid flow problems. Use of computer codes. Introduction to nonlinear techniques. Pre: 3404 or ESM 3054. (3H,3C).

4514: METHODS IN GEOTECHNICAL ENGINEERING
Principles and techniques for characterizing earth materials (soil and rock) for civil engineering projects in various regional environments; with emphasis on the interdisciplinary approach to field exploration and site description through soil mechanics theory, geologic correlations, geophysical methods, in site testing and sampling. Pre: 3514. (3H,3C).

4534: EARTH PRESSURES AND FOUNDATION STRUCTURES
Earth pressure theories and their applications to the design of retaining structures, anchors, and excavation bracing. Bearing capacity and settlement of shallow foundations. Types and capacity of deep foundations. Pre: 3514. (3H,3C).

4544: APPLIED GEOTECHNICAL ENGINEERING ANALYSIS
Applied geotechnical engineering Analysis Methods for selecting appropriate analysis procedures and for effectively using analytical tools in geotechnical engineering: procedures for selecting data, for performing efficient parametric studies, and for testing the correctness of results. Strategies for development and selection of computer programs for analysis of geotechnical engineering problems. Pre: 4534. (3H,3C).

4554: NATURAL DISASTER MITIGATION AND RECOVERY
Causes, mechanics, classifications, and forces associated with tornadoes, hurricanes, floods, earthquakes, and landslides. Resistance evaluation for existing ground, facilities and structures. Hazard-resistant design of new facilities. Risk and reliability assessment and decision analysis. Strategies and designs for natural disaster risk mitigation. Emergency response for protection of life and property and restoration of lifelines. Includes an interdisciplinary team project. Pre: 014, 3304, 3404, 3514, 3684. (3H,3C).

4594 (CSES 4594): SOIL AND GROUNDWATER POLLUTION
Application of mathematical models for chemical movement in soils and groundwater to evaluate soil and groundwater pollutant behavior; discussion of pollution remediation technologies; design of subsurface monitoring networks; case studies in soil and groundwater pollution; applications to landfills, waste spills, septic drainfields, pesticide/fertilizer leaching, and other problems of environmental concern. Pre: (MATH 2224 or MATH 2514), (4314 or GEOL 4114). (3H,3C).

4604: TRAFFIC ENGINEERING
Study of traffic and parking characteristics; application of traffic control devices; principles and techniques used to improve the efficiency and safety of traffic flow systems. Pre: CEE 3604. (3H,3C).

4614: ADVANCED CIVIL ENGINEERING MATERIALS
Fundamental properties and the physical and chemical aspects of the structure of Portland cement concretes. Emphasis placed on environmental performance aspects and the application of studies of concrete performance under various exposure conditions. Pre: 3684. (3H,3C).

4624: PLANNING TRANSPORTATION FACILITIES
Transportation planning process; urban and regional studies, surveys, data analysis, model development and testing; transportation management, administration, finance, system evaluation, implementation, and integration. Pre: 3604. (3H,3C).

4634: INFRASTRUCTURE CONDITION ASSESSMENT
Infrastructure components and assessment needs; physical and chemical properties of construction materials; deterioration causes, assessment methods, nondestructive evaluation techniques, infrastructure management systems, performance models, service-life-cycle estimates. Pre: 3684. (3H,3C).

4654: GEOMETRIC DESIGN OF HIGHWAYS
Functional design of highways; curves, intersections, interchanges, drainage, and other features involved in highway safety and traffic efficiency. Pre: 3604. (3H,3C).

4664: PAVEMENT DESIGN
Principles underlying methods for the design of various elements of flexible and rigid pavements for highways and airports; climate and traffic effects; pavement management systems. Pre: 3604. (3H,3C).

4674: AIRPORT PLANNING AND DESIGN
Airport planning and economic justification, site selection, configuration, development and design of terminal areas, demand forecasting, access, traffic control. Pre: 3604. (3H,3C).

4814: ANALYSIS OF INFRASTRUCTURE SYSTEMS
Analysis of the role of infrastructure in society. Mathematical modeling of infrastructure systems for predicting socioeconomic and environmental impacts of development. Systems dynamics methodology and applications to regional and national systems, including national defense, water resource systems, transportation systems, and infrastructure maintenance. Pre: 3804. (3H,3C).

COMMUNICATION

Rachel L. Holloway, Department Head
John C. Tedesco, Director of Graduate Studies

W. Thomas Rice Professor: R.E. Denton, Jr.
Professors: S.R.Prince; S.G. Riley; J.B. Weaver
Associate Professors: R.L. Holloway; W.W. Hopkins; E.H. Sewell, Jr.; J.C. Tedesco; B.M. Waggenspack
Assistant Professors: M.M. Preston; S.L. Sargent; A.Q. Stokes; A.P. William
Affiliated Faculty: E.C. Fine (Center for Interdisciplinary Studies); M.W. Fishwick (Center for Interdisciplinary Studies); A.L. Kavanaugh (Center for Human-Computer Interaction); J. Ryan (Sociology)

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The Master of Arts Degree in Communication at Virginia Tech is a 36-hour degree program that offers students advanced study in public and mass communication research from a variety of theoretical and methodological perspectives. Two areas of emphasis in communication research – media studies and public advocacy – are offered, each influenced by the latest trends in communication scholarship and communication technology. Media studies includes such sub-areas as mass media effects, mediated technology and society, and media criticism; public advocacy explores public relations, campaign communication, and political communication research. The M.A. in Communication will prepare graduates to pursue research positions in communication industries, advanced teaching careers, advanced careers as communication professionals, and doctoral studies in Communication.

DEGREE REQUIREMENTS

Thirty-six credits are required for the M.A. in Communication. Students in both the thesis and non-thesis tracks are required to take COMM 5014, COMM 5024, and 9 credits of cognate courses, comprising 15 of the 36 total hours. The remaining 21 hours are completed as follows: Students in the thesis track are required to take15 credits of major courses and successfully complete a thesis for which 6 credits are earned. Successful completion of a thesis includes receiving a passing grade on an oral defense of the thesis. Students in the non-thesis track are required to take 18 credits in major courses and successfully complete 3 credits in COMM 5904. Non-thesis students must also receive a passing grade on a written examination on the student's course work and to orally present the results of a Project & Report or an Internship experience.

GRADUATE COURSES (COMM)

5014: COMMUNICATION THEORY
A broad survey of contemporary theories and processes of interpersonal, public, and mediated human communication. Pre: Graduate standing. Co: 5024. (3H,3C).

5024: COMMUNICATION RESEARCH METHODS
Advanced treatment of a variety of research related issues germane to the discipline of communication studies. Topics include the scientific method; elements of the research process; experimental, quasi-experimental, and non-experimental research designs; and legal and ethical issues in research. Pre: Graduate standing. Co: 5014. (3H,3C).

5114: INTERPERSONAL COMMUNICATION
Study of theory and research identifying communication variables involved in relationship development, maintenance, and dissolution; nonverbal aspects of interpersonal relationships; personality and interpersonal relationships. Pre: Graduate standing. (3H,3C).

5124: ORGANIZATIONAL COMMUNICATION
An examination of theoretical issues and current research in organizational communication. Emphasis on the role of communication in organizational structure, power, and decision making, worker satisfaction and socialization, organizational culture, and organizational change. (3H,3C).

5214: NONFICTION WRITING FOR THE MASS MEDIA
An advanced writing course designed to increase knowledge and skill in the writing of journalistic nonfiction. Students will read the work of the best mass media writers and will write their own stories, some of which will be submitted for publication. The course will address both service journalism and literary journalism. (3H,3C).

5224: PUBLICATION DESIGN FOR ELECTRONIC MEDIA
Principles of design and publication in various electronic media including desktop publishing, Web publishing, interactive media, and video-based media. (3H,3C).

5314: ADVANCED COMMUNICATION LAW
Examination of the delicate balance between freedom and control of the institutions of mass media; examination of the concepts of individual freedom of expression; examination of historical and philosophical bases of freedom of expression; introduction to legal research and writing for communication law. (3H,3C).

5414: MASS MEDIA EFFECTS
Explores major areas of theoretical study of mass communication and the social impact of mediated messages. (3H,3C).

5424: MEDIA CRITICISM
Different methods, explanations, and perspectives to critique mass media messages, focusing on television and advertising. Special attention to ideological issues and the relation of media messages to social power. Pre: Graduate standing. (3H,3C).

5434: FILM THEORY & CRITICISM
Examines the theoretical approaches toward critical analysis of film; focuses on characteristics, strengths, and limitations of realist, auteurist, historicist, structural/semiotic, psychoanalytic, ideological, and cognitive models of film theory. Application of theoretical models to contemporary film. (3H,3C).

5444: NEW COMMUNICATION TECHNOLOGY
Explores the social implications surrounding the design, production, use, and evaluation of communication technology. Emphasis is on how communication functions in the creation and use of technology, and how communication and other social factors may be influenced by technology. (3H,3C).

5514: PUBLIC RELATIONS THEORY & PRACTICE
Examines fundamental theory and research in public relations, including systems theory, symbolic interactionism, organizational theory, cognitive processing and persuasion; models of public relations practice; ethics. (3H,3C).

5544: MASS MEDIA & U.S. POLITICS
This course explores the role of the mass media in contemporary American politics by examining the development of the media as sources of social and political influence in twentieth century America; how the mass media cover electoral and issue campaigns; the impact such coverage has had on candidates and their campaign strategies and on the behaviors of voters. Various perspectives on what the future may hold for American politics. (3H,3C).

5564: PERSUASION & SOCIAL INFLUENCE
Examines fundamental theory and research on persuasion and social influence. Emphasis on a broad-based perspective, encompassing the full scope of persuasion as it is found in everyday life. This course examines persuasion in a variety of contexts and settings, including advertising, small groups, and face-to-face encounters. (3H,3C).

5614: RHETORICAL THEORY & CRITICISM
Survey of theories of rhetoric. Focuses on the multiple conceptions of rhetoric through history and the critical methods emerging from rhetorical theory. (3H,3C).

5814: SEMINAR IN COMMUNICATION STUDIES
Topical seminar examining various aspects of contemporary theory and research in interpersonal, public, and mediated human communication. Repeatable with different content for a maximum of six hours credit. (3H,3C).

5894: FINAL EXAMINATION
For non-thesis candidates who are required to register for their final examination and have completed their program of study. Not to be included in minimum 36 hours required for degree. Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
For students pursuing a non-thesis degree. Projects may involve guided research/scholarship or an internship. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSE (COMM)

The following 4000-level course has been approved for graduate credit:

4044 (IS 4044): INTERNATIONAL COMMUNICATION
Comparative perspectives on global communication systems; problems with the flow of information; roles of international organizations; mass communication and national development; implications for conflict resolution; selected case studies. Senior standing required. (3H,3C).

COMPUTER SCIENCE

Dennis G. Kafura, Head

Professors: O. Balci; R.W. Ehrich; E.A. Fox; L.S. Heath; D.G. Kafura; F. Quek; L.T. Watson
Associate Professors: J.D. Arthur; S. Bohner; A. Bouguettaya; I.R. Chen; S.H. Edwards; C.J. Egyhazy; W.R. Frakes; T.M. Murali; N. Ramakrishnan; C.J. Ribbens; A. Sandu; E.E. Santos; C.A. Shaffer; D. Tatar
Assistant Professors: G. Back; D. Bowman; V. Choi; D. Gracanin; C.T. Lu; D.S. McCrickard; C.L. North; A. Onufriev; M.A. Perez-Quinones; S. Varadarajan; L. Zhang
Instructors: N.D. Barnette; W. McQuain

E-mail: gradprog@cs.vt.edu
Web: www.cs.vt.edu/

The Department of Computer Science offers a graduate program leading to the M.S. and Ph.D. in computer science. Opportunities exist to pursue research with faculty working in the following areas: algorithms, bioinformatics, computer-aided education, digital libraries, grid computing, high performance computing, human-computer interaction, simulation, software engineering, and virtual environments.

Degree Requirements

The M.S. requires a minimum of 30 credits. A candidate may elect to pursue one of two options: the research-oriented thesis option (21 course credits plus thesis) or a course work only option (33 course credits). The requirement of a final examination in the M.S. program can be fulfilled in one of three ways. Coursework-only students must meet the final exam requirement either by writing an individualized Independent Study or by passing the written Ph.D. qualifying examination at the master's level. Thesis students must pass an oral defense of their thesis.

The doctoral program requires a minimum of 90 credits beyond the bachelor's degree. A minimum of 33 of these credits must be course work, and the remainder can be research hours. Among their course work, Ph.D. students take two non-CS courses from an approved list of cognate courses that will supplement their individual research area.

During their first year, Ph.D. students will be working to complete their qualifier process. This requires obtaining a minimum of six points from three areas (each area can yield a maximum of three points): coursework GPA, the qualifier exam (given in February), and research productivity. The qualifier process is designed to get Ph.D. students moving quickly in their research career.

Three further examinations form milestones on the path to the Ph.D. One is the preliminary proposal exam, an oral examination in which a research proposal is presented by the candidate and both the proposal's appropriateness as a Ph.D. topic and the candidate's preparedness to perform the proposed research are evaluated by the candidate's committee. An oral research defense is held after the bulk of the research has been completed to verify that an adequate body of work has been done. Doctoral study concludes with an oral final defense of the dissertation.

Students in the Ph.D. program planning an academic career are given the opportunity to acquire teaching experience at increasing levels of responsibility.

Information Systems

In addition to the computer science program, the department offers, at the Northern Virginia campus only, an information systems program leading to the master of information systems (M.I.S.). All information systems students must complete a minimum of 33 hours. Working with an advisor, each student develops a program that includes: a firm grounding in the theory and design of information systems, supporting course work in computing technology, specific work in systems analysis techniques, and an exposure to organization theory and behavioral science. Each student selects a specialization area within which the student devotes attention to a specialized component of information system theory and design. Written and oral communication skills are stressed in the program.

Computational Facilities

The Department of Computer Science facilities house computers and related equipment that support both instruction and research. These facilities include two Beowulf clusters and over 200 workstations powered by Pentium and similar processors as well as SGI, SUN, and other workstations. Microsoft Windows and UNIX serve as operating systems on departmental computers. All departmental computers are interconnected via a high-speed network as well as connected to the university network and the Internet. There are specially equipped laboratories offering opportunity for work in each of the following areas: human-computer interaction, software engineering and systems design, multimedia development, parallel computation, digital libraries, and virtual environments, including a CAVE. Several of these state-of-the-art laboratories are located in the university's ultra-modern Advanced Communications and Information Technology Center which opened in fall 1999.

Graduate Courses (CS)

5014: RESEARCH METHODS IN COMPUTER SCIENCE
Preparation for research in computer science. Technical communication skills. Design and evaluation of experiments. The research process. (3H,3C).

5024: MODELS & ANALYSIS
Tools and models for the nondeterminism inherent in computer systems. Sets, combinatorics, and probability. Stochastic models of queuing behavior in computer systems modeling. Probabilistic techniques used in reliability characterization of hardware and software systems. Pre: 3204, MATH 2534. (3H,3C).

5034: MODELS OF COMPUTATION
Formal models for computational processes and their meaning. Formal languages, automata, and computability. Semantics of programming languages. Properties of programs. Techniques of abstraction and specification. (3H,3C).

5044: OBJECT-ORIENTED PROGRAMMING WITH JAVA
Object-oriented programming concepts with the Java programming language. The application of design strategies, notations, and patterns related to object-oriented systems. Techniques and libraries for developing applications related to the World Wide Web. Credit will not be given for both 2704 and 5044. Not for Computer Science major or minor credit; not for graduate credit for CSA or INFS programs. Pre: Proficiency in a high-level programming language (e.g., FORTRAN, C, C++, or Java) equivalent to 1044 and prior course work, practical training, or work experience related to developing computer software and systems. (3H,3C).

5045: COMPUTATION FOR THE LIFE SCIENCES
Fundamentals of computer science, including specific programming languages; program design, implementation, and testing; programming language syntax and semantics; abstraction and object-oriented programming; data structures; algorithms and algorithm analysis; software engineering; databases; user interfaces; distributed and parallel computing; and computer networks. Background needed by graduate students pursuing the bioinformatics option in computer science, life sciences, or statistics, but not having a computer science background. Not for CS major or minor credit; not for graduate credit in CSA program. Graduate standing with bioinformatics option or permission of the instructor is required. (3H,3C).

5104: COMPUTABILITY & FORMAL LANGUAGES
Formal theory of computability, the halting problem, models of computation, and Church's thesis, and formal languages. X-grade allowed. Pre: 5034. (3H,3C).

5114: THEORY OF ALGORITHMS
Methods for constructing and analyzing algorithms. Measures of computational complexity, determination of efficient algorithms for a variety of problems such as searching, sorting and pattern matching. Geometric algorithms, mathematical algorithms, and theory of NP-completeness. Pre: 5034. (3H,3C).

5124: ALGORITHMS IN BIOINFORMATICS
Algorithms to solve problems found in biology, especially molecular biology. A variety of current problems in computational molecular biology will be introduced, investigated, analyzed for computational complexity, and solved with efficient algorithms, when feasible. A number of such problems will be shown to be intractable or other evidence of their difficulty will be presented. Prerequisites or graduate standing in CSA required. Pre: 4104 or 5046, PPWS 5314. (3H,3C).

5204: OPERATING SYSTEMS
Issues in the design and functioning of operating systems. Emphasis on synchronization of concurrent activity in both centralized and distributed systems. Deadlock, scheduling, performance analysis, operating system design, and memory systems including distributed file systems. Pre: 3204, 5034. (3H,3C).

5214: MODELING & EVALUATION OF COMPUTER SYSTEMS
An overview of modeling, simulation, and performance evaluation of computer systems, i.e., operating systems, database management systems, office automation systems, etc. Fundamentals of modeling, the life cycle of a simulation study, workload characterization, random number and variate generation, procurement, measurement principles, software and hardware monitors, capacity planning, system and program tuning, and analytic modeling. Duplication of subject matter of 4214 and 4224. Maximum of 6 hours credit may be obtained from 4214, 4224, 5214. Pre: 5024, STAT 4705 or STAT 4714, STAT 4105. (3H,3C).

5224: SYSTEMS SIMULATION
An in-depth treatment of systems simulation and simulation programming languages (SPLs). Input data modeling, simulation model formulation and representation, conceptual frameworks for modeling, a comparative study of some SPLs, principles of SPL design, statistical analysis of simulation output data, credibility assessment stages, model development environments. Pre: 5204, STAT 4105 or STAT 4714, STAT 4705. (3H,3C).

5244: INTERNET SOFTWARE
Languages and technologies needed to develop software for the Internet and World Wide Web (WWW). Commonly used protocols and standards. Advanced technologies for distributed computation, component-based systems, interoperability with legacy systems, and database access. Principles and technologies for agent-based systems and electronic commerce. Credit will not be given for 4244 and 5244. Pre: 5044 (3H,3C).

5304: TRANSLATOR DESIGN & CONSTRUCTION
Fundamental theory of parsing and translation and practical applications of this theory. Lexical analysis, parsing techniques based on top-down (LL, Recursive Descent) and bottom-up (LR, Precedence), code generation, code optimization techniques, and runtime systems. Pre: 4114 or 5034. (3H,3C).

5314: PROGRAMMING LANGUAGES
In-depth investigation of the principles of programming systems, not necessarily restricted to programming languages, both from the point of view of the user implementor. Algorithms of implementation, syntax and semantic specification systems, block structures and scope, data abstraction and aggregates, exception handling, concurrency, and applicative/functional/data-flow languages. Pre: 4114. (3H,3C).

5465-5466 (MATH 5465-5466): NUMERICAL ANALYSIS
A survey of the construction, analysis, and implementation of numerical algorithms in linear algebra, nonlinear equations and optimization, approximation by polynomials, quadrature, and ordinary differential equations. (3H,3C).

5474 (MATH 5474): FINITE DIFFERENCE METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Finite difference methods for initial and boundary value problems for partial differential equations. Consistency, stability, convergence, dispersion, and dissipation. Methods for linear and nonlinear elliptic and parabolic equations, first- and second-order hyperbolic equations, and nonlinear conservation laws. Pre: 3414. (3H,3C).

5484 (MATH 5484): FINITE ELEMENT METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Weak formulations of boundary-value problems for elliptic partial differential equations. Finite element spaces. Approximation theory for finite element spaces. Error estimates. Effects of numerical integration and curved boundaries. Nonconforming methods. Concrete examples of the application of the finite element method. Efficient implementation strategies. Time dependent problems. Pre: 3414. (3H,3C).

5485,5486 (MATH 5485, 5486): NUMERICAL ANALYSIS & SOFTWARE
Presentation and analysis of numerical methods for solving common mathematical and physical problems. Methods of solving large sparse linear systems of equations, algebraic eigenvalue problems, and linear least squares problems. Numerical algorithms for solving constrained and unconstrained optimization problems. Numerical solutions of nonlinear algebraic systems. Convergence, error analysis. Hardware and software influences. Efficiency, accuracy, and reliability of software. Robust computer codes. X-grade allowed. Pre: MATH 4445, MATH 4446. (3H,3C).

5504 (ECE 5504): COMPUTER ARCHITECTURE
Advanced computer architectures, focusing on multiprocessor systems and the principles of their design. Parallel computer models, programming and interconnection network properties, principles of scaleable designs. Case studies and example applications of pipeline processors, interconnection networks, SIMD and MIMD processors. Pre: 4504. (3H,3C).

5515-5516 (ECPE 5515-5516): COMPUTER & NETWORK ARCHITECTURES
5515: Advanced computer architectures, focusing on multiprocessor systems and the principles of their design. Parallel computer models, program and network properties, principles of scalable designs. Case studies and example applications of pipeline processors, interconnection networks, SIMD and MIMD processors. 5516: Local area networks, wide area networks, and internets. Protocols and the ISO Open Systems Interconnect reference model. Design, analysis, and performance evaluation. Emphasis on data link, network, and transport protocols. Pre: ECE 4504, CS 4504. (3H,3C).

5565-5566 (ECE 5565-5566): NETWORK ARCHITECTURE & PROTOCOLS
5565: Principles and concepts of networking and protocols, with emphasis on data link, network, and transport protocols. Contemporary and emerging networks and protocols to illustrate concepts and to provide insight into practical networks including the Internet. Quantitative and qualitative comparisons of network architectures and protocols. 5566: Performance evaluation, design, and management of networks. Use of queuing and other analytical methods, simulation, and experimental methods to evaluate and design networks and protocols. Network management architectures and protocols. Graduate standing in EE, ECE, CS, or IT required. Pre: STAT 4714 for 5565; 5565 for 5566. (3H,3C).

5604: INFORMATION STORAGE & RETRIEVAL
Analyzing, indexing, representing, storing, searching, retrieving, processing and presenting information and documents using fully automatic systems. The information may be in the form of text, hypertext, multimedia, or hypermedia. The systems are based on various models, e.g., Boolean logic, fuzzy logic, probability theory, etc., and they are implemented using inverted files, relational thesauri, special hardware, and other approaches. Evaluation of the systems' efficiency and effectiveness. Graduate standing required. (3H,3C).

5614: DATABASE MANAGEMENT SYSTEMS
Emphasizes concepts, data models, mechanisms, and language aspects concerned with definition, organization, and manipulation of data at a logical level. Concentrates on relational model, plus some semantic, logic-based, object-oriented, and knowledge-based modeling. Functional dependency and normalization of relations. Relational algebra, relational calculus, mapping languages, graphical languages. Pre: 4004. (3H,3C).

5634: DATA MANAGEMENT IN BIOINFORMATICS
Data models, query languages, and data management systems for bioinformatics applications. Logical data organization, functional dependencies, design of schemas, querying, manipulation, information integration, and data mining. Specialized data structures, interchange formats, and designs for applications such as sequencing and microarray analysis. Partially duplicates 5614. Prerequisite or graduate standing in CSA required. Pre: 5046. (3H,3C).

5704: SOFTWARE ENGINEERING
Study of the principles and tools applicable to the methodical construction and controlled evolution of complex software systems. Tools for all phases of the life cycle are presented; particular attention focuses on the design, testing, and maintenance phases. Attention to measurement models of the software process and product which allow quantitative assessment of cost, reliability, and complexity of software systems. Pre: 5034. (3H,3C).

5714 (ISE 5714): USABILITY ENGINEERING
Design and evaluation of effective user interfaces, beginning with principles for designing the product. Development process for user interaction separate from interactive software development. Development process includes iterative life cycle management, systems analysis, design, usability specifications, design representation techniques, prototyping, formative user-based evaluation. Integrative and cross-disciplinary approach with main emphasis on usability methods and the user interaction development process. (3H,3C).

5724: MODELS AND THEORIES OF HUMAN-COMPUTER INTERACTION
Survey of models and theories of users and their use of computer equipment; conditions of application for various approaches. Task analysis, task modeling, representations and notations. (3H,3C).

5734: COMPUTER-SUPPORTED COOPERATIVE WORK
Review and critique of state-of-the-art computing systems supporting cooperative work. Introduction to toolkits, software architectures and implementation issues relevant to development of systems for cooperative work. Analysis of group interactions and concerns in collaborative activities such as writing, design, meetings, communication, and decision-making. (3H,3C).

5744: SOFTWARE DESIGN & QUALITY
This course focuses on critical aspects of the software lifecycle that have significant influence on the overall quality of the software system including techniques and approaches to software design, quantitative measurement and assessment of the system during implementation, testing, and maintenance, and the role of verification and validation in assuring software quality. Pre: 5704. (3H,3C)

5754: VIRTUAL ENVIRONMENTS
Introduction to the theory and practice of three-dimensional virtual environments (VEs). 3D input and output devices, applications of VEs, 3D user interfaces and human-computer interaction, 3D graphics techniques for VEs, 3D modeling and level of detail, evaluation of VEs, VE software systems and standards, collaborative and distributed VEs. Includes hands-on experience with VE hardware and software. (3H,3C).

5764: INFORMATION VISUALIZATION
Examine computer-based strategies for interactive visual presentation of information that enable people to explore, discover, and learn from vast quantities of data. Learn to analyze, design, develop, and evaluate new visualizations and tools. Discuss design principles, interaction strategies, information types, and experimental results. Research-oriented course surveys current literature, and group projects contribute to the state of the art. Pre: 2604. (3H,3C).

5774: USER INTERFACE SOFTWARE
Survey of software architectures to build user interfaces, particularly focused on graphical user interfaces. Includes the design and implementation of user interfaces, the use of object-oriented application frameworks, software architecture for command undo, document management, layout managers, customized components, and separation of concerns in user interface software architectures. Discussion of research and advanced topics in User Interface Software. Pre: 2704. (3H,3C).

5804: INTRO ARTIFICIAL INTELLIGENCE
A graduate-level overview of the areas of search, knowledge presentation, logic and deduction, learning, planning, and artificial intelligence applications. Pre: 2604. (3H,3C).

5814: DIGITAL PICTURE PROCESSING
Representation and processing of greytone images. Construction and simulation of grey scales, digitization, thresholding, local neighborhood operations, template matching and filtering, enhancement and restoration, segmentation, connected components, matching, morphology. Pre: 1704, MATH 1114. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C)

5904: PROJECT & REPORT
Variable credit course.

5944: GRADUATE SEMINAR
Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH & THESIS
Variable credit course.

6104: ADVANCED TOPICS IN THEORY OF COMPUTATION
This course treats a specific, advanced topic of current research interest in the area of theory of computation. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5104 or 5114. (3H,3C).

6204: ADVANCED TOPICS IN SYSTEMS
This course treats a specific advanced topic of current research interest in the area of systems. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5204 or 5214. (3H,3C).

6304: ADVANCED TOPICS IN LANGUAGES & TRANSLATION
This course treats a specific advanced topic of current research interest in the area of languages and translation. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5304 or 5314. (3H,3C).

6404: ADVANCED TOPICS IN MATHEMATICAL SOFTWARE
This course treats a specific advanced topic of current research interest in the area of mathematical software. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5485. (3H,3C).

6504: ADVANCED TOPICS IN COMPUTER ARCHITECTURE
This course treats a specific advanced topic of current research interest in the area of architecture. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5515 or 5516. (3H,3C).

6604: ADVANCED TOPICS IN DATA & INFORMATION
This course treats a specific advanced topic of current research interest in the area of data and information. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5604 or 5614. (3H,3C).

6704: ADVANCED TOPICS IN SOFTWARE ENGINEERING
This course treats a specific advanced topic of current research interest in the area of software engineering. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5704 or 5714. (3H,3C).

6724: ADVANCED TOPICS IN HUMAN-COMPUTER INTERACTION
Addresses a specific advanced topic of current research interest in the area of human-computer interaction (HCI). Research monographs and papers from the current literature used as a source of material too new to be in a textbook. Student participation in a seminar-style format. Each offering of this course will address a different subtopic area of HCI. May be repeated for credit. Pre: 5714 or 5714 or 5724 or 5734. (3H,3C).

6804: ADVANCED TOPICS IN INTELLIGENT SYSTEMS
This course treats a specific advanced topic of current research interest in the area of intelligent systems. Papers from the current literature or research monographs are likely to be used instead of a textbook. Student participation in a seminar-style format may be expected. Pre: 5804 or 5814. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (CS)

The following 4000-level courses have been approved for graduate credit:

4004: DATA & INFORMATION STRUCTURES
Formal underpinnings of computer science: logic, sets, relations as they apply to computer science. Principles of data structures, algorithm analysis, file management, databases. Not for CS major or minor credit; not for graduate credit in CSA program. Pre: 1704. (3H,3C).

4014: PRINCIPLES OF COMPUTER ARCHITECTURE & OPERATING SYSTEMS
Principles of computer hardware organization and operating systems. From individual microprocessor hardware components to computer network architectures. Operating system principles, with emphasis on concurrency and synchronization, deadlock, memory, scheduling and performance. Not for CS major or minor credit; not for graduate credit in CSA program. Pre: 4004. (3H,3C).

4104: DATA & ALGORITHM ANALYSIS
This course emphasizes the understanding of data structures and algorithms from an analytical perspective rather than from an implementation standpoint. The concepts developed allow discussion of the efficiency of an algorithm and the comparison of two or more algorithms with respect to space and run-time requirements. Analytical methods are used to describe theoretical bounds as well as practical ones. In general, this course addresses the constraints that affect problem solvability. Pre: 2604, (MATH 3134 or MATH 3124). (3H,3C).

4114: INTRODUCTION TO FORMAL LANGUAGES & AUTOMATA THEORY
The course presents a study of formal languages and the correspondence between language classes and the automata that recognize them. Formal definitions of grammars and acceptors, deterministic and nondeterministic systems, grammar ambiguity, finite state and push-down automata, and normal forms will be discussed. Pre: MATH 3134 or MATH 3034. (3H,3C).

4124: THEORY OF COMPUTATION
Theoretical analysis of the computational process; fundamental concepts such as abstract programs, classes of computational machines and their equivalence, recursive function theory, unsolvable problems, Church's thesis, Kleene's theorem, program equivalence, and generability, acceptability, decidability will be covered. Pre: MATH 3134 or MATH 3034. (3H,3C).

4204: COMPUTER GRAPHICS
Hardware and software techniques for the display of graphical information. 2D and 3D geometry and transformations, clipping and windowing, software systems. Interactive graphics, shading, hidden surface elimination, perspective depth. Modeling and realism. Pre: 2604, (MATH 3134 or MATH 3034). (3H,3C).

4214: SIMULATION & MODELING
Overview of discrete-event digital computer simulation and modeling. Fundamentals of model development, Monte Carlo simulation, the life cycle of a simulation study, input and output data analysis, world views and time control, random number and variate generation, credibility assessment of simulation results, simulation languages, applications of simulation using the General Purpose Simulation System (GPSS). Pre: 1704, STAT 4714. (3H,3C).

4224: PERFORMANCE EVALUATION OF COMPUTER SYSTEMS
Overview of techniques for measuring, improving, and tuning the performance of computer systems. Procurement, workload characterization, measurement principles, the representation of measurement data, software and hardware monitors, capacity planning, bottleneck detection, system and program tuning, simulation and analytic models and their applications, case studies. Pre: 3204, (STAT 4714 or STAT 4105 or STAT 4705). (3H,3C).

4234: PARALLEL & DISTRIBUTED COMPUTATION
Survey of parallel computer architectures, models of parallel computation, and interconnection networks. Parallel algorithm development and analysis. Programming paradigms and languages for parallel computation. Example applications. Performance measurement and evaluation. Pre: 3204. (3H,3C).

4244: INTERNET PROGRAMMING
Key technology underlying the World-Wide Web. Web architecture, including server design, caching, network protocols, and related standards (e.g. http, SHTTP, TCP/IP, MIME). Programming systems (e.g. Java, Active-X, component models). Security and cryptography. Document representations (e.g. XML, HTML, PDF, VRML). Legal and social issues of the Web. Pre: 3204. (3H,3C).

4254: COMPUTER NETWORK ARCHITECTURE & PROGRAMMING
Introduction to computer network architecture, and methods for programming network services and applications (e.g. DNS, Email and MIME, http, SNMP, multimedia). Wired, wireless, and satellite network architectures. OSI protocol model, with an emphasis on upper layers. Congestion control, quality of service, routing. Internet protocol suite (e.g. IP, TCP, ARP, RARP). Server design (e.g. connectionless, concurrent). Network programming abstractions (e.g. XDR, remote procedure calls, sockets, DCOM). Case studies (e.g. TELNET). Pre: 3204. (3H,3C).

4304: COMPILER DESIGN & IMPLEMENTATION
This course includes the theory, the design, and the implementation of a large language translator system. Lexical analysis, syntactic analysis, code generation, and optimization are emphasized. Pre: 3204. (3H,3C).

4504 (ECPE 4504): COMPUTER ORGANIZATION
Information representation and transfer; instructions and data access methods; the control unit and microprogramming; memories; input/output and interrupts; secondary storage; the von Neumann SISD organization; high level language machines; the RISC concept; special purpose processors including operating system, file, text, floating point, communication, etc. Multicomputers; multiprocessors; concurrent processing support; Pipeline machines, processor arrays, database machines; the data flow/data directed approach; computer networks. Pre: 3204, ECE 2504. (3H,3C).

4570 (ECE 4570): WIRELESS NETWORKS & MOBILE SYSTEMS
Multidisciplinary, project-oriented design course that considers aspects of wireless and mobile systems, including wireless networks and link protocols, mobile networking including support for the Internet Protocol suite, mobile middleware, and mobile applications. Students complete multiple experiments and design projects. Pre: 4254 or ECE 4564. (3H,3C).

4604: INTRODUCTION TO DATA BASE MANAGEMENT SYSTEMS
Emphasis on introduction of the basic data base models, corresponding logical and physical data structures, comparisons of models, logical data design, and data base usage. Terminology, historical evolution, relationships, implementation, data base personnel, future trends, applications, performance considerations, data integrity. Senior standing required. Pre: 2604. (3H,3C).

4704: SOFTWARE ENGINEERING
Introduction to the basic principles of software engineering. Issues in the software life cycle. Emphasis on methods for software design and testing. Project management and quality assurance. Significant software project required. Pre: 3204. (2H,3L,3C).

4804: INTRODUCTION TO ARTIFICIAL INTELLIGENCE
Overview of the areas of problem solving, game playing, and computer vision. Search trees and/or graphs, game trees, block world vision, syntactic pattern recognition, object matching, natural language, and robotics. Senior standing required. Pre: 2604. (3H,3C).

CROP & SOIL ENVIRONMENTAL SCIENCES

Steven C. Hodges, Head

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Graduate programs lead to both the M.S. (non-thesis or thesis required) and the Ph.D. The principal objective is to educate students in advanced concepts and research methods in one or more of the various fields of crop, soil, and environmental sciences. This is accomplished through courses and research work that bridge a number of physical and biological sciences. Additional supporting graduate-level courses are available in other departments. Individually planned programs are developed to provide training and experience in environmental resource management and control, biotechnology, seed physiology, crop physiology and ecology, breeding and genetics of agronomic crops, and in the mineralogy, fertility, chemistry, classification, genesis, interpretation, microbiology, and physics of soils.

The department has extensive facilities, instrumentation, and equipment for research and teaching in crop, soil, and environmental sciences. Laboratories are instrumented for physiological research on seeds and whole plants; for microbiological research in water quality, nitrogen fixation, and biological control of plant diseases; for biotechnological investigations and their applications to crops; for modelling research on contaminant movement to groundwater; for soil chemistry and physics research on waste-product utilization; for soil testing and plant analysis research on nutrient cycling and on economic inputs in crop production; for soil genesis research relative to land use and soil taxonomy; and for soil mineralogy and physical chemistry research on soil acidity and on thermodynamics and kinetics of anion and cation reactions in soils.

In addition to departmental laboratories, traditional agronomic equipment, greenhouses, and extensive field facilities at Blacksburg, graduate students have access to Virginia Agricultural Experiment Station research facilities at twelve locations throughout Virginia. Of particular note are field facilities for peanut, small grains, soybean, tobacco, forage-livestock, and turfgrass research. Excellent computer and library facilities are available. Also available on campus

are electron microscopes, an electron probe, mass spectrometers, and additional facilities for biotechnological research.

All graduate students are expected to assist with teaching for at least one semester as part of their plan of study.

GRADUATE COURSES (CSES)

5004: GRADUATE SEMINAR
Lectures and discussions by faculty and graduate students on current research topics in the areas of crop science, soil science and environmental quality. May be repeated. (1H,1C).

5124: TOPICS IN SOIL GENESIS
Topics in soil genesis of regional interest will be addressed. This is a one-week field course that will rotate each year among four regions in the northeastern United States. The regions are Virginia-Maryland, Pennsylvania-West Virginia, New York, and the New England states. This will provide students the opportunity to observe and study soils in the field over a much broader geographic area that otherwise is not possible in a conventional semester course. May be repeated. Pre: 4134. (3L,1C).

5144: ADVANCED PLANT BREEDING & GENETICS
Plant genetics and breeding theory and methodology in the improvement of self-pollinating species; emphasis on genetic diversity, gene transfer and inheritance, gene expression and interaction, and phenotypic selection and stability; goals and criteria in hybridization, breeding systems, and breeding for disease resistance. Pre: 4144. (3H,3C).

5214: SOIL-PLANT RELATIONSHIPS
An interdisciplinary study of soil-plant relationships, with particular emphasis placed on soil chemical and physical properties and their influence on plant growth and development. Topics studied include: root growth, soil compaction, water in the soil-plant-atmosphere continuum, soil acidity, nutrient movement to plant roots, soil aeration, and nitrogen in the soil-plant environment. Pre: 4214. (3H,3C)..

5244 (GEOG 5244): ADVANCED SOIL INTERPRETATIONS USING GIS AND DSS
Use of Geographic Information System (GIS) software to compile digital maps, imagery, and natural resource data and decision support systems (DSS) to produce interpretative maps from digital soil data as part of a research proposal and project. Field trip and class attendance required. Pre: CSES 4124 and either GEOG 4084, BSE 4344, or CEE 4204. (2H, 3L, 3C).

5344: ADVANCED CROP PHYSIOLOGY
Physiological considerations in a crop community: light interception, gas exchange, water stress, flowering, and senescence; key metabolic processes that most directly affect yield: photosynthesis (C3 and C4), photorespiration, and N-metabolism; cropping systems as symbioses. Pre: 4344. (3H,3C).

5444: AGRONOMIC RESEARCH
Principles and problems encountered with planning, establishing, executing, and interpreting experiments. Practical methodology associated with commonly used field, laboratory, greenhouse, and growth chamber experiments. Topics include: proposals, planning experiments, managing experiments, experimental materials, field plot techniques, collecting and recording data, statistical analyses, coping with errors, and presenting results. Pre: 4214. (2H,3L,3C).

5544: SOIL-PLANT-ANIMAL INTERRELATIONSHIPS IN GRASSLANDS
The principles of plant competition and succession during the establishment and maintenance of herbaceous species and communities are interrelated to soil, biotic, and microclimatic factors and their interactions. Ecological and nutritional principles embodying plant and animal factors in the utilization of herbaceous plants by livestock are established. Research methodology in grassland systems is presented. X-grade allowed. Pre: 4214, 4544, ALS 3204. (3H,3C).

5594: MODELING SUBSURFACE WATER & CHEMICAL TRANSPORT
Formulation and solution of mathematical models for movement of water and chemicals in soils and groundwater including consideration of flow in variably saturated media, convective-dispersive transport of nonreactive and reactive water-soluble chemicals, and selected other topics in transport modeling. Analytic and numerical methods of solving governing equations are discussed. Students will develop and program numerical solutions for selected problems and will utilize existing codes for a variety of other problems. Pre: 4594.

5634: SOIL CHEMISTRY
Chemical and colloidal properties of clays and organic matter in soil systems including ion exchange, retention and precipitation; soil acidity and salinity; mineral weathering and formation; oxidation-reduction reactions; trace and toxic elements, and organic pollutants in soils. Pre: 3114, 3124. (3H,3L,4C).

5694: SOIL BIOCHEMISTRY
Comprehensive presentation and analysis of the biochemistry of soil humic acid formation, physiochemical properties of humic substances, and interactions of soil humic substances with toxic organics and metals. Microbial degradation of organics, including pesticides, and the fate of genetically engineered microbes in soil. Pre: 4684, 4694, BIOL 4684. (2H,3L,3C).

5734 (GEOL 5734): CLAY MINERALOGY
Structure, composition, classification, identification, and properties of clay minerals; emphasis on characteristics of mixed-phase systems in sediments and soils. Pre: 5634 or GEOL 3504. (3H,3L,4C).

5844 (GBCB 5844): PLANT GENOMICS
Comprehensive overview of genomics and its applications. Topics include: molecular markers, map construction, map-based cloning, quantitative trait loci, and functional genomics. Even years. Pre: Knowledge of general principles of genetics and molecular biology. (3H,3C).

5904: PROJECT & REPORT
Project for non-thesis Masters of Science degree option. Constitutes 3 to 6 of the 30 credit hours required for the degree. This course will emphasize critical interpretation, review, and oral/written reporting of an assigned topic. Review grade only. May be repeated. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6634: SOIL PHYSICAL & COLLOIDAL CHEMISTRY
Rigorous theoretical and applied treatments of soils and molecular adsorption, desorption, distribution, and exchange from soil colloidal systems. Pre: 5634, CHEM 4616. (3H,3L,4C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (CSES)

The following 4000-level courses have been approved for graduate credit:

4114 (ENSC 4114): SOIL PHYSICS
Application of the principles of physics and mathematical analysis to the study of soils. Covers the physical nature and properties of soil solids, basic soil mechanics, physical state of water in soils, infiltration and movement of water in soils, mass transport in soil solutions, soil gases and soil aeration, heat and heat transfer in soils. Pre: 3114, PHYS 2205, MATH 2015. (3H,3L,4C).

4124: SOIL SURVEY AND TAXONOMY
Identification and evaluation of soil morphological characteristics; techniques for writing soil map and taxonomic unit descriptions; characterization and delineation of soil landscapes into discrete soil map units on an aerial photographic base; classification of soil taxonomic units by criteria of the National Cooperative Soil Survey. Co: 3114 or 3124. (1H,6L,3C).

4134: SOIL GENESIS AND CLASSIFICATION
The form and dynamics of soil bodies across the landscape; soil-forming factors and processes; state factor analysis as a predictive tool to explain the evolution of unique soils across the terrain; diagnostic horizons and other important pedological features used in Soil Taxonomy; history and development of soil classification systems. Taught even years. Pre: 4124. (3H,3C).

4144: PLANT BREEDING AND GENETICS
Genetic variation in plants and its importance in plant breeding, and comparisons of theories and procedures in breeding of self-pollinated versus cross-pollinated plants. Taught even years. (2H,3L,3C).

4214: SOIL FERTILITY AND MANAGEMENT
Soil productivity and nutrients required for crop growth; fertilizer sources and nutrient reactions in soil; methods of fertilizer nutrient placement in major tillage systems; and interpretation of soil tests and plant analyses for determining crop nutrient requirements. Pre: 3114. (3H,3C).

4224: SOIL FERTILITY AND MANAGEMENT LABORATORY
Determination of essential elements for plant growth in soils and plants. Techniques for obtaining representative soil and plant samples. Comparison of soil test methods and interpretation of results and instrumentation utilized in analytical work. Co: 4214. (3L,1C).

4344: CROP PHYSIOLOGY AND ECOLOGY
Developmental and ecological processes important in cropping situations: seed physiology, root and canopy development, flowering, water stress, energy flow, competition; emphasis on physiological adaptations, limitations to yield, and yield-optimizing strategies. (3H,3C).

4444: ADVANCED CROP MANAGEMENT
Analysis and evaluation of conventional and alternative crop management systems; natural resource problems associated with agriculture; directions of crop management research and science; low-input, sustainable agriculture. Pre: 2444, 3114, 3124. (3H,3C).

4524: AGROMETEOROLOGY
In-depth, quantitative treatment of weather in relation to crop production. Covers physical basis for global weather and weather patterns, measurement of weather elements, analysis and interpretation of weather data series, quantifying the influence of weather on crop growth and development, estimating dynamic energy and water balance of field crops using weather data series, soil heat transfer, and bio-physical crop models. Pre: 4344. (3H,3C).

4544: FORAGE CROP ECOLOGY
Species adaptation interrelated with soil, climatic, and biotic factors as associated with establishment, production, utilization, and nutritional value of forages. Pre: ALS 3204. (3H,3C).

4594 (CEE 4594): SOIL AND GROUNDWATER POLLUTION
Application of mathematical models for chemical movement in soils and groundwater to evaluate soil and groundwater pollutant behavior; discussion of pollution remediation technologies; design of subsurface monitoring networks; case studies in soil and groundwater pollution; applications to landfills, waste spills, septic drainfields, pesticide/fertilizer leaching, and other problems of environmental concern. Pre: (MATH 2224 or MATH 2514), (GEOL 4114 or CEE 4314). (3H,3C).

4644: LAND-BASED SYSTEMS FOR WASTE TREATMENT
Soils as a medium for waste treatment; potential for environmental degradation from biologicals and chemicals added to soils; development of land-based treatment and utilization systems for solid and liquid wastes; issues and concerns relating to large-scale applications of municipal and industrial wastes to land. Taught odd years. (3H,3C).

4734 (CHEM 4734) (ENSC 4734): ENVIRONMENTAL SOIL CHEMISTRY
Chemistry of inorganic and organic soil components with emphasis on environmental significance of soil solution-solid phase equilibria, sorption phenomena, ion exchange processes, reaction kinetics, redox reactions, and acidity and salinity processes. Pre: 3114, 3124, CHEM 2514, CHEM 2535, CHEM 3114, MATH 2015. (3H,3C).

4754 (CHEM 4754) (ENSC 4754): INSTRUMENTAL ANALYSIS FOR AGRICULTURAL AND ENVIRONMENTAL SCIENCES
Theory and principles of common analytical instruments and their applications to agriculture and environmental science research. Topics include atomic absorption and emission spectroscopy, spectrophotometric methods (UV, visible, luminescence, and automation), chromatography, ion-selective electrodes, and microwave digestion. Infrared spectroscopy, atomic ratio and molecular mass spectroscopy, nuclear magnetic resonance will also be included. Provide hands-on experience with modern analytical instruments. Prerequisites or graduate standing required. Pre: (3114, 3124) or (CHEM 3114, CHEM 3124). (3H,3L,4C).

4834 (GEOG 4834): SOIL CHARACTERIZATION AND INTERPRETATION
Soil characteristics that influence land use and environmental quality evaluated by methods specified by the National Cooperative Soil Survey Program. Influence of spatial soil variability on soil-interpretation accuracy. Interpretive-class criteria for agricultural and urban land uses appraised. Pre: 3114, 3124, 4124. (1H,6L,3C).

4844 (ENSC 4844) (GEOG 4844): SOIL INTERPRETATION USING GIS AND DSS
Use of Geographic Information System (GIS) software to compile digital maps, imagery, and natural resource data. Digital data will be downloaded from the Internet and verified in the field with GPS units. Decision support systems (DSS) will be used to produce interpretative maps from digital soil data. A hypothesis, proposal, and GIS project will be created and project results presented in class. Attendance required on daylong field trips to GIS application sites. Pre: 4124, GEOG 4084 or BSE 4344 or CEE 4204. (2H,3L,3C).

DAIRY SCIENCE

Stephen C. Nickerson, Head

Horace E. and Elizabeth F. Alpin Professor: R.M. Akers
David R. and Margaret Lincicome Professor: F.C. Gwazdauskas
Professors: M.A. Barnes; B.G. Cassell; R.E. James; M.L. McGilliard; R.L. Nebel; S.C. Nickerson; R.E. Pearson; C.C. Stallings
Associate Professor: J.H. Herbein, Jr.
Assistant Professor: K.F. Knowlton
Lecturer: D.R. Winston
Career Advisor: M.A. Barnes

E-mail: shumaker@vt.edu
Web: www.dasc.vt.edu/

Recent advancements in science and technology have accelerated change and increased the complexity of the dairy industry. Thus, the need for professional people in dairy science with education at the graduate level is increasingly important. Excellent career opportunities are available. The dairy science department offers programs leading to the degrees of M.S. and Ph.D.

All advanced degree candidates are required to complete a thesis based on an independent research effort, except for nonthesis M.S. candidates. Current programs of specialization include: physiology and biochemistry of reproduction, ruminant nutrition, genetics, physiology and biochemistry of lactation, and dairy herd management. Special programs also may be arranged in other areas in cooperation with other departments and in dairy extension education.

Prerequisite to graduate work in this department is the satisfactory completion of an undergraduate program in the agricultural or life sciences. Candidates with educational experience in extension or business and with adequate background and interest in the dairy industry may also be admitted. Students with an inadequate dairy science background may be required to take additional courses according to need and academic goals. All students are required to teach in some capacity for at least one semester during their program.

GRADUATE COURSES (DASC) (ALS)

DASC 5004: SEMINAR
Reports and discussion of current research in dairy science. Required of DaSc graduate students. May be repeated. (1H,1C).

ALS 5004: ANIMAL NUTRITION SEMINAR
Reports and discussion of current research in animal nutrition on an inter-departmental basis. May be repeated. (1H, 1C).

ALS 5014: SEMINAR IN PLANT PHYSIOLOGY
Formal presentation of principles and concepts in plant physiology. Review, discussion, and critical evaluation of current primary literature and research data. May be repeated. Pass/Fail only. (1H,1C).

ALS 5024: SUPERVISED EXPERIENCE PROGRAMS IN AGRICULTURE
Designed to provide information and assistance for developing and conducting a supervised occupational experience program. Includes indentification of principles and trends in occupational experience programs, procedures for surveying and selecting training centers, procedures in conducting an occupational experience program, and evaluation of experience programs. (3H,3C).

ALS 5034: TEACHING AGRICULTURAL MECHANICS
The coordination of essential elements required for an effective agricultural mechanics program. Special emphasis placed upon integrating agricultural mechanics instruction into a local agricultural education program, liability, curriculum content selection, special teaching methodologies, and student assessment. (3H,3C).

ALS 5044: PROGRAM AND CURRICULUM DESIGN IN AGRICULTURAL AND EXTENSION EDUCATION
Methods involved in the organization, management, and evaluation of programs and curricula for agricultural education and cooperative extension. (3H,3C).

ALS 5054 (HNFE 5054): METHODOLOGY IN NUTRITION RESEARCH
Use of laboratory techniques, instrumentation, and experimental design in the solution of fundamental problems in human and animal nutrition. Odd years. (2H,2C).

ALS 5064 (BCHM 5064) (BIOL 5064) (PPWS 5064): SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty and outside speakers. Taken on pass-fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A-F basis. Graduate status in participating MCBB departments required. (1H,1C).

ALS 5074: FOUNDATIONS OF AGRICULTURAL AND EXTENSION EDUCATION
The history and philosophy of agricultural education and the cooperative extension service along with the inter-relationship of the two, including a common heritageis included. Leaders of both agencies, along with their philosophies are discussed. (3H,3C).

ALS 5104 (HNFE 5104): NUTRITIONAL ASPECTS OF DIGESTIVE SYSTEMS
Principles of gastrointestinal tract structure, motility, and digestive functions with emphasis on neuroendocrine and metabolic regulation of absorption and transport of carbohydrates, lipids, amino acids, minerals, and vitamins during the life cycles of food animals and humans. Pre: 3204, HNFE 3026. (2H,2C).

ALS 5105-5106: POPULATION GENETICS
Principles of population genetics; gene frequency; forces that change gene frequency (migration, mutation, selection); genetic drift; biometric relationships between relatives; calculation of inbreeding and relationship; additive, dominance, and epistatic effects; estimation and use of repeatability, heritability, and genetic correlations; and formation and use of selection goals and selection criteria. Co: STAT 5615, STAT 5616. (3H,3C).

ALS 5114 (HNFE 5114): VITAMINS & MINERALS
Study of metabolic regulation and physiologic functions of micronutrients; micronutrient functions as related to maintenance of health and prevention of disease; analytical methods, determination of micronutrient requirements and assessment of status. Odd years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (3H,3C).

ALS 5124 (HNFE 5124): PROTEIN & AMINO ACID METABOLISM
Protein and amino acid metabolism in liver, muscle, kidney, and brain; effects of dietary protein on gene expression; protein turnover in tissues; protein quality evaluations; analytical problems in amino acid metabolism. Even years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (2H,2C).

ALS 5134 (HNFE 5134): CARBOHYDRATES, LIPIDS & ENERGY METABOLISM
Concepts in the utilization, metabolism and regulation of carbohydrates and lipids as related to energy metabolism in the various organs and energy balance and its control; metabolism of carbohydrates, lipids and amino acids during activity, fasting, and different disease states in the liver, brain, adipose tissue, kidney and heart; methods of assessment of carbohydrate and lipid metabolism. Odd years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (2H,2C).

ALS 5144 (HNFE 5144): MOLECULAR ASPECTS OF NUTRITION & DISEASE
The role of specific nutrients in human and animal health at a physiologic and molecular level. Emphasis is placed on the influence of nutrients on gene expression especially with regard to pathophysiology of diseases. Physiological and molecular aspects of nutrition and immune function will also be discussed. Even years. Pre: BCHM 5124, ALS 5104 or HNFE 5104. (3H,3C).

ALS 5154: COMMUNITY PARTNERSHIP AND VOLUNTEERISM
Students will develop competencies in the development and direction of community volunteer partnerships and collaborations. Students will explore current volunteer development models, collaborations process theory, and key management areas including: visioning, organizing a partnership or collaboration; creating motivating volunteer positions; recruiting, screening, and interviewing; orientation and training; supervising; evaluation; retention and recognition; group process/facilitation; conflict resolution; risk management; and measuring program effectiveness. (3H,3C).

ALS 5204: RESEARCH & INFORMATION SYSTEMS IN THE LIFE SCIENCES
A focus on research techniques and processes for life science professions. Topics include: history of applied life sciences, current structure of the scientific enterprise, the scientific method and quality assurances, researching the literature, scientific writing and presentation of research results, instructional techniques, professionalism, and ethical considerations. Information technology is employed throughout the course. Students learn to use digital technologies for communication, presentation, and publication. (1H,2L,3C).

ALS 5254: ADVANCED TOPICS IN SWINE NUTRITION
Current concepts of swine nutrition with emphasis on problems associated with high levels of productivity in modern confinement operations are covered. (2H,2C).

ALS 5274: ADVANCED TOPICS IN RUMINANT NUTRITION
Digestion and absorption in neonate; functional rumen development; microbial population and nutrient requirements; and forage analysis and animal performance, protein chemistry of grains and utilization, particle size and effective fiber, intake regulation and chemical modifiers, anion-cation balance, unusual feed sources, and net energy value alterations. Topics change with advances in research. Even years. Pre: 5304. (2H,2C).

ALS 5284: ADVANCED TOPICS IN EQUINE NUTRITION
A critical review of current research in equine nutrition is presented. Special emphasis is placed on new concepts of nutrient requirements and interrelationships, and on factors affecting nutrient intake and utilization. (1H,1C).

ALS 5304: ADVANCED PHYSIOLOGY & ANATOMY OF DOMESTIC ANIMALS
Mammalian physiology and anatomy will be evaluated in domestic animals, laboratory animals, and primates. Emphasis will be on the cardiovascular, renal, respiratory, neural, muscle, and digestive physiology. Pre: 2304. (4H,3L,5C).

ALS 5314: COMPARATIVE REPRODUCTIVE PHYSIOLOGY
Comparative mechanisms of all major aspects of male and female reproductive physiology will be examined in domestic animals, laboratory animals, and primates. Emphasis will be given to species variation in regard to reproductive function and to a detailed examination of key reproductive events in both sexes. Pre: 4304. (4H,4C).

ALS 5344 (PPWS 5344): MOLECULAR BIOLOGY FOR THE LIFE SCIENCES
A multi-disciplinary treatment of gene organization and expression in animal and plant systems. Emphasis on the applications of molecular biology to current problems in applied biology and biotechnology. Pre: BCHM 4116 or BCHM 5124. (3H,3C).

DASC 5474: DAIRY MANAGEMENT DECISIONS
Principles and techniques of evaluating dairy management alternatives, with emphasis on integration of interest, borrowed capital, income taxes, and risk in the decision process. Effective use of microcomputers, production records, and modeling techniques to evaluate management strategies. Even years. Pre: 4474. (3H,3C).

ALS 5504: TRACERS IN ANIMAL RESEARCH
Application of tracer techniques, including radioisotopes, to research problems of animal physiology, nutrition, and metabolism. Methods of detection and interpretation of experimental approach and resultant data stressed. Laboratory safety, environmental transfer of isotopes, and radiation effects on metabolic processes included. Pre: 5304. (1H,3L,2C).

ALS 5754: INTERNSHIP IN AGRICULTURAL & EXTENSION EDUCATION
Student participation in a planned clinical experience under supervision of a university faculty member in an approved, appropriate professional setting. A written Internship Agreement must be completed and approved before the internship begins. Variable credit course.

ALS 5904: PROJECT & REPORT
Variable credit course.

DASC 5904: PROJECT & REPORT
Variable credit course

ALS 5954: STUDY ABROAD
Variable credit course.

ALS 5964: FIELD STUDY
Pass/Fail only. Variable credit course.

ALS 5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

DASC 5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

ALS 5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

DASC 5984: SPECIAL STUDY
Variable credit course.

DASC 5994: RESEARCH & THESIS
Variable credit course.

ALS 6024 (PPWS 6024): TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle assembly, and of growth and development, structure and function of

polyamines and of proteases will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: BCHM 5214..

ALS 6104: ADVANCED TOPICS IN SELECTION
Theoretical and applied concepts involving selection. Emphasis is on long and short-term responses to artificial selection, control populations, genotype-environment interactions, natural selection, and genetic homeostasis. Pre: 5106. (3H,3C).

ALS 6114: LINEAR MODEL APPLICATIONS IN ANIMAL BREEDING
Application of mixed linear model procedures in genetic evaluation. Prediction of realized values of random variables with unknown means for fixed effects (Best Linear Unbiased Prediction). Extension of methods to consider genetic relationships, differing genetic populations, multiple records, environmental correlations, culling bias, and multiple trait evaluation. Pre: 5106, STAT 5616. (3H,3C).

ALS 6124: NONADDITIVE GENETICS
Genetic and physiological bases for heterosis or hybrid vigor in plant and animal models; design and evaluation of selection programs to utilize nonadditive gene effects; effects of inbred line formation and crossing on genetic variances; utilization of heterosis in commercial production; estimation of additive and nonadditive gene effects in crosses; theory of the diallel cross. Pre: 5106. (2H,2C).

ALS 6314: ENDOCRINOLOGY
Mechanisms in endocrine control of physiological systems will be discussed. Emphasis will be on hypothalamic, pituitary, adrenal, thyroid, parathyroid, pancreatic, and reproductive systems. Pre: 5304. (2H,3L,3C).

ALS 6324: ADVANCED NEUROCHEMICAL CONTROL
Mechanisms in vertebrate brain controlling physiological processes will be examined. Emphasis will be placed on the chemical coding underlying the control of these processes and will include some of the coding defects which cause abnormal functions. Pre: 5304. (3H,3C).

ALS 6984: SPECIAL STUDY
Variable credit course.

ALS 7964: FIELD STUDIES
Pass/Fail only. Variable credit course.

DASC 7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (DASC) (ALS)

The following 4000-level courses have been approved for graduate credit:

DASC 4174: APPLIED DAIRY CATTLE GENETICS
Application og genetic principles to dairy cattle improvement. Setting goals for genetic improvement, characteristics of traits included in selection, current methods of estimating breeding values, the role of artificial insemination and breed associations in genetic improvement, cattle genetics. Pre: ALS 3104. (2H,3L,3C).

ALS 4234 (EDCT 4234) (EDVT 4234): CURRICULUM FOR CAREER AND OCCUPATIONAL EDUCATION
Provides current and prospective career and occupational education teachers with research bases, resources, and available curricula for teaching content in the respective disciplines. Develops the ability to plan, manage, develop, and evaluate curricula. The prerequisite EDVT 2604 will be waived for agriculture education students. Pre: EDVT 2604. (3H,3C).

ALS 4244 (EDVT 4244): METHODS OF TEACHING IN CAREER AND OCCUPATIONAL EDUCATION
Developing instructural plans, delivering and evaluating instruction, and evaluating learner performance for career and occupational education. The prerequisite EDVT 4234 will be waived for agriculture education students. Pre: ALS 4234. (3H,3C).

ALS 4254 (EDVT 4254): ADULT VOCATIONAL AND TECHNICAL EDUCATION
Theory, practices, and procedures involved in planning, developing, implementing, managing, and evaluating adult education programs in Vocational and Technical Education. Completion of, or concurrent enrollment in, courses in teaching methods and curriculum required. (3H,3C).

ALS 4304: PHYSIOLOGY OF REPRODUCTION
Physiological mechanisms that control and affect reproductive processes in domestic animals, birds, humans, and selected other species. Pre: ALS 2304. (3H,3L,4C).

DASC 4304: PRINCIPLES & PRACTICES OF BOVINE REPRODUCTION
Principles and techniques in reproductive physiology and herd management related to health, record keeping, estrus detection and synchronization, and ultrasonography. Ovarian function and superovulation, semen handling, artificial insemination and pregnancy detection are also considered. (1H,3L,2C).

ALS 4505: NATURAL RESOURCE CONSERVATION
Designed primarily to train elementary and secondary teachers, supervisors, and administrators in natural resource conservation. A three-week course. Emphasis is placed on soils, water, geology, forestry, wildlife, and marinelife. Available for graduate credit except to agronomy, forestry, and wildlife majors. (3H,3L,4C).

ALS 4524: FARMING SYSTEMS RESEARCH AND DEVELOPMENT
Characteristics of extensive and intensive farming systems in developing countries. Comparision with U.S. small farming systems. Methods of multi-disciplinary team organization, informal team surveys, grouping farm households, and design and analysis of onfarm trials. Introduction of these methods into developing country and domestic research and extension systems. (3H,3C).

ALS 4554 (BIOL 4554): NEUROCHEMICAL REGULATION
Neurochemical transmission within the vertebrate brain will be examined. Emphasis will be placed on the chemical coding underlying the control of various behaviors and how these systems can be modified by various drugs or diet. Pre: ALS 2304 or BIOL 3404, CHEM 2535. (3H,3C).

ALS 4574 (BIOL 4574): SOCIAL BEHAVIOR OF BIRDS & MAMMALS
Animal behavior from the viewpoint of group organization during the life cycle of the organism. Emphasis is on adaptive mechanisms as they relate to the behavior-physiology-genetic interaction. Pre: BIOL 1106. (2H,2C).

ALS 4884: YOUTH PROGRAM MANAGEMENT
Organizational design of educational youth programs such as 4-H and FFA, including administrative planning, human resource development, marketing, and budgeting. Pre: ALS 4304. (3H,3C).

ECONOMICS

Aris Spanos, Head

Professors: R. Ashley; C. Eckel; H. Haller; A. Kats; D. Salehi-Isfahani; A. Spanos; T.N. Tideman;
Associate Professors: S. Ball; R. Cothren; R. Gilles; N. Lutz; M. Stegeman; D. Yang
Assistant Professors: M. Mello
University Distinguished Professor Emeritus: J. Buchanan
Professor Emeritus: A. Mandelstamm
Adjunct Professor: G. Amacher
Graduate Director: R. Ashley
Career Advisor: S. Ball (231-4349)

E-mail: econgrad@vt.edu
Web: www.econ.vt.edu/

In addition to the high demand in academic and government research and advisory positions, new demand for economists has emerged in recent years. Business firms actively seek economists for research and administrative positions. In government and international agencies, the use of economists in traditional positions has been supplemented by their involvement in sophisticated program planning and high-level administrative positions. Economists engaged in academic, business, and government jobs usually hold advanced degrees. The department has a graduate program leading to the Ph.D. degree. The Ph.D. program is jointly administered with the Department of Agricultural and Applied Economics in the College of Agriculture and Life Sciences. The M.A. program in Northern Virginia is currently not operating. These programs provide students with basic theoretical fundamentals and specialized knowledge of various fields and topics.

The department offers programs of study in economic theory: microeconomics and macroeconomics, econometrics, markets and industrial organization, resource and environmental economics, public and regional/urban economics, and development and international economics.

Most students entering the graduate program have the equivalent of an undergraduate degree in economics, although this is not required. The desired minimal background is course work corresponding to intermediate economic theory (both micro and macro), a sequence in statistics, and college mathematics through calculus.

Students with undergraduate degrees in other areas, who show evidence of academic potential, are also admitted; deficiencies in undergraduate preparation can be remedied in a routine and straightforward way. Students applying for graduate study in economics must take the Graduate Record Examination prior to entrance.

GRADUATE COURSES (ECON)

5005,5006: PRICES, MARKETS, & RESOURCE ALLOCATION
This sequence, which is part of the core curriculum in the Economics Ph.D. program, covers fundamental concepts at the foundation of modern microeconomic theory. The sequence relies heavily on calculus and other mathematical tools. 5005: noncooperative game theory, competitive and non-competitive markets, theory of the firm. 5006: consumer theory, general equilibrium and welfare economics, uncertainty and asymmetric information. (3H,3C).

5015,5016: THEORY OF MONEY, INCOME, EMPLOYMENT, & THE PRICE LEVEL
Part of core curriculum in the Econ Ph.D. program providing an intensive treatment of modern macroeconomic and monetary theory. The course uses mathematical tools and analytic concepts. National income accounts; effective demand; neoclassical and Keynesian theories of capital and interest; supply and demand in money securities markets; introduction to macroeconomic dynamics; rational expectations. Co: 5025. (3H,3C).

5124: MATHEMATICAL METHODS IN ECONOMICS
Extensive treatment of new techniques for economic modeling. Review of linear algebra and calculus; static optimization, with Lagrangian and Kuhn-Tucker methods; differential and difference equations; dynamic optimization, with calculus of variations, optimal control and dynamic programming. (3H,3C).

5125-5126 (AAEC 5125-5126): EMPIRICAL RESEARCH METHODS IN ECONOMICS
Extensive treatment of new techniques for economic modeling. 5125: Probability and statistical inference, linear regression and related dynamic models, specification, estimation, misspecification, respecification, identification. 5126: Simultaneous equations, dynamic systems, time series, limited dependent variable models. (3H,3C).

5504: ECONOMICS OF BUSINESS DECISIONS
Economic theory applied to business problems and business behavior. Demand analysis, production, cost, pricing policies, market structure, and government policies toward business. Designed for non-economic students. Basic differential calculus required. Pre: 2115. (3H,3C).

5514: MACROECONOMIC POLICY EVALUATION & FORECASTING
An introduction to the macroeconomic environment in which both federal policymakers and private sector management must operate. The consequences of various federal policies are examined theoretically and simulated numerically on a microcomputer. The course also provides an introduction to the theory and practice of macroeconomic forecasting. No previous computer experience required. Pre: 5504, 2115, 2116. (3H,3C).

5524: NEGOTIATION: THEORY & PRACTICE
This course will promote understanding of both the theory and practice of negotiation in a variety of management, legal, and everyday life situations. The goal of this course is twofold: to develop analytical skills which are drawn from both microeconomic theory and game theory to discover the best solutions to problems, and skills to implement these solutions. Pre: 5504. (3H,3C).

5804: GENERAL ECONOMIC ANALYSIS
Introduction to the economic system. An accelerated presentation of the basic tools of economic analysis for graduate students in all fields who have no previous work in basic economics. Emphasizes applications to social behavior and social problems. Market behavior, production, the distribution of income, and the impact and the role of public policy. Carries graduate credit except for students in the Economics or M.B.A. programs. Satisfies the prerequisite for Econ 5504. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5914: APPLICATIONS OF MICROECONOMIC ANALYSIS
Topics that broaden the student's exposure to and experience with the range of modern microeconomic theory emphasizing mathematical tools and models. Industry structure, bargaining theory, uncertainty and limited information, oligopoly games or other topics may be highlighted at the initiative of the instructor and by agreement with the director of the Northern Virginia program. A core course in the Northern Virginia M.A. program. Pre: 5934. (3H,3C).

5924: MONEY, EMPLOYMENT, & BUSINESS FLUCTUATIONS
Survey of the macroeconomic foundations of aggregate functions such as consumption, investment, money demand and supply. Development of neoclassical and Keynesian models of the aggregate economy, exploration of the continued tension between these views of the economy in modern rational expectations models. Applications to the theory of stabilization, monetary reform, and the effects of budgetary changes in government. A core course in the Northern Virginia M.A. program. Pre: 2115. (3H,3C).

5934: MICROECONOMIC THEORY
An intensive treatment of demand and production theory with emphasis on constrained optimization techniques and results and their implications for econometric testing. A core course in the Northern Virginia M.A. program. Pre: 2116. (3H,3C).

5945-5946: ECONOMETRIC THEORY & PRACTICE
An intensive coverage of the most important techniques of econometric estimation and hypothesis testing, addressing the use of both cross-section and time series data. A core sequence in the MA program in both locations. Prerequisite to the research-thesis seminar in the Northern Virginia M.A. program. Pre: 2115 or 2116. (3H,3C).

5955,5956: TOPICS IN APPLIED ECONOMIC ANALYSIS
Subject matter is drawn from the main applied fields of economics and varies from offering to offering; it is announced in the Timetable of courses. Either course may be taken more than once for credit so long as the topics differ. Provides advanced coverage for honors undergraduate major, and graduate students not enrolled in the economics Ph.D. program. X-grade allowed. (3H,3C).

5964: EXPERIMENTAL ECONOMICS
Laboratory techniques are valuable for answering research questions which defy traditional empirical analysis due to lack of field data. Examples include proposed regulations, new market designs and tests of theory. The goal of this course is two-fold: to develop skills in experimental methods appropriate for economics and related fields and to familiarize students with the results of experimental tests of economic theory. Requirement: Graduate or honors undergraduate, major standing, and permission of the departmental director of graduate study or course instructor. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course. X-grade allowed.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course. X-grade allowed.

6004: STRATEGIC BEHAVIOR
Emphasizes strategic behavior in the presence of multiple decision makers. Game theory deals with strategic interaction and provides the formal framework to describe and analyze situations with conflicting interests–as well as situations with both common and conflicting interests. Proof of applicability is provided by means of numerical examples and real life cases, e.g., bargaining, contract theory, economic policy games, and voting. Pre: 5005, 5006. (3H,3C).

6005: CONTEMPORARY ALLOCATION THEORY
Recent developments in microeconomics and game theory. Ph.D. students are introduced to current research in equilibrium analysis, bargaining theory, theory of cooperative and noncooperative games, and the economics of uncertainty. X-grade allowed. Pre: 5005, 5006. (4H,4C).

6014: AGGREGATE ANALYSIS: FINANCE, DEVELOPMENT & GROWTH
Research topics of current importance in theoretical and empirical macroeconomics. Monetary theory; financial markets; development macroeconomics; stochastic growth theory; time series analysis; cross section analysis. Pre: 5006, 5016, 5125. (3H,3C).

6015-6016: AGGREGATE ECONOMIC ANALYSIS
Research topics of current importance in theoretical and empirical macroeconomics for Ph.D. students. Monetary theory, the theory and econometrics of rational expectations, linear projection theory, time series analysis in macroeconomics, stochastic growth theory. Pre: 5006, 5016, 5125. (4H,4C).

6024: ADVANCED TOPICS IN ECONOMETRICS THEORY
This course assumes a basic understanding of multiple regression and simultaneous equations modeling and introduces students to advanced econometric techniques commonly used in empirical work. These techniques include linear time series modeling in the time domain, discrete choice models, and panel data methods. Pre: 5126. (3H,3C).

6034: COMPARATIVE ECONOMIC SYSTEMS
The theories of market capitalism and market socialism. The centrally planned economy and the planning process. Efficiency and equity outcomes of alternative approaches as observed in world economics. Pre: 5506, 5506. (4H,4C).

6044: COLLECTIVE CHOICE
Analysis of decision-making processes in committees, clubs, legislatures, and electorates. Pre: 5005, 5006. (4H,4C).

6054: DEVELOPMENT ECONOMICS
A modern approach to economics of growth and development for graduate students in economics and related disciplines. Topics include sources of growth; neo-classical, endogenous, and dualistic theories of growth; household economics and human capital accumulation; economics of population; and consequences of imperfect markets for land, labor and capital. Pre: 3104, 3204. (3H,3C).

6074: GRADUATE LAW & ECONOMICS
Economic analysis of the impact of legal institutions on the economy, and of the impact of economic motives and reasoning on both common law and statute law. (4H,4C).

6104: LABOR ECONOMICS
Labor demand and supply, investment in human capital, discrimination in the labor market, and the theory of equalizing wage differentials; search and unemployment, unions, and income distribution. Pre: 5005. (4H,4C).

6204: PUBLIC ECONOMICS
This course describes the theory of government expenditures, stressing market failure as the rationale for government activity. The course describes the normative outcome achieved by a benevolent government, and the positive outcome achieved under rules of collective choice. Tax policy for different levels of government and selected topics in state and local public finance are also addressed. Pre: 5005, 5006. (3H,3C).

6304: INTERNATIONAL TRADE & FINANCE
Core models in int'l trade and finance; current topics in international economics. Ricardian, Hecksher-Ohlin-Samuelson, Dynamic imperfect competition trade theories; Political economy of trade; Trade policy, Factor mobility, Uncertainty, and Intra-industry trade. Mundell-Fleming, Monetary, Real- and Imperfect competition-Micro- foundations theories of international macroeconomics; exchange rate determination; and capital markets. Extensions to monetary and fiscal policy, economic growth, and external debt analysis. Pre: 5005, 5015. (3H,3C).

6404: INDUSTRY STRUCTURE
Effects of industry structure on price and non-price behavior of firms, on market equilibrium, and on economic welfare. Problems of oligopolistic industries and analysis of government policies (regulation, anti-trust). Pre: 5005. (3H,3C).

6444 (AAEC 6444): REGIONAL & URBAN ECONOMICS
An advanced study of the theory and application of regional and urban economics, with particular focus on spatial aspects of economic activity. Topics include: nature of regional and urban areas, models of regional economies, location choice of firms and consumers, local public finance, housing, transportation, and labor markets. Taught alternate years. Pre: 5005, AAEC 5126 or ECON 5126. (3H,3C).

6474 (AAEC 6474): APPLIED GENERAL EQUILIBRIUM ANALYSIS
Theoretical and empirical issues in developing and implementing numerical general equilibrium models. Development of basic analytic framework and model properties, and study of selected applications in international trade, public finance, and resource and environmental economics. Pre: 5005, 5006. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ECON)

The following 4000-level courses have been approved for graduate credit:

4014: ENVIRONMENTAL ECONOMICS
Economic dimensions and aspects of programs designed to impose quality controls upon the environment. Special emphasis on problems of controlling air and water pollution. Pre: 2005 or 2116 or 2126 or 2025H. (3H,3C).

4024: HISTORY OF ECONOMIC THOUGHT
Review of the emergence of economics as a discipline and science in England. Surveys of major thinkers, doctrines and theories, with emphasis on the policy issues that motivated their work. Pre: 2006. (3H,3C).

4034: COMPARATIVE ECONOMIC SYSTEMS
Analysis of national economies, emphasizing structure differences, and differences in efficiency and distributive outcome which result from primary reliance on decentralized (market) allocation or centrally directed(planned) allocation. Pre: 2006. (3H,3C).

4044: PUBLIC ECONOMICS
Economic rationale of the public sector. Proper size and functions of government. Market failure, Cost-benefit analysis, public goods provision. Pricing of public enterprise services. Pre: (3104 or 4104H), (MATH 1206 or MATH 1526 or MATH 2015). (3H,3C).

4054: PUBLIC FINANCE
The structure and incidence of taxation in the U.S. Effects of taxes on incentives and economic efficiency. Tax Policy. Pre: 3104. (3H,3C).

4064: COLLECTIVE DECISIONS
Economic analysis of methods for group decision making, voting rules, voting strategies and outcomes; cost-sharing problems; efficiency and equity impacts of government action. Pre: (3104), (MATH 1206 or MATH 1526 or MATH 2015). (3H,3C).

4074: LABOR ECONOMICS
Human capital theory, labor supply and demand, discrimination, effects of labor unions and collective bargaining, wage differentials, income distribution. Pre: 2005 or 2116 or 2126 or 2025H, (3254 or 4304). (3H,3C).

4084: INDUSTRY STRUCTURE
The structure and performance of American industry. Dimensions and measures of market structure. Factors affecting maket structure. The relationship between structure and performance. Purpose and effects of antitrust policy, regulation, and other public policies toward industry. Pre: 3104 or 4924. (3H,3C).

4094: PUBLIC UTILITY AND TRANSPORTATION ECONOMICS
Policy issues centering on natural monopolies, such as transportation and utility networks. Profit and rate regulation, marginal cost pricing, public ownership. Issues of equity and efficiency in regulation of industry. Pre: 3104. (3H,3C).

4124: GROWTH AND DEVELOPMENT
Theories of economic growth. Policies to foster growth, and their consequences. Pre: 2006, 3104. (3H,3C).

4135,4136: INTERNATIONAL ECONOMICS
4135 International Trade: Factor mobility and commercial policy (tariffs, quotas, export licensing). 4136 International Finance: Liquidity, exchange rates, comparative international living standards, foreign aid. Pre: 3104 for 4135; 3204 or 4204H for 4136. (3H,3C).

4144: ECONOMICS OF CHINA
Evolution of the Chinese economy since 1949. Exposition of alternative economic systems, the commune, incentive problems, and state owned enterprises. Analysis of recent reforms and their effects on economic efficiency; and key issues of economic transition related to Russia and other East European countries. Pre: 3104. (3H,3C).

4214: ECONOMICS OF HEALTH CARE
Effects of medical care on health; cost and production of medical care; demand for medical care and its financing; structure of the health care industry; reorganization for efficiency. Pre: 2005. (3H,3C).

4304: INTRODUCTION TO ECONOMETRIC METHODS
An introduction to econometric modelling techniques, including regression methods. Particular emphasis on the special problems posed by economic data. Pre: STAT 3005. Co: 3104, 3204. (3H,3C).

4404: ECONOMICS OF ORGANIZATIONS
Economic theories of organization, with specific attention to their internal structure, and to design of incentive systems. Application to mergers, to the relationship between stockholders and managers, etc. Students with one year of economics, calculus and major in some other social science, by permission of the instructor. Pre: 3104 or 4924. (3H,3C).

4414: ECONOMIC FORECASTING
An introduction to economic forecasting – theory, methods, and applications. Pre: 2006. (3H,3C).

4424: THE THEORY OF GAMES AND ECONOMIC BEHAVIOR
Introduction to games and solution concepts, such as prisoner's dilemma, noncooperative equilibrium and Nash's bargaining solution. These concepts are applied in analyzing economic problems including bargaining problems, oligopoly and agency. Pre: 3104 or 4104H. (3H,3C).

4434: EXPERIMENTAL ECONOMICS
This is a course in the use of laboratory methods to study behavior in economics and the social sciences. Students will study state-of-the-art methodology in experimental economics, including experimental design, laboratory technique, financial incentives, and analysis of data. Students will participate in, design, and conduct experiments in bargaining, auctions, asset markets, public goods and commons situations, and risky decision-making. Pre: (3104 or 4104H), (BIT 2406 or MSCI 2406 or STAT 2004 or STAT 3005). (3H,3C).

4704: URBAN ECONOMY
The economics of urbanization. Land values, location decisions, problems of transportation congestion, housing markets, and land use regulation. Pre: 2005. (3H,3C).

4714 (UAP 4714): ECONOMICS AND FINANCING OF STATE AND LOCAL GOVERNMENTS
Examines the provision and financing of public goods and services in local governments. Analyzes associated policy issues. Reviews experience in Western Europe and developing countries, as well as in the United States. Pre: 2006 or 2115 or 2125 or 2026H. (3H,3C).

4894: LAW AND ECONOMICS
Analysis of the economic effects of legal rules, with emphasis on the law of property, contract, liability, and land use. Pre: 2005. (3H,3C).

4924: MANAGERIAL ECONOMICS
Economics of managerial decision-making. Production theory and cost, theory of the firm, market structure and firm interactions. Pre: 2005, MATH 1526 or MATH 1206 or MATH 2015. (3H,3C).

EDUCATIONAL LEADERSHIP & POLICY STUDIES

UNIVERSITY EXEMPLARY DEPARTMENT *

M. David Alexander, Chair

Professors: M.D. Alexander; P. Burge; D.G. Creamer; D.J. Parks; R.G. Salmon; K. Singh
Associate Professors: G. Belli; E.G. Creamer; J.B. Crockett; H.M. Getz; J.B. Hirt; D. Inman; S. Janosik; D.D. Ostroth; S.R. Parson; G.E. Skaggs; E.G. Spencer; C. Turrentine; T. Twiford; E. Wolfe
Assistant Professors: N. Bodenhorn; P. Brott; M. Chang; L.G. Driscoll; S... Hein; G. Lawson; Y. Miyazaki; J. Sughrue

The Department of Educational Leadership and Policy Studies offers exclusively graduate programs leading to advanced degrees in counselor education, educational research and evaluation, administration and supervision of special education, and educational leadership. The educational leadership degree program has two areas of study 1) elementary and secondary education which is a state certified program and 2) higher education for individuals pursuing employment in institutions of higher learning. All programs are designed to prepare education professionals for positions in educational institutions, government, and education-related agencies. Graduate study is offered at various sites throughout the commonwealth. Concentrated programs of study are offered at graduate centers located in Falls Church serving Northern Virginia, at Roanoke and Abingdon, and Virginia Beach serving the Tidewater and Richmond area.

GRADUATE COURSES (ELPS)

5004: SCHOOL PERSONNEL ADMINISTRATION & INSTRUCTIONAL SUPERVISION
Administration and supervision of human resources and instructional programs in schools. Content encompasses human resources planning, recruitment, selection, assignment, induction, supervision and appraisal, development, compensation and benefits, employee relations, and other topics of current interest. (3H,3C).

5024: SCHOOL LAW
Federal and state laws governing public education and the legal responsibilities and powers of various state and local governing bodies and individuals. Emphasis given case law, federal and state, affecting such topics as rights of teachers, rights of students, due process, liability, and equal protection. (3H,3C).

5034: PUBLIC SCHOOL FINANCE
Basic policies, principles, and practices involved in solution of problems of public school finance. Meets Virginia certification requirements for the principalship. 1 year or more of teaching experience required. (3H,3C).

5054: ADMINISTRATION OF SPECIAL-NEEDS PROGRAMS
Basic provisions of federal/state laws, policies, and regulations pertaining to special education, vocational education, and other special-needs client groups of the public schools. Pre: 5014. (3H,3C).

5284: PRACTICUM: COLLEGE STUDENT AFFAIRS
Supervised on-the-job experiences in settings, such as community colleges and college and university student personnel divisions. Experiences accompanied by regularly scheduled seminars designed to provide positive evaluation and analysis of the field experience. (1-12 C). Must have 20 hours previous course work in the field. Variable credit course. X-grade allowed.

5304: STUDENT DEVELOPMENT IN HIGHER EDUCATION
The evolution and current practice of student development in higher education. Analysis of the contemporary college student. Emphasis on philosophical, conceptual, and research foundations for practice and on the organizational contexts of professional practice. (3H,3C).

5314: THEORY & APPRAISAL OF COLLEGE STUDENT DEVELOPMENT
Theories explaining college student development and change. Cognitive-developmental, psychosocial, person-environment interaction, and humanistic-existential theories are included. Emphasis on late adolescent and adult theories about effects of college on students. Also includes procedures for measuring student development and change. (3H,3C).

5324: PROGRAM INTERVENTIONS FOR PROMOTING STUDENT DEVELOPMENT
Analysis of applications of college student personnel theories and models for practice for the design of programs to promote college student development and change. Pre: 5304, 5314. (3H,3C).

5334: THE AMERICAN COLLEGE STUDENT & THE COLLEGE ENVIRONMENT
Study of the characteristics and attitudes of traditional and nontraditional college students; effect of the college environment on students. Pre: EDRE 5404. (3H,3C).

5984: SPECIAL STUDY
Variable credit course.

6004: THEORIES OF EDUCATIONAL ADMINISTRATION
A general course for students of administration in public and private schools, community colleges, four-year colleges, and universities. Content includes purposes and nature of theory in educational administration and the application of organizational theory to education. Theories of decision making, communication, leadership, climate, power, conflict, change, morale, and motivation are covered. (3H,3C).

6014: ADMINISTRATION OF INSTRUCTIONAL PROGRAMS & SUPPORT SERVICES
The roles and responsibilities of central office (system) and building level (school) personnel in the administration of instructional programs and services. Students engage in a variety of activities designed to improve their skills in planning, organizing, delivering, and monitoring instructional programs and services within this dynamic environment. Must have administrative or supervisor certification and experience. Pre: 6004. (3H,3C).

6024: PUBLIC SCHOOL BUDGETING
Policies, principles, and practices involved in the practice of public school budgeting. Pre: 5054. (3H,3C).

6034: PLANNING EDUCATIONAL FACILITIES
Basic information needed by administrators to mount an effective planning effort within an organization; to plan, develop, and maintain satisfactory buildings to house modern educational programs; to supervise the work of other professionals and technicians in designing and constructing facilities; and to evaluate such efforts. Meets Virginia requirements for placement on the Eligible List of Division Superintendents. Pre: 5014. (3H,3C).

6044: GOVERNANCE & POLICY IN EDUCATION
Antecedents of public policy affecting education in the United States, and the relationships between policy making and implementation and educational administration. Pre: 6004, 5024. (3H,3C).

6054: COLLEGE & UNIVERSITY ADMINISTRATION
Advanced graduate study of the governance and administration of the modern, contemporary university in the United States with a focus on the research literature in the field. Pre: 6004. (3H,3C).

6064: HIGHER EDUCATION IN THE UNITED STATES
Diversity of institutions of higher learning is examined through variations in the respective goals and purposes of distinct types of institutions and examined through variations in the constituencies served by different types of institutions and their differential impact on students and faculty. (3H,3C).

6074: HIGHER EDUCATION LAW
Legal process in higher education. Emphasis on corporate responsibilities, faculty and student rights, tort liability, and accreditation. Analysis of current national and state court decisions affecting higher education. (3H,3C).

6084: FINANCIAL ADMINISTRATION IN HIGHER EDUCATION
Financing higher education. Emphasis on examination of the revenue source and patterns of funding and the roles of federal, state, and local governments in the fiscal support of higher education. Methods for the determination of institutional resource allocation, program and financial planning, and the internal allocation and effective use of resources. Pre: 6054 or EDCC 6314. (3H,3C).

6104: ORGANIZATION DEVELOPMENT IN EDUCATION
Methods of planned change in education. Emphasis on the application of organization development practices to educational settings and to an analysis of the relationship of these practices to contemporary educational administration. Pre: 6004, 6064. (3H,3C).

6114: STAFFING PRACTICES IN EDUCATION
A study of human resource management in education. Emphasis will be given to recruitment and selection, induction and orientation, supervision, staff development, and performance appraisal practices at all levels of education. Doctoral standing or instructor permission is required. (3H,3C).

6204: POLICY STUDIES IN EDUCATION
Study of policy-making, policy analysis, and educational reform. Emphasis will be given to the policy-making process, state and federal roles in public education, the role of values and interest groups, policy analysis, equality of educational opportunity, systemic reform and implementation, and politics of education. (3H,3C).

6214: STATE ROLE IN EDUCATION
Focuses on acquiring knowledge and understanding of state education public policy formulation and on the role of state government in education. The course will address four major areas: government structures, the processes of policy development at the state level, process of policy implementation, and critical issues in the analysis of implementation strategies and policy effects. All levels of the educational system will be examined (i.e., elementary secondary, and post-secondary levels, including community colleges). (3H,3C).

6304: THEORIES OF EDUCATIONAL ORGANIZATIONS
Study of educational organization theory and behavior. Emphasis will be given to understanding institutional structures and cultures in their educational, social, economic, and political contexts with a view toward organization improvement, development, and reform. (3H,3C).

6424: INSTITUTIONAL EFFECTIVENESS & OUTCOME ASSESSMENT IN HIGHER EDUCATION
Study of institutional conditions that determine effectiveness including effects of institutions on student learning and personal development. Includes assessment of general education, the academic major, affective student learning, retention, employment suitability, and other aspects of student life related to teaching and learning. (3H,3C).

ADULT AND CONTINUING EDUCATION (ALHR)

(See Department of Human Development.)

EDUCATIONAL RESEARCH, EVALUATION, AND POLICY STUDIES (EDRE)

The Educational Research and Evaluation program is designed to prepare a small cadre of research methodologists for employment in universities, government agencies, school systems, and private organizations. The program emphasizes the design and analysis of both qualitative and quantitative studies and offers a Ph.D. in Educational Research and Evaluation.

GRADUATE COURSES (EDRE)

5404: FOUNDATIONS OF EDUCATIONAL RESEARCH & EVALUATION
Research and evaluation in education with emphasis on development of skill requisite for utilizing research and evaluation studies in practical situations. Applies these skills in exercises related to various research and evaluation models. (3H,3C).

5644: QUESTIONNAIRE DESIGN & SURVEY RESEARCH IN EDUCATION
This course provides an overview of survey research for graduate students in education. It covers the process from project formulation and sampling, through instrument design and question formulation, to data processing and report writing. Emphasis will be on a questionnaire design, providing students with an opportunity to create and revise their own questionnaire and critique instruments used in educational surveys. Pre: 5404. (3H,3C).

6605-6606: QUANTITATIVE RESEARCH METHODS IN EDUCATION I & II
This two-course sequence is designed to provide an overview of basic research design, measurement and statistical concepts in social and behavorial research. Emphasis will be placed on understanding the process of social and educational research in field settings, hands-on experience of designing and conducting research, and analysis of data. Pre: 5404. (3H,3C).

6614: QUALITATIVE METHODS IN EDUCATIONAL RESEARCH
Introduces students to methods which are largely nonquantitative. Topics include: data collection through structured and semi-structured interviews, records research; field observation; scaling concerns; internal and external validity problems in qualitative research; and data aggregation and analysis. Pre: 6604. (3H,3C).

6624: MEASUREMENT THEORY IN EDUCATION
Methods and theories of estimating and enhancing test score characteristics, particularly reliability and validity of aptitude and achievement tests. Problems associated with test construction, use, and score interpretation will be emphasized. Pre: STAT 5634. (3H,3C).

6634 (STAT 6634): ADVANCED STATISTICS FOR EDUCATION
Multiple regression procedures for analyzing data as applied in educational settings, including curvilinear regressions, dummy variables, multicollinearity, and introduction to path analysis. Pre: STAT 5634. (3H,3C).

6644: ADVANCED RESEARCH DESIGN & METHODOLOGY
Principles of experimental design with applications to the behavioral sciences emphasizing appropriate statistical analysis. Pre: STAT 5634. (3H,3C).

6654: MULTIVARIATE STATISTICS FOR APPLICATIONS TO EDUCATIONAL PROBLEMS
Multivariate statistical procedures presented in an applied research setting. Oriented toward the logical extension of univariate tests of significance and estimation procedures to multivariate problems. Emphasis on using existing computer software packages. Pre: EDRE 6634, EDRE 6644, STAT 6634, STAT 6644. (3H,3C).

6664 (SOC 6664): APPLICATION OF STRUCTURAL EQUATIONS IN EDUCATION
Applications of structural equation causal models in educational research and discussion of the methodological questions pertaining to such models. Topics include recursive and nonrecursive models, measurement errors in causal models, latent unobserved variables, and covariance structures. Pre: 6634. (3H,3C).

6704: EVALUATION METHODS IN EDUCATION
Principles of evaluation with emphasis on practices applicable to a variety of educational settings. The theoretical and philosophical bases which lead to alternative methodologies. Design and measurement alternatives are considered within the jurisdictional, theoretical, and philosophical contexts. Pre: 6604. (3H,3C).

6724: PLANNING & DEVELOPING EDUCATIONAL RESEARCH
Strategies for conducting sponsored research in education with emphasis on developing specifications for research (RFP's), developing research proposals, and evaluating competitive research project proposals. Course focus includes requirements for post-award project administration with attention paid the role of the project director. Pre: 6634. (3H,3C).

6734: PROGRAM & POLICY EVALUATION IN EDUCATION
An advanced course in policy research and program evaluation strategies and methods in aid of education policy decisions particularly in state and local government jurisdictions. Pre: 6704. (3H,3C).

6794: ADVANCED TOPICS IN EDUCATIONAL RESEARCH
Advanced treatment beyond standard courses in topics such as questionnaire design, survey sampling, factor analysis, and meta analysis. May be repeated with different topics for up to 6 hours of credit. Variable credit course. Pre: 6604, STAT 5634.

COUNSELOR EDUCATION (EDCO)

Areas of master's specialization include school counseling (major emphasis) and community counseling. This graduate program leads to the M.A. in counselor education, and the Ed.D. and Ph.D. and is designed to prepare competent professionals to provide counseling to individuals of all ages, with an emphasis on children and adolescents. All programs are CACREP approved. Students study a variety of theoretical approaches to individual and group counseling, consultation, and intervention strategies. Appraisal/assessment methods, counseling theories and techniques, career development through the lifespan, and research are emphasized. Concern for diverse populations and emphasis on legal and ethical issues are used throughout the curriculum.

SPECIAL ADMISSION REQUIREMENTS

Plans of study for master's students are determined by faculty advisors and require a minimum of at least 48 semester hours. Students must complete extensive clinical

studies and practicum work, primarily in schools. Programs of study for post-master's students require at least 100-130 semester hours.

GRADUATE COURSES (EDCO)

5204: PRINCIPLES & PRACTICES OF COUNSELING
Survey of the philosophy, scope, purposes, and methods employed in a variety of counseling settings including agencies, private practice, higher education, and elementary/middle/secondary schools with emphasis on services offered and professional identity and ethical issues. X-grade allowed. (3H,3C).

5214: THEORY CNSLG & CONSUL
Major theories used to understand and change behavior in a counseling setting. Emphasis is placed on the application of theoretical orientations to understanding and changing behavior of clients. Systematic integration of themes used in the counseling process, including consulting and coordination roles in school and community settings. Pre: 5204. (3H,3C).

5224: COUNSELING TECHNIQUES
Systematic integration of techniques used in the counseling process. Course provides extensive practice, learning, integrating, and practicing skills characteristic of effective helping relationships. Extensive use is made of audio and video feedback in critiquing counseling interviews and techniques. Pre: 5214. (3H,3C).

5234: GROUP COUNSELING
Introduction to group counseling theory and practice. Emphasis on application of group counseling principles to practical settings. In a laboratory setting, students receive feedback about their personal behavior in a group and supervised practice in the design, implementation, and evaluation of a short term group counseling project. Pre: 5214, 5224. (3H,3C).

5244: COUNSELING DIVERSE POPULATIONS
Examination and application of counseling strategies for special client populations including the exceptional; economically disadvantaged; culturally, racially and ethnically different; those with different life styles. Emphasis on the range of human characteristics. Pre: 5204. (3H,3C).

5254: CAREER DEVELOPMENT & INFORMATION SERVICES
Evolution of how the relationships of work and leisure have evolved into the concept of Career Development. Brief review of the major theories of Career Development and their application to the collection, evaluation, and use of career information in a variety of counseling/student development settings. Pre: 5204. (3H,3C).

5264: APPRAISAL IN COUNSELING
Various individual and group tests and informal approaches to better understanding of the individual in counseling. Case study methods examined in detail. Interpretation of test data and role of counselor in testing emphasized. Designed for masters level counselor preparation. 12 additional hours of suitable courses in education, psychology, or statistics required. Pre: 5204, EDRE 5404 or EDCI 4604. (3H,3C).

5284: PRACTICUM: COUNSELOR EDUCATION
Supervised experience in the practice of counseling. Didactic instruction in advanced counseling techniques and methods coupled with practice with clients in a supervised setting. Extensive feedback on counseling practice in individual sessions and group seminar. Must have liability previous course work in the field required. insurance. X-grade allowed. Pre: 5204, 5214, 5224. (3H,3C).

5354: COUNSELING THE SUBSTANCE ABUSER
An overview of the strategies, goals, methodologies, program and types of knowledge and skills necessary for effective identification and treatment of substance abuse. Examines the classifications of drugs, their impact on users and their family members, the process of addiction and recovery, treatment resources, and the legal and ethical guidelines for working with substance abusers. (3H,3C).

5364: SCHOOL COUNSELING
Theory and practice of school counseling at the elementary, middle, and high school level, and introductory skills for those settings. Provides understanding of basic services performed by the school counselor; developmental characteristics of the age groups served; ethical, legal and societal issues that affect school counselors; special education terminology; techniques useful in school counseling; and sources of materials available for educational and career counseling at various school levels. Pre: 5204, 5214. (3H,3C).

5374: COMMUNITY COUNSELING
Designed for counselors who are interested in understanding, learning, and/or working as a counseling professional in a community counseling setting. Familiarizes students with community counseling and prepares them with skills for that setting. Examines concepts of social intervention, implications for the counseling process, the role of the community counselor, prevention in community counseling and current controversies and issues. Pre: 5204, 5214. (3H,3C).

5614: INTERNSHIP
Clinical experience (minimum 600 hours) under the supervision of a university staff member and a site supervisor in an appropriate field site: school (at least 300 hrs K-6 & at least 300 hrs 7-12), community agency, university counseling center, or other setting. Extensive feedback in individual sessions and group seminar. (12 hours minimum for program). Must have liability insurance. Pass/Fail only. Variable credit course. Pre: 5284.

6304: CLINICAL SUPERVISION
A didactic and clinical study of supervision. Training in the differential conceptual approaches and the different methodologies of supervision, as well as the application of the theory and skills to actual supervisory processes with supervisees. Trainees will supervise master's students and document their supervision skills for clinical review. Students will supervise a counselor or intern as a part of the course and document with videotape. Must have liability insurance. (3H,3C).

6404: ADVANCED COUNSELING THEORY & RESEARCH
Theories of counseling examined in the context of contemporary research and practice. Effectiveness of selected counseling theories and practice is evaluated. Aspects of past and contemporary research in counseling are reviewed. Pre: 5214, 5224. (3H,3C).

6414: ADVANCED GROUP COUNSELING
Design, delivery, and facilitation of group counseling content at an advanced level. Students supervise group counseling practices of graduate students taking the basic master's course. Students participate in an intensive interpersonal examination of personal behavior in a group setting and derive implications for group facilitation from both the experiential and reading bases. Extensive coursework and experience in counseling required. Pre: 5234. (3H,3C).

6424: CROSS CULTURAL COUNSELING
Study and supervised experience in counseling with clients who are culturally different. Pre: 5244. (3H,3C).

6454: ADVANCED VOCATIONAL APPRAISAL
In-depth study of vocational appraisal techniques and strategies to assist in counseling and school psychology programs. Emphasis upon vocational assessment programs and techniques for adolescents and adults, with some emphasis on assessment of handicapped and disadvantaged clients. Pre: 5264. (3H,3C).

6464: CAREER DEVELOPMENT THROUGH THE LIFE SPAN
To review the basic principles of Human Growth and Development through the Life Span with a special emphasis on career development. Consideration will be given to the social, economic, political, family, and educational influences on an individual as each one attempts to balance work and leisure into a satisfying pattern of career development over the life span. 12 or more hours of counseling required. Pre: 5254. (3H,3C).

6474: ADVANCED PRACTICUM
Provides advanced graduate students in counseling/student development with in-depth supervision and student personnel experiences in various field settings. Experiences accompanied by intense faculty supervision and evaluation. (Maximum 12C). 30 hours previous coursework in the field required. Variable credit course.

6484: LEGAL & ETHICAL ISSUES IN COUNSELING & CONSULTATION
Principles and practices of legal and ethical issues in counseling and consultation as applied to school, community counseling, and/or private practice settings. Discusses the laws, the court system, and court cases that affect counseling and consultation, as well as the sources and parameters of ethical behaviors. Examines the objectives and practices of ethical codes of counseling and consultation. (3H,3C).

6524: DOCTORAL INTERNSHIP
Provides advanced graduate students in Counselor Education with in-depth supervision and experiences in various field settings for a minimum of 600 clock hours. May include supervised experiences in a clinical setting, clinical supervision, and teaching. Includes most activities of a regularly employed professional in the setting. Experiences accompanied by intense faculty and on-site supervision and evaluation. (12 hours minimum required in program). Must have liability insurance and instructor consent. Pass/Fail only. Variable credit course.

6534: DSM APPLICATION IN COUNSELING
Advanced study of the criteria of mental disorders and standard diagnostic and assessment procedures. Provides students with the extensive knowledge and skills necessary to differentiate abnormal from normal behavior in children and adults, with special emphasis upon the identification and assessment of the mental disorders included in the Diagnostic and Statistical Manual of Mental Disorders (DSM). Emphasis will be on the application of the DSM in counseling situations. (3H,3C).

ADMINISTRATION AND SUPERVISION OF SPECIAL EDUCATION (EDSE)

This program offers only post-master's degrees–Ed.S., Ed.D., and Ph.D. The Ed.S. and Ed.D. are designed for personnel preparing to be administrators and supervisors of special education in local, state, and federal education agencies or in the private sector. The Ph.D. is designed for experienced administrators and supervisors of special education who aspire to positions in higher education in preparation of such personnel. Courses may be applied to meet state licensure requirements in educational administration and supervision, toward advanced graduate degrees in administration and supervision of special education, or toward graduate and advanced graduate degrees in educational administration.

SPECIAL DEGREE REQUIREMENTS

Course work is available at off-campus graduate centers. A 3.3 grade point average in a master's degree program is required for admission, and a 3.5 average is required for continuance in the program. The Ed.S., Ed.D., or Ph.D. applicant must have completed three years of successful experience working with individuals with disabilities.

Each student's program of study will be determined by a faculty advisory committee according to the student's background and professional goals.

GRADUATE COURSES (EDSE)

5104: CURRENT ISSUES IN SPECIAL EDUCATION
Examination of the most significant current issues in special education. (3H,3C).

6204: ADMINISTRATION & SUPERVISION OF SPECIAL EDUCATION
Examination of the role and responsibilities of the administrator, director, or supervisor of special education at the school district, state, and federal levels. Statutory requirements, fiscal basis, organizational structure, relationship to general school administration, instructional and related services delivery systems are explored. (3H,3C).

6214: ANALYSIS OF MANAGEMENT PROBLEMS IN SPECIAL EDUCATION
Detailed analysis of management problems facing the administrator of special education in the public schools. Topics include analysis of federal and state regulations governing special education, various state and federal funding patterns, facilities, transportation, cooperative and regional programs, policy development, personnel recruitment, and personnel retention. Pre: 6204. (3H,3C).

6234: SUPERVISION OF SPECIAL EDUCATION TEACHERS & PROGRAMS
Theory and practice of instructional supervision in educational programs for children with disabilities. Focus on strategies for responding to the persistent issues and problems surrounding the provision of effective special education programs. Three years teaching experience required. (3H,3C).

6254: LEGAL ASPECTS OF SPECIAL EDUCATION
Review and analysis of current case law and litigation related to special education. Focus on the legal system that assures children with disabilities free appropriate public education, with emphasis on due process procedures and other procedural safeguards, discipline, program accessibility, and application of the least restrictive alternative principle in special education programming. (3H,3C).

6264: EVALUATING SPECIAL EDUCATION PROGRAMS
Emphasis on contextual factors related to the evaluation of special education. Evaluation focus on specific aspects of the local special education program. (Course not usually considered a part of the research requirement in education.) Pre: EDCI 5384 or EDRE 6704. (3H,3C).

GRADUATE COURSES (EDAE)

5604: GRADUATE SEMINAR IN EDUCATION
Selected topics in administration, counseling, adult and continuing education, research and evaluation, and community college and other domains of higher education. Emphasis on interactive discourse on topics not typically included in regularly scheduled courses. Maximum 3C per course. Variable credit course. X-grade allowed.

5614: INTERNSHIP
Student participation in a planned clinical experience under the supervision of a university staff member in an appropriate work center. Maximum 12C. Consent required. Variable credit course.

5624: EXTERNSHIP IN EDUCATION
Special problem-solving clinics for experienced educational practitioners who are engaged part-time in graduate study while continuing in positions of leadership in education. Faculty work with groups of experienced administrators, student personnel workers, supervisors, or instructors in systematic analysis of current educational problems and evaluation of educational practice. Students judged on quality of their investigations, reports, and discussion. Maximum 12C. Variable credit course. X-grade allowed.

5704 (EDVT 5704): POST-SECONDARY OCCUPATIONAL & COMMUNITY SERVICE EDUCATION
(3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6304: FUNDAMENTALS OF COMMUNITY COLLEGE EDUCATION
(3H,3C).

6914: PROBLEMS IN EDUCATION
Study of contemporary problems in various education settings such as administration, counseling, community college education, and adult and continuing education. Maximum 3C per course. Variable credit course. X-grade allowed.

6924: PROFESSIONAL SEMINAR
Critical review, presentation, and discussion of current data-based and issues-related literature, either published or presented at recent national meetings. Provides students an opportunity to amalgamate their prior course experiences to produce a draft dissertation prospectus. Maximum 6C credit allowed toward program of study. Pass/Fail only. Variable credit course. Pre: EDRE 6604.

7704: FIELD STUDIES IN EDUCATION
Advanced applied research and/or evaluation study in one or more educational institutions or agencies. The student is graded on the basis of the design of the study and ability to conduct the study and report the results. Maximum 12C. Pass/Fail only. Variable credit course. Pre: EDRE 6604.

7714: INTERNSHIP IN EDUCATION
Planned program of advanced clinical practice in education through assignment under direct supervision of outstanding practitioner for periods up to two semesters. Maximum 24C. Pass/Fail only. Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ELECTRICAL & COMPUTER ENGINEERING

J.S. Thorp, Department Head and Hugh P. and Ethel C. Kelly Professor

W.H. Tranter, Assistant Department Head for Graduate Education and Bradley Professor of Communications

University Distinguished Professors: F.C. Lee
Alumni Distinguished Professor: C.W. Bostian
Lewis A. Hester Chair in Engineering: R.O. Claus[1]
Bradley Distinguished Professor of Electromagnetics: G.S. Brown
J. Bryon Maupin Professor: J.D. van Wyk
University Distinguished Professor Emeritus: A.G. Phadke
Thomas L. Phillips Professor Emeritus: W.L. Stutzman
Professor Emeritus: I.M. Besieris; D.Y. Chen; D.A. de Wolf; G.G. Gray, W.S.W. Stephenson; H.F. VanLandingham
Associate Professor Emeritus: R.W. Conners; R.L. Moose; C.E.Nunnally
Professors: J.R. Armstrong; P.M. Athanas; A..A. Beex; D. Boroyevich; R.P. Broadwater; G.S. Brown[2]; N.J. Davis IV; W.A. Davis[2]; D.S. Ha; R.W. Hendricks; I. Jacobs; Y. Liu; G.Q. Lu[1]; S.F. Midkiff[2]; L.M. Mili; T.C. Poon; T. Pratt; S. Rahman; K. Ramu; J.H. Reed; S.M. Riad; A. Safaai-Jazi; J.G. Tront[2]; A. Wang; A. Zaghloul
Associate Professors: A.L. Abbott; W.T. Baumann; A.E. Bell; W.R. Cyre; L. DaSilva; J. De La Ree Lopez; L.J. Guido[1]; M. Hsiao[2]; M.T. Jones; P. Kachroo; D.K. Lindner[2]; A. Mishra; C.D. Patterson; S. Raman; B. Ravindran; W.A. Scales; K.S. Tam; Y.J. Wang
Assistant Professors: A. Annamalai; M. Buehrer; V. Centeno; S.W. Ellingson; T. Hou; Y. Liang; A.B. MacKenzie; T.L. Martin; K. Meehan; H. Odendaal; J.M. Park; S. Shukla; D.J. Stilwell; C.L. Wyatt[2]
Instructors: M.P. Alley; L.K. Pendleton; G.F. Reid; J.S. Thweatt

[1] Joint appointment with Materials Science & Engineering
[2] Joint appointment with Biomedical Engineering & Sciences

Graduate Counselor: C.B. Hopkins

E-mail: vt.ece.gradadv@vt.edu (graduate counselor);
vt.ece.gradadm@vt.edu (admission-related matters)

Web: www.ece.vt.edu/

The Harry Lynde Bradley Department of Electrical and Computer Engineering offers graduate programs leading to the M.E., M.S., and PhD. in electrical engineering and computer engineering. For the master's degree, each plan of study, developed by the student in consultation with his or her faculty advisor, must contain a limited number of "core" courses. Except for research assistants, the thesis is optional. The non-thesis option is especially suitable for part-time graduate students employed as engineers by industry and government agencies. Students may also earn a M.E. in the practice-oriented master's program through the National Capital Region extended-campus program located in Falls Church, VA.

The Ph.D. degree programs are research-oriented; applicants applying for this degree program must have a M.S. degree in CPE, EE, or Physics. Undergraduate students having a B.S. degree, earning 3.5 or higher GPA, are automatically placed in the direct-Ph.D. program. Upon completion of 21 course credit hours, student is placed in the M.S. thesis option or Ph.D. program accordingly. The student and

advisory committee compose the Ph.D. Plan of Study and courses may be designed to meet the student's individual interest and needs.

The Graduate Record Examination is required for all applicants (other than Virginia Tech BS/MS applicants and undergraduate students earning a BS degree in ECE at Virginia Tech with a 3.5 or higher GPA , or those students who take the exam prior to a change in status or special categories of excellence for students enrolled in the Commonwealth Campus Program).

Applicants earning a degree from non-English institutions are required to take the TOEFL test earning 250 or higher computer-based score before consideration is given for admission.

There are no foreign language requirements for graduate degrees in Electrical Engineering or Computer Engineering.

RESEARCH AREAS IN ECE

Students select their area of interest for M.S. (non-thesis and thesis options) and Ph.D. degree programs. The following are approved areas of concentration.

Electrical Engineering:

Biomedical Engineering
Communications & Signal Processing
Controls/Systems
Electromagnetics
Electronics/Circuits
Power Systems

Computer Engineering:

Computer Systems
VLSI & Design Automation
Networking
Software & Machine Intelligence

SCHOOL OF BIOMEDICAL ENGINEERING

Students in ECE have the ability to get an M.S. or Ph.D. degree option in Biomedical Engineering through the School of Biomedical Engineering and Sciences.

Additional information can be obtained under Biomedical Engineering in this catalog.

SPECIAL FACILITIES

Facilities and computers are available for research in several different areas of electrical and computer engineering. These well-equipped facilities include the following laboratories and research centers.

Antenna and Radio Laboratory
Autonomous Systems and Control Laboratory
Center for Energy and the Global Environment
Center for Microelectronics, Optoelectronics, and Nanotechnology
Center for Photonics Technology
Center for Power Electronics
Center for Rapid Transit Systems
Center for Wireless Telecommunications
Computer Research Laboratory
Computer Systems Laboratory
Configurable Computing
Controls/Simulation Laboratory
Digital Signal Processing Laboratory
Electromagnetic Interactions Laboratory
Electronic Materials and Hybrid Microelectronics Laboratory
Energy Systems Research Laboratory
Fiber and Electro-Optics Research Center
Future Energy Electronics Center
Hardware Accelerator Project
Machine Intelligence Laboratory
Mobile and Portable Radio Research Group
Motion Control Laboratory
Networking Lab
Optical Image Processing Laboratory
Robotics Laboratory
Satellite Communications Laboratory
Satellite Tracking Station
Systems and Control Research Facility
Testing, Verification, and Power Management Lab
Time Domain Laboratory
Virginia Tech Information Systems Center
VLSI for Telecommunications (VTVT)
Wireless Microsystems

Graduate fellowships, such as Bradley Fellowships, Department Head Doctoral Fellowships, and Pratt Fellowships, as well as teaching and research assistantships are available.

GRADUATE COURSES (ECE)

5004: NETWORK ANALYSIS
Modeling and analysis of networks by t-domain and s-domain techniques. Network topology, state-space models and solutions. Multiports, scattering parameters, frequency and time domain representations of network functions. Large-scale networks. Computer aided analysis and optimization. Linear noisy networks. Pre: 3604. (3H,3C).

5015-5016: NETWORK SYNTHESIS & DESIGN
Positive real and bounded real concepts. Synthesis of two-element-kind lumped networks. Scattering description. Synthesis of RLC impedances. Approximation methods for lumped filters. Synthesis of microwave filters. Synthesis of switched-capacitor networks. Design techniques for active RC filters modeled on classical structures. Pre: 4205. (3H,3C).

5105-5106: ELECTROMAGNETIC WAVES
Maxwell's electromagnetic field theory and its applications to engineering problems. 5105: Fundamental concepts and theorems; elementary wave theory and boundary value problems; applications to radiation, transmission line, and waveguide problems. 5106: Analytical techniques (Green's theory, modal analysis, etc.) pertaining to guided wave propagation and to scattering and diffraction by discontinuities and inhomogeneties in metallic and dielectric waveguiding structures. Pre: 3106. (3H,3C).

5144: INTRODUCTION TO ELECTRO-OPTICS
Physical optics, wave propagation in inhomogeneous media, acousto-optic and electro-optic effects and their applications in intensity modulation and phase modulation of laser beams, lasers, optical detection. Pre: 3106. (3H,3C).

5154: OPTICAL WAVEGUIDES: THEORY & APPLICATIONS
Modal analysis of planar and cylindrical dielectric waveguides; weakly guiding fibers and LP modes; graded index fibers; ray analysis of optical waveguides; radiation and leaky modes; coupled-mode theory and applications; special fibers; nonlinear effects. Pre: 5105. (3H,3C).

5200 (MSE 5200): SOLID-STATE MATERIALS & DEVICES
Introduction to the structural, thermal, optical, electrical, and magnetic properties of solid-state materials. Atomic scale models of physical phenomena at the macroscopic scale. Connection is made between basic materials properties and the operational characteristics of selected solid-state devices. Pre: 4214 or MSE 3255 or PHYS 3455. (3H,3C).

5204: POWER SEMICONDUCTOR DEVICES
Characteristics, fabrication and application of power semiconductor devices which includes BJT, FET, power diodes, insulated gate and static induction transistors. Device drive requirements and power circuit interaction. Pre: 3204. (3H,3C).

5205-5206: BASIC SEMICONDUCTOR DEVICES
Description of the performance characteristics and limitations of basic semiconductor electronic devices in terms of the properties of semiconductor materials and device structure. (3H,3C).

5214: PHASE-LOCKED LOOPS: THEORY & PRACTICE
Fundamental theory and design concepts of frequency synchronization techniques. Emphasis is on phase-locked loops and applications in communications for frequency synthesis, tracking, and demodulation. Laboratory investigates fundamental principles of operation with a final project to develop specific aspects of a loop in detail. Alternate year course. Pre: 4405. (2H,3L,3C).

5220: RADIO FREQUENCY INTEGRATED CIRCUIT TECHNOLOGY & DESIGN
Integrated circuit (IC) implementation of RF circuits for wireless communications applications. Transceiver architectures for current wireless communications standards; active/passive device technologies for RFIC implementations; low noise amplifiers; mixers; frequency sources; power amplifiers; single-chip radios; and RFIC packaging and testing. Case studies of modern RFIC chip sets for current wireless communications standards are examined. The course involves circuit design at the IC level; modern RF/microwave CAD software will be used in conjunction with the course. Design of wireless transceiver functional block component RFIC chip. Pre: (3204, 3614), (4605 or 4104). (3H,3C).

5224: NON-LINEAR COMMUNICATION CIRCUITS
Advanced methods of analysis and design of communication circuits with emphasis on nonlinear effects and filtering. Nonlinear device models and their use in the design of oscillators and mixers at HF through UHF frequencies. The design of power amplifiers. Pre: 4605. (3H,3C) I. Alternate years.

5234: EMI AND NOISE REDUCTION TECHNIQUES
Theory and practice of E.M. noise coupling. Techniques for noise reduction: shielding, grounding and filtering. Measurement of EMI to comply with government regulation. EMI problems and solutions to switching power supply applications. Design of EMI filter. Pre: 4224 or 4205. (3H,3C).

5244: ADVANCED POWER CONVERSION TECHNIQUES
High-frequency resonant, quasi-resonant, and multi-resonant power conversion techniques; zero-voltage and zero-current switching techniques in pulse-width modulation converters and inverters. Pulse-width modulation and frequency modulation; non-linear analysis techniques for resonant and soft-switching converters and inverters. Power factor correction rectifiers and distributed power systems. Pre: 4224. (3H,3C).

5254: POWER CONVERTER MODELING & CONTROL
Nonlinear modeling of power conversion circuit using discrete and average techniques analysis and design of voltage mode and current mode control; parallel module operation and system interactions; distributed power systems; time domain simulation and frequency domain measurement techniques. Pre: 4224. (3H,3C).

5260: POWER ELECTRONICS SYSTEM INTEGRATION
A broad overview of advanced power electronics technologies with an emphasis on multi-disciplinary aspects of integrated design. Investigation of relationships between system application requirements and technological challenges in circuit topologies, power semicinductor devices, sensing and control, integrated packaging, and thermal management, and their impact on the system reliability and cost. Introduction to the concept of integrated power electronics modules and their application in distributed power systems and motor drives. The course is organized as a series of seminar lectures jointly taught by leading researchers from several universities and industry, via distance access. Pass/Fail only. Pre: 4224. (1H,1C).

5264: ADVANCED POWER ELECTRONICS LABORATORY
Design and testing of resonant converters and control circuits for high frequency power conversion applications. Pre: 5244. (3L,1C).

5274: MODELING & CONTROL OF THREE-PHASE PWM CONVERTERS
Power conversion principles for three-phase pulse-width modulation techniques, control and converters. Development of averaged models of three-phase rectifiers and inverters in stationary and rotating coordinates. Small-signal models in rotating coordinates and control design. Introduction of switching state vectors and different modulation schemes. Three-phase inverter and rectifier applications. Parallel and multi-level three-phase converters. Prerequisite or equivalent. Pre: 4224. (3H,3C).

5314: POWER SYSTEM OPERATION & CONTROL
A course dealing with modern power system operational and control problems and solution techniques. State estimation, contingency analysis, load-frequency control, and automatic generation control. Load flow analysis and external equivalents for steady-state operations. Pre: 4334. (3H,3C).

5324: POWER SYSTEM PLANNING
A study of generation planning, bulk power supply systems, production costing analysis, and load forecasting. Dispersed generation. Electric power system reliability and stability. Pre: 4334. (3H,3C).

5334: ELECTRIC MACHINES & TRANSIENTS
Development of inductances, flux linkages, voltage equations, linear transformations, continuous simulation techniques, and machine models. Transients on transmission lines, transformers, and machines. Arcing and restriking phenomena. Lightning arresters and insulation coordination. Pre: 4314. (3H,3C).

5364: ELECTRIC ENERGY & ENVIRONMENTAL SYSTEMS
Role of electricity from fossil and nuclear fuels, and renewable resources. Impact of high voltage transmission lines. Health effects of electricity generation. Assessment of cogeneration cycles and demand side management. Emission control in the US electric utility industry. Evaluation of uncertainties in quantifying emissions impacts. (3H,3C).

5404: MULTIVARIABLE CONTROL
An introduction to state space control design. The solutions to the linear-quadratic regulator problem, Kalman filtering problem, and the linear-quadratic-Gaussian problem will be examined. The robustness of the resulting control system will be analyzed and the loop-transfer recovery technique introduced. Pre: 5704. (3H,3C).

5504 (CS 5504): COMPUTER ARCHITECTURE
Advanced computer architectures, focusing on multiprocessor systems and the principles of their design. Parallel computer models, programming and interconnection network properties, principles of scaleable designs. Case studies and example applications of pipeline processors, interconnection networks, SIMD and MIMD processors. Pre: 4504. (3H,3C).

5505-5506: TESTING & FAULT-TOLERANT COMPUTING
Various topics on digital circuit testing and verification. 5505: Digital circuit testing including simulation, test pattern generation, design for testability, built-in-self-test, and diagnosis. 5506: circuit verification including two-level and multi-level circuit verification, sequential circuit verification, model-checking simulation-based verification, and ATPG-based verification. Graduate standing in ECE required. (3H,3C).

5514: DESIGN OF SYSTEMS ON A CHIP
System On a Chip (SOC) components. System level design representations and modeling languages. System level modeling. Target architecture models. Intra-chip communication. Graph partitioning algorithms. Task time measurement. Interconnect latency modeling. Back annotation of lower level timing to high level models. Synthesis of SOC components. Co-verification of SOC components: emulation, co-simulation. PRE: 4514. (3H,3C).

5524: PATTERN RECOGNITION
Computational methods for te identification and classification of objects. Feature extraction, feature-space representation, distance and similarity measures, decision rules. Supervised and unsupervised learning. Statistical pattern recognition: multivariate random variables; Bayes and minimum-risk decision theory; probability of error; feature reduction and principal components analysis; parametric and nonparametric methods; clustering; hierarchical systems. Syntactic pattern recognition: review of automata and language theory; shape descriptors; syntactic recognition systems; grammatical inference and learning. Artifical neural networks as recognition systems. Pre: STAT 4714. (3H,3C).

5534: REPRESENTATION & SYNTHESIS OF COMPUTER SYSTEMS
Application of artificial intelligence to high-level design automation. Various graphical and textual notational systems for the specification of digital systems will be examined. Methods of artificial intelligence will be used to integrate specifications and check for inconsistencies, and synthesis of designs from the integrated knowledge representation will be studied. Pre: 4504 or ECPE 4505. (3H,3C).

5544: CODING THEORY
Use of codes to improve the reliability of transmission over noisy channels. Algebraic structure of codes. Includes error detecting and correcting codes. BCH Codes, Reed Solomon Codes, and convolutional codes and codes for checking arithmetic operations. Pre: MATH 4124, STAT 4714. (3H,3C).

5545-5546: ADVANCED VLSI DESIGN
Advanced concepts in CMOS-based digital system are studied. The topics include implementation of special-purpose structures for complex digital systems, automation and verification of the design process, and design for testability (5545); and design techniques for low-power design, power dissipation estimation, and application of low-power techniques in the different levels of the design hierarchy (5546). Pre: 4540. (3H,3C).

5554: COMPUTER VISION SYSTEMS
Gives a critical examination of current theories of computer vision. Explores both image analysis and scene analysis methods with the emphasis being given to scene analysis techniques. Emphasis is placed on the strategies that can be used rather than upon particular operators. Gives the design trade-offs associated with the various strategies. Draws analogies between computer vision techniques and the operations that are seemingly performed in human vision. Co: CS 5534, CS 5814. (3H,3C).

5560: COMPUTER & NETWORK SECURITY
Introduction to the fundamentals of computer and network security. Students will analyze the client-server architecture for security weaknesses. Course topics include: legal and ethical aspects of computer security, the techniques used to penetrate systems and networks, analysis and repair of security flaws in Internet protocols, conceptual framework of computer network security architectures, and the identification of computer attacks. Pre: 4564. (3H,3C).

5564: WEARABLE & UBIQUITOUS COMPUTING
Issues in the design and use of wearable and ubiquitous computing systems. Topics covered include current research issues in system-level low power design, input/output devices, location and context-aareness, and networking. Students are expected to design, implement, and evaluate a wearable computing device or application. Pre: 4534 or 4550. (3H,3C).

5565-5566 (CS 5565-5566): NETWORK ARCHITECTURE & PROTOCOLS
5565: Principles and concepts of networking and protocols, with emphasis on data link, network, and transport protocols. Contemporary and emerging networks and protocols to illustrate concepts and to provide insight into practical networks including the Internet. Quantitative and qualitative comparisons of network architectures and protocols. 5566: Performance evaluation, design, and management of networks. Use of queuing and other analytical methods, simulation, and experimental methods to evaluate and design networks and protocols. Network management architectures and protocols. Graduate standing in EE, ECE, CS, or IT is required. Pre: STAT 4714 for 5565: 5565 for 5566. (3H,3C).

5575, 5576: OBJECT-ORIENTED SOFTWARE DEVELOPMENT
Use cases, class models, state models, interaction modeling, constraint modeling, message design, and concurrent and real-time systems. Students develop analysis documentation for an Engineering-related project. Pre: 4574. (3H,3C).

5604: COMPUTER-AIDED DESIGN & ANALYSIS OF COMMUNICATION SYSTEMS
Simulation techniques for communication systems operating in random environments. Simulation models for stochastic signals and system components including coders, decoders, modulators, non-linear amplifiers, bit and carrier synchronizers, equalizers and receivers. Techniques for modeling time-varying channels. Monte Carlo simulation, semi-analytic simulation and variance reduction techniques applied to the analysis, design and performance evaluation of communication systems. Programming experience required. Pre: 4624, 4634, STAT 4714. Co: 5605. (3H,3C).

5605-5606 (BMES 5525-5526): STOCHASTIC SIGNALS & SYSTEMS
Engineering applications of probability theory, random variables and random processes. Time and frequency response of linear systems to random inputs using both classical transform and modern state space techniques. Pre: STAT 4714 for 5605; 5605 for 5606. (3H,3C).

5614: FIBER OPTIC COMMUNICATIONS
Advanced fiber optic communications technology (including laser and optical amplifier dynamics, tunable optical filters, and non-linear phenomena), and applications to high-speed long-distance systems, local area networks and television distribution. Interrelationships between the technology, architecture, and application of fiber optic communication systems. Pre: 4134, 4634, 5605. (3H,3C).

5620: ADVANCED DSP & FILTER DESIGN
Advanced analysis, design, and realization of digital filters. Efficient Discrete Fourier Transform algorithm implementations, finite word-length arithmetic, fixed point implementation, limit cycles, noise shaping, decimation and interpolation, multi-rate digital filter design, Hilbert transformers, analytic signal generation, basic adaptive filtering. Pre: 4624, STAT 4714.

5624: WAVELETS, FILTER BANKS & APPLICATIONS
Advanced digital signal processing topics. Review of filter design from a matrix perspective; relationship of time, frequency, and scale; downsampling, upsampling and multirate signal processing systems; quadrature mirror filters (QMF) and subband coding, biothogonal and orthogonal filter banks; multi-resolution analysis; wavelet basis construction and the cascade algorithm; wavelet representation of signals and Mallat's fast wavelet algorithm; and applications of wavelets and filter banks. Pre: 4624. (3H,3C).

5634: INFORMATION THEORY
Transmission of information over noisy channels. Measures of information and transmission channel capacity. Use of codes to improve the reliability of such transmission. Mathematical theory of information. Transmission at rates above channel capacity. Includes linear codes, error detecting and correcting codes, Hamming codes. Pre: 4634, 5605, STAT 4714. (3H,3C).

5635-5636: RADAR SYSTEMS ANALYSIS & DESIGN
5635: Theory and practice of radar systems used for detection, tracking, and location of targets. Covers measurement of range and velocity, pulse compression, design of radar transmitters, receivers, and antennas. 5636: Performance analysis of modern radar signal processing techniques. Topics include radar signal detection theory and optimal receiver analysis, target parameter estimation, pulse compression techniques, clutter reduction, and tracking. (3H,3C).

5644: OPTIMAL DISCRETE TIME
Estimation theory, the design, and computational aspects of linear and nonlinear discrete time state estimators for applications in control, communications, and signal processing. Gauss-Markov modeling, discrete time Kalman filter, nonlinear filtering, innovations representations, colored noise, reduced order filters. Pre: 5605, 5704. (3H,3C).

5654: DIGITAL COMMUNICATIONS
Fundamentals of theory, design, and analysis of modern digital communication systems. Representation of signal in digital form and optimum nonuniform quantization. Design and analysis of digital modulation formats and receivers using signal space techniques. Combining error correction techniques with digital modulation. Viterbi algorithm for maximum likelihood sequence estimation. Design and analysis of spread-spectrum communication systems. Pre: 4634, 5605. (3H,3C).

5655-5656: COMMUNICATION SYSTEM DESIGN
5655: Physical concepts and practical topics providing tools to calculate carrier-to-noise ratio in communication systems are discussed, including: noise processes, polarization topics, atmospheric propagation, receiver components, antennas, system calculation, and case studies. 5656: Advanced topics in digital satellite communications are discussed. These include multiple access, digital modulation, error correction coding, carrier phase, and symbol timing recovery. Co: 5105. (3H,3C).

5660: SPREAD SPECTRUM COMMUNICATIONS
Major topics include: direct sequence and frequency hopping methods, synchronization, resistance to jamming, low probability of detection, spreading codes and their generation, system performance, RAKE receivers, Code Division Multiple Access, cellular CDMA applications, wireless LAN applications, as well as commercial and military applications. Pre: 4634, 5605. (3H,3C).

5664: CELLULAR RADIO & PERSONAL COMMUNICATIONS
Fundamental theory and design of high capacity wireless communications systems. Topics include trunking, propagation, frequency reuse, modulation, coding, and equalization. Pre: 4634, 5605. (3H,3C.)

5674: SOFTWARE RADIOS: MODERN RADIO ENGINEERING
An introduction to software radios, devices that can be programmed to work with a variety of different radios. The course will cover the following topics: software radio architectures, existing software radio efforts, a review of basic principles, an analysis of receiver operation. Pre: 4624, 4634. (3H,3C).

5704: LINEAR SYSTEM THEORY
Introduction to the theory of linear systems represented by state equations; Jordan canonical form; solutions to state equations, relationship to transfer functions, stability, pole placement, observers. Graduate standing required. (3H,3C).

5714: ROBUST ESTIMATION & FILTERING
An introduction to the analysis and design of robust estimators and filters. Robustness concepts: qualitative robustness, breakdown point, influence and change-of-variance functions; Robust estimators: M-estimators, bounded influence and high breakdown point estimators: Robustification of the Kalman filter with application to system identification, spectral analysis, and electric power systems. Pre: STAT 4714. (3H,3C).

5724: NEURAL & FUZZY SYSTEMS
Introduction to various structures of artificial neural networks and fuzzy logic systems, as well as special learning mechanisms such as generalized back-propagation, clustering and genetic algorithms. Applications will be made to classification problems, binary associative memories, self-organizing maps, and nonlinear system modeling and control including on-line adaptation. Pre: 5704. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
To acquaint graduate students with recent and current research results and trends and to introduce researchers to students performing important work in Electrical and Computer Engineering. Pass/Fail only. (1H,1C).

5964: FIELD STUDY
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course. X-grade allowed.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course. X-grade allowed.

6104: ADVANCED TOPICS IN ELECTROMAGNETICS
Advanced topics of current interest in electromagnetic engineering. Topics are selected from current technical literature. Certain topics may be repeated. (3H,3C).

6114: ADVANCED ANALYTICAL ELECTROMAGNETICS
This course comprises Ph.D.-level material covering exact analytical and asymptotic techniques for the analysis of advanced electromagnetic problems involving wave propagation and scattering by finite and extended media inhomogenieties. Alternate Years. Pre: 5106. (3H,3C).

6115-6116: ANTENNA THEORY & DESIGN I, II
6115: Aperture theory. Aperture antennas: horns, reflectors, feeds. Array antennas. Phased arrays. 6116: Measurements. Antennas in wireless systems. Antenna synthesis. Waveguide slot arrays.

Microstrip antennas. Numerical techniques. Moment method analysis of wire antennas. Geometrical theory of diffraction. Finite difference time domain techniques. Co: 5105. (3H,3C).

6124: ADVANCED NUMERICAL ELECTROMAGNETICS
A thorough coverage of numerical methods for electromagnetics, including topics on the foundations of function theory, Green's functions, mode-matching, and numerical expansion techniques in both the time and frequency domains. Emphasis will be placed on the method of moments and the finite element method, with development of the theoretical foundations of these methods. Alternate year course. Pre: 5106. (3H,3C).

6204: ADVANCED TOPICS IN ELECTRONICS
Advanced topics of current interest in electronics engineering, with particular emphasis on microelectronics. Topics are selected from current technical literature to stress and reflect important potential areas in the electronic field. These topics include multichip modules, electronic packaging, microwave packaging, modeling simulation and evaluation of high speed devices, wideband characterization of electronic materials and multilayer structures, time and frequency domain measurement techniques. (3H,3C).

6304: ADVANCED TOPICS IN POWER SYSTEMS
Advanced topics of current interest in Electric Power Engineering. Topics are selected from current technical literature. Certain topics may be repeated. (3H,3C).

6314: MICROCOMPUTER APPLICATIONS IN POWER SYSTEMS
Role of microcomputers in monitoring, control, and protection of power equipment and networks. Hierarchical computer systems. Protection algorithms. Protection of line, transformers, and buses with microcomputers. Real time phasor measurements. Measurement of frequency. Pre: 4354. (3H,3C).

6334: COMPUTATIONAL METHODS IN POWER ENGINEERING
This course is designed to introduce various linear and nonlinear program-based optimization algorithms that are specially suited for the design, analysis and operation of electric power systems, power processing devices, machines, and transformers. Pre: 5324. (3H,3C).

6404: OPTIMAL CONTROL SYSTEMS
Application of dynamic programming and the calculus of variations to optimal control problems. Pontryagins maximum principle and its applications. Advanced optimization techniques. Pre: 5404. (3H,3C).

6414: ADAPTIVE CONTROL & NONLINEAR STABILITY THEORY
Survey of approaches to adaptive control, stability in the sense of Liapunov, absolute stability, input-output stability, design of stable adaptive controllers. Pre: 5704. (3H,3C).

6444: ADVANCED TOPICS IN CONTROLS
Advanced topics of current interest in control theory. May be repeated. (3H,3C).

6504: ADVANCED TOPICS IN COMPUTER ENGINEERING
Advanced topics of current interest in computer engineering which are taken from current research topics and/or technical publications. Prerequisites at 5000 level dependent on specific topics. (3H,3C).

6514: APPLICATIONS OF AUTOMATA THEORY TO DIGITAL DESIGN
Applications of theory of finite automata, push-down automata, and Turing machines to the design of digital machines. Emphasis will be on the computational capabilities of classes of finite and infinite automata and on the consequences for digital design. Theory of NP-completeness, description of NP complete problems in digital design, and the consequences for design processes. Pre: 3504, MATH 5454. (3H,3C)..

6604: ADVANDED TOPICS IN COMMUNICATIONS
Advanced topics of current interest in communications, which are taken from publications and industrial information. Pre: 5606. (3H,3C).

6614: DETECTION THEORY
Techniques of signal detection and parameter estimation theory. Topics include hypothesis testing, detection of stochastic signals in noise, detection and maximum likelihood estimation of signal parameters, sequential detection theory, optimal receiver design, and performance analysis. Pre: 5606. (3H,3C).

6624: SPECTRAL ESTIMATION & MODELING
An advanced introduction to the processing and modeling of random discrete-time signals. Random time series, auto- and cross-correlation sequences and their generation, filtering of random sequences, Wiener filters, matched filters, modeling assumption errors, one-step predictors, rational modeling of random sequences, parametric and non- parametric spectral estimation. Pre: 5605, 4624. (3H,3C).

6714: SYSTEM IDENTIFICATION
Various approaches to model structure proposition, determination and evaluation for deterministic and stochastic, continuous and discrete, linear and nonlinear systems from port measurements. Applications to communication controls and signal processing. Pre: 5704, 5605. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ECE)

The following 4000-level courses have been approved for graduate credit:

4104: MICROWAVE THEORY AND TECHNIQUES
Passive and active Radio Frequency and microwave components and circuits for wireless communications; transmission-line theory; planar transmission-lines and waveguides; S-parameters; resonators; power dividers and couplers; microwave filters; sources, detectors, and active devices; modern RF & microwave CAD; measurement techniques. Pre: (3106, 3204). (3H,3L,4C).

4114: ANTENNAS
Antenna fundamentals, analyses and design principles, and a survey of antenna types including: arrays, wire antennas, broadband antennas, and aperture antennas. Pre: 3106. (3H,3C).

4124: RADIO WAVE PROPAGATION
Behavior of radiated electromagnetic waves in atmosphere, space, urban and indoor environments; path, frequency and antenna selection for practical communication systems; propagation prediction. Pre: 3106. (3H,3C).

4134: FIBER OPTICS AND APPLICATIONS
Theory of optical fiber waveguide propagation and design applications in communication and sensing systems. Pre: 3106. (3H,3C).

4144: INTRODUCTION TO OPTICAL INFORMATION PROCESSING
Modern wave optics. The application of Fourier transforms to image analysis, optical spatial filtering, and image processing. Pre: 3106. (3H,3C).

4164: INTRODUCTION TO GLOBAL POSITIONING SYSTEM (GPS) THEORY AND DESIGN
Fundamental theory and applications of radio navigation with the Global Positioning System GPS. Satellite orbit theory, GPS signal structure and theory, point positioning with pseudoranges and carrier phases, selective availability, dilution of precision, differential GPS, atmospheric effects on GPS signals. Pre: 3106 or AOE 4134. (3H,3L,4C).

4184: FIBER OPTICS LABORATORY
Experimental analysis of optical fiber communication and sensing devices and systems including fiber construction and its properties. Optical sources and detectors, and system design. Pre: 4134. (3L,1C).

4205-4206: ELECTRONIC CIRCUIT DESIGN
Stability and response of feedback amplifier, wideband amplifiers, operational amplifier characterisitics, waveform generators and wave shaping, nonlinear circuit applications, signal generators, and photolithography. Design of analog electronic circuits, circuit simulation, response characterization, and printed-circuit construction. Pre: 3204. (3H,3C)

4214: ELECTRONICS
Semiconductor devices and materials, Heterojunctions, light-emitting diodes, photodetectors, solar cells, Gunn devices, coupled charge-devices, and thyristors. Pre: 3204. (3H,3C).

4224: POWER ELECTRONICS
Power devices and switching circuits including inverters and converters; electronic power processing and control as applied to industrial drives, transportation systems, computers, and spcacecraft systems. Pre: 3204. (3H,3C).

4234 (MSE 4234): SEMICONDUCTOR PROCESSING
Manufacturing practices used in silicon integrated circuit fabrication and the underlying scientific basis for these process technologies. Physical models are developed to explain basic fabrication steps, such as substrate growth, thermal oxidation, dopant diffusion, ion implantation, thin film deposition, etching, and lithography. The overall CMOS integrated circuit process flow is decribed within the context of these physical models Pre: 3054, 2204. (3H,3C).

4235-4236 (MSE 4235-4236): PRINCIPLES OF ELECTRONIC PACKAGING
This two-course sequence covers principles and analyses for design and manufacture of electronic packages. 4235: design issues such as electrical, electromagnetic, thermal, mechanical, and thermomechanical, are covered at the lower levels of packaging hierarchy. Materials and process selection guidelines are discussed for the manufacturing and reliability of chip carriers, multichip and hybrid modules. 4236: system-level package design issues for meeting application requirements and modeling tools for analyzing electronic packages are introduced. Materials and process selection guidelines are discussed for the manufacturing and reliability of packaged electronic products. Pre: 2204. Co: 3054. (3H,3C).

4274 (MSE 4274): ELECTRONIC PACKAGING LABORATORY
A laboratory course on electronic package design, fabrication and processing, and testing. Technologies addressed in the course are thick-film hybrid, thin-film processing, surface mount, wire bonding, and multichip module technologies. Pre: 4235 or MSE 4235. (3L,1C).

4284: POWER ELECTRONICS LABORATORY
Design and testing of electronic power processing systems for commercial and aerospace applications. Pre: 4224. (3L,1C).

4304: DESIGN IN POWER ENGINEERING
A study of the principles in electric power engineering. Expert systems, superconductivity, DC transmission, motor control, system protection, high performance motors, solar energy, microcomputer applications, machine design, computer-aided design, digital relaying and space station application. (3H,3C).

4314: CONTROL AND APPLICATIONS OF ELECTRIC MACHINES
Dynamics and control of different applications of electric machines, DC machines, synchronous machines, polyphase induction machines, and fractional horsepower machines. Pre: 3304. (3H,3C).

4324: ELECTRONIC CONTROL OF MACHINES
Dynamics and control of electric machines driven by electronic power converters. Pre: 4405, 4224. (3H,3C).

4334: POWER SYSTEM ANALYSIS AND CONTROL
Development of methods for power analysis and control. An analysis and design of systems for steady state, transient, and dynamic conditions. Digital solutions emphasized. Pre: 3304. (3H,3C).

4344: ELECTRIC POWER QUALITY FOR THE DIGITAL ECONOMY
Causes, consequences and solutions of power quality problems that affect the operation of computerized processes and electronic systems. Industry standards, monitoring techniques and economic consideration of power quality issues. Pre: 3304. (3H,3C).

4354: POWER SYSTEM PROTECTION
Protection of power apparatus and systems. Fuses. Voltage and current transducers. Relays. Coordination of relays. Pilot channels. Grounding practices. Surge phenomena. Insulation coordination. Pre: 4334. (3H,3C).

4364: ALTERNATE ENERGY SYSTEMS
Electric energy from alternative energy sources including solar, wind, hydro, biomass, geothermal and ocean. Characteristics of direct conversion, electromechanical conversion, and storage devices used in alternative energy systems. Power system issues associated with integration of small scale energy sources into the electricity grid. Pre: STAT 4714. (3H,3C).

4374: POWER SYSTEM PROTECTION LABORATORY
Experimental verification of principles and practice of protective relaying. Experiments and design projects to demonstrate the principles and techniques of industrial power system design. Fuses, time overcurrent, and instantaneous relays. Differential relaying for transformers. Distance relaying. Current and voltage transformers. Pre: 4334. Co: 4354. (3L,1C).

4405-4406: CONTROL SYSTEMS
4405: Introduction to control systems, modeling techniques, root locus analysis and design, Nyquist criteria, frequency domain compensation. 4406: Introduction to sample data techniques for control system design. Pre: ECPE 3704 for 4405; 4405 for 4406. (3H,3C).

4415-4416: CONTROL SYSTEMS LABORATORY
Design and implementation of controllers for physical systems. System identification techniques. 4415: Supplements material in ECPE 4405. Continuous-time modeling and control. 4416: Supplements material in ECPE 4406. Discrete-time modeling and control. Co: 4405 for 4415; 4406 for 4416. (3L,1C).

4500: FUNDAMENTALS OF COMPUTER SYSTEMS
Fundamental principles and concepts of computer systems. Computer hardware; Boolean logic; number systems and representation; design and operation of digital logic; instruction set architectures and computer organization; and basics of data communication and networking. Partially duplicates ECE 3504 and 4504. Master of Information Technology students only. Pre: Ability to program in a modern high-level programming language. (3H,3C).

4504 (CS 4504): COMPUTER ORGANIZATION
Information representation and transfer; instructions and data access methods; the control unit and microprogramming; memories; input/output and interrupts; secondary storage; the von Neumann SISD

organization; high level language machines; the RISC concept; special purpose processors including operating system, file, text, floating point, communication, etc. Multicomputers; multiprocessors; concurrent processing support; Pipeline machines, processor arrays, database machines; the data flow/data directed approach; computer networks. Pre: ECE 2504, CS 3204. (3H,3C).

4510: GENETIC ALGORITHMS AND EVOLUTIONARY DESIGN
Introduction to evolutionary computation and design, including genetic algorithms, genetic programming, evolutionary programming and evolution strategies. Applications in engineering optimization, digital systems design, automatic programming and knowledge discovery. Pre: 2504, CS 2704. Co: STAT 4714. (3H,3C).

4514: DIGITAL DESIGN II
In this course, students will learn to use a hardware descriptive language (VHDL) in the digital design process. Emphasis will be on system-level concepts and high-level design representations. Methods will be learned that are appropriate for use in automated synthesis systems. Students will have the opportunity to use commerical schematic capture and simulation tools to design a series of increasingly complex devices. Students will also use a logic synthesis tool and synthesize assignments into Field Programmable Gate Arrays. Pre: 3504. (3H,3L,4C).

4524: ARTIFICIAL INTELLIGENCE AND ENGINEERING APPLICATIONS
Problem solving methods; problem spaces; search techniques; knowledge representation; programming languages for AI; games; predicate logic; knowledge-based systems; machine learning; planning techniques; reactive systems; artificial neural networks; natural language understanding; computer vision; robotics. Pre: 2574, STAT 4714. Co: STAT 4714. (3H,3L,4C).

4534: EMBEDDED SYSTEM DESIGN
Microprocessor development systems, programming using assembly and higher-level languages. Implementation of embedded application algorithms. Details of a contemporary microprocessor architecture. Comparative analysis of advanced architecture and speciality architectures. Laboratory work is required. Software development including mutltiple memory models, device drivers, basic network principles including internet applications. Pre: 3534. (3H,3L,4C).

4540: VLSI CIRCUIT DESIGN
Introduction to the design and layout of Very Large Scale Integrated Circuits (VLSI). Emphasis is placed on digital CMOS circuits. Static and dynamic properties of MOSFET devices, along with integrated circuit fabrication are examined. Computer-aided design tools are used to produce working integrated circuit designs. Pre: 3204, 3504. (3H,3C).

4550: REAL-TIME SYSTEMS
Introduction to real-time systems, real-time scheduling including multiprocessor scheduling, real-time operating systems (kernels), real-time communication, real-time programming languages, reliability and fault-tolerance, and real-time system requirements and design methods. Design, analysis, and implementation of real-time kernel mechanisms and real-time applications using kernels such as Linux and programming languages such as C (with POSIX primitives) and Ada 95. Pre: 2504, CS 3204. (3H,3C).

4564: NETWORK APPLICATION DESIGN
Application program interface and network transport services including User Datagram Protocal and Transmission Control Protocol from the Internet Protocol suite. Client-server organization and design of synchronous, asynchronous, and multithreaded client and server applications. Design, implementation, and testing techinques to improve robustness and performance. Partially duplicates CS 4254 and credit will not be allowed for both. Pre: (2504, 2574). (3H,3C).

4570 (CS 4570): WIRELESS NETWORKS AND MOBILE SYSTEMS
Multidisciplinary, project-oriented design course that considers aspects of wireless and mobile systems including wireless networks and link protocols, mobile networking including support for the Internet Protocol suite, mobile middleware, and mobile applications. Students complete multiple experiments and design projects. Pre: 4564 or CS 4254. (3H,3C).

4574: LARGE-SCALE SOFTWARE DEVELOPMENT FOR ENGINEERING SYSTEMS
Large-scale software implementations of the hierarchy of engineering analysis, design, and decision evaluation. Computer-aided engineering programs with state-of-the-art computer tools and methods. Operator overloading, dynamic polymorphism, graphical user interfaces, generic programming, dynamic link libraries, and multiple threads. Pre: 3574. (3H,3C).

4605-4606: RADIO ENGINEERING
Wireless application circuit design for gain and filter control at radio frequencies to interface the baseband processing systems and the antennas of communication systems. 4605: Design of radio transmitter and receiver circuits using scattering-parameter methods. Circuits include oscillators, radio frequency amplifiers and matching networks, mixers and detectors. 4606: Design of amplitude, frequency, and pulse-modulated communication systems, including modulators, detectors, and the effects of noise. Design basics and guidelines for phaselocked loops and several power amplifier configurations. Pre: 3106, 3204, 3614 for 4605; 4605 for 4606. Co: 4675. (3H,3C).

4614: TELECOMMUNICATION NETWORKS
Architecture, technology, operation, and application of telecommunication networks including digital telephony, data networks, and integrated services networks. Design and analysis of networks for voice, data, and video applications. Pre: 3614, STAT 4714. (3H,3C).

4624: DIGITAL SIGNAL PROCESSING AND FILTER DESIGN
Analysis, design, and realization of digital filters. Discrete Fourier Transform algorithms, digital filter design procedures, coefficient quantization, finite wordlength arithmetic, fixed point implementation, limit cycles, noise shaping, decimation and interpolation. Pre: 3704. (3H,3C).

4634: ANALOG AND DIGITAL COMMUNICATION
System level analysis and design for digital and analog and communications systems: analog-to-digital conversion, digital and analog modulation types, matched filters, receiver design, link budgets, signal to noise ratios and bit error rates in noisy channels. Pre: 3614, STAT 4714. (3H,3C).

4644: SATELLITE COMMUNICATIONS
Theory and practice of satellite communications. Orbits and launchers, spacecraft, link budgets, modulation, coding, multiple access techniques, propagation effects, and earth terminals. Pre: 3614. (3H,3C).

4654: DSP IMPLEMENTATION OF COMMUNICATION SYSTEMS
An introduction to designing communication subsystems and involves designing and implementing in software demodulators, signal synthesizers, and synchronizers. A significant part of this class will be DSP programming. Pre: 4624, 4634. (3H,3C).

4674: SCATTERING PARAMETERS LABORATORY
Laboratory techniques for ultra-high frequency measurements. Emphasizes the design of a microstrip amplifier using scattering parameter measurement and analysis. Pre: 4605, 4675. (3L,1C).

4675-4676: RADIO ENGINEERING LABORATORY
Laboratory techniques for radio frequencies including the design of amplifiers, oscillators, and a single-side-band receiver. Associated measurements will be used. Pre: 3106, 3204 for 4675; 4675 for 4676. Co: 4605 for 4675; 4606 for 4676. (3L,1C).

4704: PRINCIPLES OF ROBOTICS SYSTEMS
Introduction to the design, analysis, control, and operation of robotic mechanisms. Introduction to the use of homogeneous coordinates for kinematics, dynamics, and camera orientation; sensors and actuators, control, task planning, vision, and intelligence. Pre: 3704. (3H,3C).

4734 (ME 4734): MECHATRONICS
Electromechanical system modeling, control and applications. Design of electronic interfaces and controllers for mechanical devices. Sensor technology, signal acquisition, filtering, and conditioning. Microcontroller-based closed-loop control and device communications. Sensor and actuator selection, installation, and application strategies. Pre: EE 2504, EE 2704. (3H,3C).

ENGINEERING (GENERAL)

The following courses in the College of Engineering are applicable to graduate study in several departments and do not carry departmental designations.

GRADUATE COURSES (ENGR)

The graduate courses listed below are applicable to study in the field of Systems Engineering.

5004: THE SYSTEMS ENGINEERING PROCESS
Development and implementation of the systems engineering process commencing with the identification of requirements (i.e., a consumer need) and extending through requirements allocation, system and functional analysis, synthesis and optimization, the identification of a specific system configuration, and system test and evaluation. The process includes the integration of performance factors, reliability and maintainability, human factors, logistic support, effectiveness, life cycle, and other factors necessary in systems development. (3H,3C)..

5104: APPLIED SYSTEMS ENGINEERING
Identification of the role of systems engineering–solving problems involving technology in the context of the society and the environment in which they exist using systems methodologies of current and potential usefulness in public and private decision making. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ENGINEERING SCIENCE & MECHANICS

Ishar K. Puri, Head

University Distinguished Professor: A.H. Nayfeh
Reynolds Metals Professor: H. Aref
Clifton C. Garvin Professor: R.C. Batra
Francis J. Maher Professor: D.P. Telionis
Pete White Chair: L.G. Kraige
Preston Wade Professor: M.P. Singh
Professors: R.W. Barnwell; M.S. Cramer; D.A. Dillard; N.E. Dowling; J.C. Duke; J.W. Grant; Z. Gurdal; M.R. Hajj; E.G. Henneke; M.W. Hyer; L. Librescu; D.H. Morris; S.A. Ragab
Associate Professors: S.W. Case; H. Dankowicz; K. Granata; S.L. Hendricks; R.D. Kriz; J.J. Lesko; S. Thangjitham
Assistant Professors: J. Cotton; M. Madigan; Z. Masoud
Adjunct Professor: F. dell'Isola; J.S. Wayne
Affiliate Professors: D.J. Inman, Mechanical Engineering, G.R. Goodson Professor; M. Paul, Mechanical Engineering, Assistant Professor; R. Plaut, Civil Engineering, D.H. Pletta Professor; P. Vlachos, Mechanical Engineering, Assistant Professor.
Professors Emeritus: D. Frederick; R.A. Heller; R.M. Jones; V. Maderspach; L. Meirovitch; D.T. Mook; A.A. Pap; D. Post; K.L. Reifsnider; D.J. Schneck; C.W. Smith; G.W. Swift; J.H. Sword; H.W. Tieleman

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The Department of Engineering Science and Mechanics offers M.S. (thesis and non–thesis) and Ph.D. research–oriented degree programs and the M.E. degree practice–oriented master's program. These programs are designed to educate engineers for creative and challenging work in research, development tasks, high–level design, and university teaching. Graduates are qualified to work in many fields in industries, government, and universities.

The discipline of engineering mechanics is concerned with understanding the static and dynamic behavior of solids and fluids from continuum and discrete viewpoints, subjected to the influence of external forces, thermal imbalances, electromagnetic fields, and other external agents. Studies are concerned with fundamental knowledge in the engineering sciences, physical sciences, applied mathematics, materials science, thermodynamics, and computer science. Students learn the analytical, experimental, approximate, and numerical techniques pertinent to each field.

Students are expected to study a few courses in each of the areas of mechanics of solids, mechanics of fluids, dynamics and vibration, applied mathematics, and materials science. Normally, students select their majors and design their programs of study in consultation with their advisory committees. Minors may be taken in other engineering fields, mathematics, physics, and other physical sciences. Engineering mechanics can be combined with other courses to form interdisciplinary programs pertinent to the solution of societal problems in fields such as biomechanics, transportation systems, and energy. Students from most engineering fields, physics, and mathematics are eligible for admission to graduate study in engineering mechanics.

The Biomechanics Program includes a coherent set of courses intended to develop the student's understanding of this specialized topic. The purpose of the program is to provide a background for application of mechanics techniques to special problems of an interdisciplinary nature which arise in areas of medicine and biology. In addition to the academic colleges at Virginia Tech, the Engineering Science and Mechanics Department (ESM) has formal affiliations with the Wake Forest Medical School (WFM), Veterans Administration Hospital System, Montgomery Regional Hospital, and the Clarilion Hospital System, providing students with ample opportunity for exposure to the clinical aspects of biomedical engineering. Research opportunities are available in the medical school environment through affiliation with the WFM. Students are permitted to take academic course work and do doctoral research while in residence at WFM. In addition, the ESM department is a key element in the School of Biomedical Engineering and Science.

Faculty and students participate in interdepartmental graduate programs in materials engineering science, computer science and applications, and systems engineering. The department also participates with interdisciplinary groups represented by the Center for Adhesive & Sealant Science, the Polymeric Materials and Interfaces Laboratory, the Center for Intelligent Materials Systems and Structures, and the Center for Infrastructure Assessment and Management.

There are no foreign language requirements for graduate degrees in engineering mechanics.

Special Facilities

The department has excellent equipment for experimental investigations. The inventory includes ten closed–loop servo–hydraulic testing machines with capacities up to ±50,000 lbs. axially and 20,000 in. lbs. in torsion in addition to eight screw–driven testing machines with capacities up to 120,000 lbs. The mechanical testing equipment is supported by an assortment of plotters, recorders and micro–processor based data acquisition systems. Dynamic test systems include a MB 50 lb. magnetic shaker with sweep frequency generator, spectrum and correlation analyzer, drop and shock testers, together with other electronic instrumentation necessary for complete and accurate dynamic measurements. Environmental test chambers are available for use with the above equipment. Optical equipment includes microscopes and an assortment of cameras, together with complete darkroom facilities.

Modern nondestructive test facilities include acoustic emission, acousto–ultrasonic, infrared radiometric, eddy current, magnetic particle, X–ray radiographic and ultrasonic equipment; a fully equipped Olympus UH–3 acoustic microscope is also available. A complete assortment of electronic equipment for measuring and recording strain, pressure, velocity, and acceleration are available including test controllers, and digital plotters, multi–channel, completely automated digital data acquisition systems with interactive displays and hard copy capabilities; automated fast Fourier transform systems; an HP 5420 signal analyzer; and a variety of data terminals. The fluid mechanics laboratory includes a 100 ft. towing basin, equipped with a piston–driven wave maker, a 2x2 ft. water tunnel that can be operated as a free–surface facility, a 20"x20" low–speed tunnel rigged to provide dynamic motions to the models tested and a 2"x6" supersonic tunnel that can be operated

continuously. Three generations of laser–Doppler velocimetry (LDV) are available, including a two–component fiber–optic probe. The laboratory is also equipped with an assortment of Argon–ion lasers and a 40W copper–vapor laser, as well as a 1000–frames–per–second CCD camera and a 10,000 frames–per–second CMOS camera. This equipment in combination with software developed in the laboratory is available for high–speed, digital particle–image velocimetry (DPIV). There is an assortment of other instruments and about a dozen modern computers that allow the automated operation and data acquisition of many independent experiments on each of the facilities as well as efficient data processing and scientific visualization. Creep frames and thermal analysis equipment (DMA, DSC, TGA and TMA) are available for time–temperature characterization of materials.

Facilities for vibration measurement and structural control include a dSpace digital controller interfaced with a SUN–UNIX system with 20 input and 8 output channels running with MATLAB and all of its tool boxes, an Optima 3, 40 state digital controller, a 60 state analog controller plus a variety of motion sensors (accelerometer, laser vibrometer, proximity probe, LVDT's) and actuation (motors, linear motor, proof mass, etc.). Modal testing hardware consists of a 16 channel GEN RAD 2515 and a 4 channel Textronix analyzer interfaced with IDEAS, MATLAB and STAR. A smart structure capability exists through a variety of piezoceramic devices, amplifier and signal conditioning components.

Other facilities on campus, such as a scanning electron microscope, an environmental scanning electron microscope, wind tunnels, and the College of Engineering Multi–media Computing Facility are often used by members of the engineering science and mechanics department.

The Department of Engineering Science and Mechanics maintain a substantial amount of computing resources. An SGI Origin 3400 series with multiple processors and several gigabytes of RAM is available for large, numerically intensive problems. Other server–class machines are available for remote access and number crunching, including a 4 processor SGI Origin 200 with 1.7 gigabytes of RAM. The department's computer lab has several Intel and MIPS–based workstations, running MS Windows, Linux, and SGI IRIX that are used for scientific visualization and general computing. The machines host a variety of applications, such as: PATRAN, a general purpose CAE package; ABAQUS, a finite element solver; Matlab and Mathematica, for numerical analysis; Tecplot, a data visualization system; and compilers for C, C++, Java, and FORTRAN. Data storage is provided by a 1.2 terabyte RAID system attached to a fault–tolerant Linux based cluster, backed up nightly to ensure continuity of service and data integrity.

Other computing facilities available to the department include the College of Engineering's SGI Origin 2000 and 3400 systems and the University's Sun Microsystems E10000 computer, each with multiple processors and several gigabytes of RAM. The university also hosts a "CAVE" system for high–end, immersive data visualization.

The department also has access to the University Visualization and Animation Group facility: CAVE Automated Virtual Environment (CAVE), Immersive Workbench, Immersive Desk, SGI Octanes, Sun Sparc 20s, and Linux desktop computers. Software in this facility includes CAVE lib API, DIVERSE API, PV–Wave, and AVS.

GRADUATE COURSES (ESM)

5014: INTRODUCTION TO CONTINUUM MECHANICS
Analysis of stress and deformation at a point. Development of the basic equations of a continuous medium by applying the basic laws of conservation of mass, linear momentum, moment of momentum and those of thermodynamics. Study of constitutive axioms and constitutive relations for fluids and solids. Specialization of the field equations to simple boundary–value problems of solid mechanics and fluid mechanics with simple solutions. Pre: 3015. (3H,3C).

5064 (AOE 5064): STRUCTURAL OPTIMIZATION
Structural optimization via calculus of variations. Application of techniques of mathematical programming to optimize trusses, beams, frames, columns, and other structures. Sensitivity calculation of structural response. Approximation techniques and dual and optimality criteria methods. A background in optimization is necessary. (3H,3C).

5074: MECHANICS OF LAMINATED COMPOSITE STRUCTURES
Constitutive relations. Classical laminated composite beams, plates, and shell theories and boundary conditions. Boundary/eigenvalue problems for statics, buckling, and vibrations. Higher order theories including shearing deformation and normal stress. Pre: 4044, 5014, MATH 4544, MATH 4564. (3H,3C).

5124: THEORY OF ELASTICITY
Equations of equilibrium, strain–displacement, compatibility, and constitutive equations in terms of Airy and complex potential stress functions applied to plane engineering boundary value problems including beams, disks, thick–walled tubes, perforated plates, and various stress raiser problems. Three–dimensional applications to torsion, bending, semi–infinite solids. Galerkin vector, Papkovich functions. Pre: 5014, MATH 4426. (3H,3C).

5134: ADVANCED MECHANICS OF MATERIALS
Thick–walled cylinders and spinning disks, introduction to thin plates and shells, beams on elastic foundations, energy methods, torsion of thin–walled members, unsymmetric bending, shear center, curved beams, beam–columns and ties, introduction to plastic collapse, introductory applied elasticity. (3H,3C).

5144 (MSE 5144): DEFORMATION & FRACTURE OF MATERIALS
Deformation and fracture of engineering materials is considered in the context of solid mechanics and engineering methods for predicting strength and life. Topics include plasticity, failure criteria, fracture mechanics, crack growth, strain–based fatigue, and creep. Microstructure–property relationships are discussed. Laboratory demonstrations of behavior in mechanical tests are included. Partially duplicates material in ESM 4024 and both should not be taken. Pre: 3054. (3H,3C).

5174 (CHEM 5174): POLYMER VISCOELASTICITY
Constitutive models of linear viscoelastic materials, experimental aspects, polymer response to mechanical and electrical inputs, solid state NMR and microwave interactions with polymers, free volume theories, temperature and environmental effects on polymers, physical aging of glasses. Consent required. (3H,3C).

5194: PHOTOMECHANICS
Study of diverse experimental methods with a common basis in optical interference. Physical analyses of methods from classical, holographic, and moire interferometry and related techniques. Fringe pattern interpretation and data reduction. Laboratory demonstrations and practice. Applications to macromechanics and micromechanics of metals, composites, and other solids. (2H,3L,3C).

5204: COMPOSITES MANUFACTURING
Fundamentals of polymeric matrix composite manufacturing. Mathematical models of curing, consolidation, and void formation processes are studied. Prepregging methods and effects of processing

on mechanical properties are discussed. Introduction to commonly used manufacturing processes. Laboratory demonstrations. Pre: 4044. (3H,3C).

5224 (BMES 5124): ADVANCED MUSCULOSKELETAL BIOMECHANICS
Skeletal anatomy and mechanics. Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research. (3H,3C).

5234 (CEE 5494): RELIABILITY METHODS IN STRUCTURES & MECHANICS
Theory of structural reliability; reliability based designs, safety index, linear and nonlinear design equations, load and resistance factors, Level I, II and III formats, code formulations; systems reliability, bounds on reliability, extreme value distributions. Pre: 4614 or STAT 4706. (3H,3C).

5264: MECHANICS OF ADHESIVE BONDING & INTERFACES
Principles of mechanics applied to adhesively bonded joints and interfaces, overview of adhesion technology, stress analysis of adhesive joints, stresses in bimaterial systems and interfaces, failure mechanisms and fracture, thermodynamic and observed toughnesses, time dependence and durability, design. Pre: 3054 or 5654. (3H,3C).

5304: MECHANICAL & STRUCTURAL VIBRATIONS
Free and forced vibration of single–degree–of–freedom systems. Response to harmonic, periodic, and nonperiodic excitations. Multi–degree–of–freedom systems; matrix methods. Continuous systems. Computational techniques for the response. (3H,3C).

5305–5306: BIOMECHANICS OF THE CARDIOVASCULAR SYSTEM
5305: Mechanics of the heart, arterial blood vessels and microcirculation; history of the circulation; anatomy and physiology of the heart; mechanics of cardiac contraction; cardiac fluid mechanics; work, energy, efficiency of cardiac function. 5306: Rheology of blood; hematology; elasticity of blood vessel walls; transport processes; control of the circulation; mathematical analysis of pulsatile blood flow and pulse–wave propagation through small arteries, capillary beds and extra–corporeal devices. Pre: 4106. (3H,3C).

5314: INTERMEDIATE DYNAMICS
Review of Newtonian mechanics, fundamental concepts of analytical mechanics, Hamilton's principle, Lagrange's equations, rigid–body dynamics, Euler's equations, gyroscopic principles, definitions of stability, geometric theory (phase–plane trajectories), limit cycles, state–space analysis, Routh–Hurwitz criterion, Liapunov direct method. (3H,3C).

5324: RANDOM VIBRATIONS IN STRUCTURES I
Stationary and nonstationary processes in random vibrations of structures; ergodicity and measurements of random loads, FFT, autocorrelation and power spectral density functions; response functions; vibrations of single– and multi–degrees of freedom mechanical and structural systems subjected to random loads; response threshold crossing rates, peak distributions, and first passage problem; application to cumulative damage potential and structural reliability assessments. Pre: 5304 or 4074, 4614 or STAT 4706. (3H,3C).

5344: WAVE PROPAGATION IN SOLIDS
Formulation and solution of propagation problems in infinite, isotropic media. Solution of the reflection–refraction problem at plane interfaces. Discussion of Rayleigh, Love, and general surface waves. General treatment of wave propagation in infinite anisotropic media. Wave diffraction phenomena. Waves in bounded media, bars and plates. Pre: 5014. (3H,3C).

5405–5406: CLINICAL INTERNSHIP IN BIOMEDICAL ENGINEERING
Off–campus student exposure and participation in a planned clinical experience for those preparing to enter the field of Biomedical Engineering. On–campus lecture/lab/demonstration sessions to supplement the clinical experience. Students are placed in selected hospitals throughout the local area during two summer sessions under close supervision of a university staff member and cooperating medical personnel. (2H,3L,3C).

5414: NONLINEAR SYSTEMS
Dynamics of conservative and nonconservative systems; phase planes; local and global stability; damping mechanisms; self–excited oscillators. Forced oscillations of one–degree–of–freedom systems; primary, secondary, and multiple resonances; period–multiplying bifurcations; strange attractors; chaos. Parametric excitations; Floquet theory; influence of damping and nonlinearity. Multi–degree–of–freedom systems; concepts of internal and external resonances; Hopf bifurcation. Applications to continuous systems; strings, beams, plates, and shells. Pre: 5754, 5304. (3H,3C).

5444 (CEE 5444): DYNAMIC STABILITY OF STRUCTURES
Modern structural stability analysis; static and dynamic instability; conservative and nonconservative systems; multiple loads; Liapunov stability analysis. Applications to columns, rotating shafts, pipes conveying fluid, and airplane panels. Pre: 4074 or AOE 3034. (3H,3C).

5454 (AOE 5054) (CEE 5454): ELASTIC STABILITY
Stability of elastic structural components under conservative loads; precise definitions of stability; energy approaches; Rayleigh–Ritz and Galerkin methods; and applications to column, arches, plates, and shells. Pre: CEE 3404 or AOE 3124. (3H,3C).

5464 (CEE 5464): STRUCTURAL DYNAMICS & EARTHQUAKE ENGINEERING
Earthquake–induced vibration of single– and multi–degree–of–freedom systems; application to frames and to shear and torsional buildings; response spectrum analysis; building codes; static and dynamic lateral force procedures; seismic resistance of steel and concrete building frames. Co: 4404. (3H,3C).

5504: INTRODUCTION TO IDEAL FLOW
Kelvin–Helmholtz theory of vorticity. Velocity potential. Stream function. Complex potential and conformal mapping. Introduction to two–dimensional panel methods. Thin–airfoil theory. Steady and unsteady lifting flows. (3H,3C).

5514: VISCOUS FLOW
Governing equations of viscous heat–conducting gases. Exact solutions to the Navier–Stokes equations. Low–Reynolds–number flows. Incompressible and compressible boundary layers. Finite–difference methods for boundary layers. Flow separation and strong viscid–inviscid interactions: interacting boundary layers and triple deck theory. Pre: 5014. (3H,3C).

5524: COMPRESSIBLE FLOW I
Introduction to fundamentals of compressible fluid flow. Linearized theory, unsteady flows, steady flows, shock waves, wave interactions, method of characteristics. Pre: 5014. (3H,3C).

5554: TURBULENCE & TURBULENT FLOWS
Nature and origin of turbulence, turbulent transport of momentum and heat, the dynamics of turbulence, statistical description of turbulence and spectral analysis. Examples of turbulent flows, boundary layers. (3H,3C).

5564 (CHE 5564): NON–NEWTONIAN FLUID MECHANICS
Development of fluid models which describe the mechanical response of non–Newtonian fluids. Use of these models with the basic equations of continuum mechanics is emphasized. (3H,3C).

5604 (MSE 5604): MECHANICS OF CERAMIC & METAL COMPOSITES
Predictive modesl of elasticity, strength, toughness, and the life of ceramic and metal composites as a function of the constituent material properties and geometry. Particulate and fiber–reinforced materials. Micromechanics and fracture mechanics. Mechanical phenomena in composites; predictive models for composite performance; experimental results in terms of the micromechanical models; selection/design of new materials for specific applications; component reliability. Recent technological developments, experimental data, and state–of–the–art models. Pre: 5014 or MSE 4604. (3H,3C).

5654 (CHEM 5654): ADHESION SCIENCE
Introduction to basic principles of adhesion science from the areas of mechanics, materials, and chemistry. Consent required. (3H,3C).

5725,5726 (MATH 5495, 5496): MATHEMATICAL METHODS IN ENGINEERING I,II
Linear algebra and matrix theory, vector calculus, complex variables and integral transforms, ordinary and partial differential equations, special functions, integral equations and calculus of variations. Facility with an existing math software package of senior level engineering mathematics required. (3H,3C).

5734: INTRODUCTION TO THE FINITE ELEMENT METHOD
Formulation and computer implementation of finite element models of typical equations of fluid flow, heat transfer, and solid mechanics. The problems considered include heat conduction and convection, torsion, ground water flow, electrostatics and magnetism, plane elasticity, flow of viscous incompressible fluids, and plate bending. Both theoretical development and computer program development are studied. (3H,3C).

5744: ENERGY & VARIATIONAL METHODS IN APPLIED MECHANICS
Variational calculus, energy principles of solid mechanics, and variational methods of approximation applied to engineering problems. Derivation of equations of mechanics from energy and variational principles (i.e. virtual work principles). Formulation and solution of initial–, boundary– and eigen–value problems of engineering by direct variational methods, such as the Ritz, Galerkin, least–squares, and collocation methods. Pre: MATH 4425. (3H,3C).

5754 (MATH 5754): INTRODUCTION TO PERTURBATION METHODS
Asymptotic expansions and series, approximate solutions of algebraic equations, straightforward expansions and their regions of nonuniformities, the Lindstedt–Poincare technique, the method of renormalization, the method of averaging, the method of matched asymptotic expansions. Pre: MATH 2214 or MATH 2514 or MATH 4544. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Discussion of current research topics in Mechanics by local and visiting scholars. This course cannot be used to fulfill the minimum requirements of 30 hours toward the Master's Degree or 90 hours toward the Ph.D. Degree in Mechanics. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6014: NONLINEAR ELASTICITY
Formulation and study of the equations of nonlinear elastic solids with application to bars, beams, plane elasticity, and plates. Updated and total Lagrangian incremental formulations using virtual work principles. Constitutive equations for compressible and incompressible solids. Analytical solution of some nonlinear problems. Nonuniqueness of solutions. Solution of the nonlinear equations by the Ritz, Galerkin and numerical methods. Pre: 5014, 5744. (3H,3C).

6044: THEORY OF PLATES & SHELLS
Reduction of 3–D elasticity to an equivalent 2–D counterpart. Basic assumptions. Field equations of the theory of plates and shells. Linear and nonlinear theories. Buckling and vibrations. Postbuckling. Refined plate and shell theories. Implications of non–classical effects on the static, dynamic and buckling behaviors. Pre: 5014, MATH 4425 or MATH 4564. (3H,3C).

6054: FRACTURE MECHANICS
Linear elastic and elasto–plastic models of local stress fields around crack tips. Concepts of stress intensity and strain energy release rate. Mathematical models for dynamic crack extension and fatigue crack growth. Correlation of mathematical models with fracture toughness testing. Pre: 5014. (3H,3C).

6084: MECHANICS OF FATIGUE
Application of elasticity, plasticity, fracture mechanics, and numerical analysis to fatigue phenomena. Study of high and low cycle ranges, high temperature effects, corrosion fatigue, mean stress effects, cumulative damage theories, stochastic aspects, and energy dissipation. Pre: 5014. (3H,3C).

6104: MECHANICS OF COMPOSITE STRENGTH & LIFE
Study of the mechanics associated with the description and prediction of the strength and life of composite materials and structures. Mechanistic, phenomenological, and analytical examination of strength and stability concepts for various reinforcement configurations. Effect of damage accumulation; micro–mechanics, damage mechanics, life prediction concepts and methods. Experimental investigative methods. (3H,3C).

6154: ANALYSIS OF COMPOSITE MATERIALS
3–D anisotropic constitutive theory, anisotropic elasticity, interlaminar stresses and edge effects, hygro–thermal stress analysis, failure, composite micro–mechanics, effective properties, heat conduction and moisture diffusion. Pre: 4044, 5074, 5124. (3H,3C).

6115–6226 (BMES 6125–6126): BIODYNAMICS & CONTROL
Study of human movement dynamics and neuromuscular control of multi–degree–of–freedom systems. 6225: Computational simulation of forward–dynamics and state–space linear control of human movement to investigate functional performance and neuromuscular pathology. 6226: Applied laboratory–based investigation and research design of human movement–control through state–of–the–art measurement techniques. Pre: 5224 or (4204 and 5314). (3H,3C).

6304: ADVANCED VIBRATIONS
Hamilton's principle and Lagrange's equations. Vibration of discrete systems; the algebraic eigenvalue problem. Vibration of distributed systems; the differential eigenvalue problem; approximate methods; the finite element method. Substructure synthesis. Pre: 5304 or MATH 4425. (3H,3C).

6314: ADVANCED DYNAMICS
Fundamental concepts of analytical mechanics, variational principles, Lagrange's equations, rigid–body kinematics and dynamics, Euler parameters, quasi–coordinates, Euler's equations, gyroscopic systems, Hamilton–Jacobi equation, transformation theory, introduction to optimal control theory, advanced concepts in stability theory. Pre: 5314. (3H,3C).

6464 (CEE 6464): ADVANCED EARTHQUAKE ENGINEERING
Characteristics of earthquake motions; seismic risk analysis; design inputs – response spectra and spectral density function; multi–degree–of–freedom classically and non–classically damped linear and nonlinear structures; spatial variation of ground motion and multiple support excitations of large structures; structure–soil interaction analysis; floor response spectra, nonstructural components, and secondary systems; passive and active structural control – base isolation, energy dissipation devices, active and semi–active devices; elevators and rotating machines. Pre: 5464 or CEE 5464 or ESM 5304. (3H,3C).

6504: IDEAL FLOW
Slender–body theory. Three–dimensional steady and unsteady flows. Virtual masses and moments of inertia. Three–dimensional panel methods. Biot–Savart law. Lifting–line theory. Lifting–surface theories. Vortex–lattice methods. Pre: 5504. (3H,3C).

6514: COMPUTATIONAL METHODS FOR VISCOUS FLOWS
Navier–Stokes equations in curvilinear systems. Thin–layer and parabolized Navier–Stokes equations. Stability analysis of finite–difference methods applied to model equations. Methods for grid generation. Finite–difference methods for compressible and incompressible Navier–Stokes equations. Spectral methods. Pre: 5514. (3H,3C).

6524: COMPRESSIBLE FLOW II
Two– and three–dimensional compressible flows. Nonlinear and three–dimensional effects. Near– and far–field approximations. Slender body theory, transonic and hypersonic flows. Similarity, equivalence and area rules for three–dimensional flows. Numerical techniques. Pre: 5524. (3H,3C).

6544: HYDRODYNAMIC STABILITY
Instability of liquid interfaces, convection in fluid layers, Taylor and Gortler vortices, instability of inviscid and viscous plane parallel flows, boundary–layer transition. Concepts and results of linear, nonlinear and secondary instability analysis, experiments and computer simulations. Pre: 5504, 5514. (3H,3C).

6714: APPLIED TENSOR ANALYSIS
Basis vectors, Christoffel symbols, metric tensor. Covarient, contravarient vectors and tensors. Covarient differentiation. Orthonormal systems and physical components of tensors. Surface tensors, curvature tensors, principal curvatures, geodesics and asymptotic lines. The basic ideas will be illustrated by and applied to problems in continuum mechanics, solid and fluid mechanics, rigid body dynamics, and electromagnetic theory. Pre: MATH 4574. (3H,3C).

6734: FINITE ELEMENT ANALYSIS
Alternative finite element models; three–dimensional problems; eigenvalue problems; nonlinear formulations for fluid flow and plate bending; and mathematical properties of finite–element approximations; direct and Newton–Raphson iterative methods for the solution of nonlinear equations; computer implementation of nonlinear finite–element models. Pre: 4734 or 5734. (3H,3C).

6754: PERTURBATION METHODS
Linear equations with variable coefficients, WKB approximation, solvability conditions, approximation of integrals, large–amplitude oscillations, nonlinear waves. Pre: 5754. (3H,3C).

6974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ESM)

The following 4000–level courses have been approved for graduate credit:

4004 (BSE 4004): INSTRUMENTATION & EXPERIMENTAL MECHANICS
Introduction to instrumentation. Data analysis: uncertainty, error and statistical concepts.Devices: digital multi–meters, oscilloscopes, power supplies, and function generators.Circuits: ballast circuits, wheatstone bridges, operational amplifiers, and transistors. Principles of data acquisition. Fourier analysis. Measurements of velocity, pressure, strain, displacement, forces and accelerations.Laboratory and design projects.Pre: 2204, 2304, 3015 or 3024, ECE 3054. (2H,2L,3C).

4024: ADVANCED MECHANICAL BEHAVIOR OF MATERIALS
Mechanical behavior of materials, emphasizing solid mechanics aspects and methods for predicting strength and life of engineering components. Plasticity, failure criteria, fracture mechanics, crack growth, strain–based fatigue, and creep. Microstructure–property relationships, and laboratory demonstrations. Pre: 3054 or ME 4614. (3H,3C).

4044: MECHANICS OF COMPOSITE MATERIALS
Properties and mechanics of fibrous, laminated composites. Classical lamination theory, micromechanics, stiffness and strength, fabrication and testing. Thermal stresses. Design, analysis, and computerized implementation. Pre: 2204. (3H,3C).

4054: SOLID AND STRUCTURAL MECHANICS
Introduction to elasticity and continuum mechanics, plane stress and plane strain; bending of beams; deflections, shear center; torsion of general cross–section bars; comparison of elasticity solutions with strength of materials; introduction to energy methods, application of virtual work to frames, beams, and shafts; elastic instability of columns. 3D trusses, cables and arches; flexibility and stiffness coefficients; indeterminate structures, superposition. Pre: (2204, 3054, 2074) or MSE 3354. (3H,3C).

4064: EXPERIMENTAL MECHANICS
Analytical and experimental methods for measuring strain fields in elastic bodies including mechanical, electrical, and optical methods (using electric resistance strain gages, photoelasticity, moire interferometry, and crack extension gages). Pre: 2204. (2H,2L,3C).

4074: VIBRATION AND CONTROL
Single–degree–of–freedom vibration, two– and n–degree–of–freedom systems, continuous systems, introduction to nonlinear systems, system stability, introduction to the control of dynamic systems. Pre: 3124, MATH 4564. (3H,3C).

4084 (AOE 4084): ENGINEERING DESIGN OPTIMIZATION
Use of mathematical programming methods for engineering design optimization including linear programming, penalty function methods, and gradient projection methods. Applications to minimum weight design, open–loop optimum control, machine design, and appropriate design problems from other engineering disciplines. Pre: MATH 2224. (3H,3C).

4105–4106: ENGINEERING ANALYSIS OF PHYSIOLOGIC SYSTEMS
Engineering analysis of human physiology. Physiologic systems are treated as engineering systems with emphasis input–output considerations, system interrelationships and engineering analogs. 4105: Mass and electrolyte transfer, nerves, muscles, renal system. 4106: cariovascular mechanics, respiratory system, digestive systems, senses. Pre: 2304, MATH 2214. (3H,3C).

4114: NONLINEAR DYNAMICS AND CHAOS
Motion of systems governed by first–, second–, and third–order differential and difference equations: stability, geometry, phase planes, bifurcations, Poincare' maps, point attractors, limit cycles, strange attractors, fractal dimensions, Lyapunov exponents. Forced oscillations of one–degree–of–freedom systems: jump phenomena, sub– and superharmonic resonances, Hopf bifurcations, period–multiplying bifurcations, chaos. Pre: 2304, MATH 2214. (3H,3C).

4154 (MSE 4154): NONDESTRUCTIVE EVALUATION OF MATERIALS
Concepts and methods of nondestructive evaluation of materials. Discussion of techniques and mathematical bases for methods involving mechanical, optical, thermal, and electromagnetic phenomena; design for inspectability; technique selection criteria; information processing and handling; materials response; laboratory. Pre: 3054, 3064, PHYS 2306. (2H,3L,3C).

4204: MUSCULOSKELETAL BIOMECHANICS
Skeletal anatomy and mechanics.Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research. Pre: 2304, (2074 or ME 2004). (3H,3C).

4234: MECHANICS OF BIOLOGICAL MATERIALS & STRUCTURES
Anatomy and physiology of connective tissue. Techniques for determining the mechanical response of biological soft and hard tissues. Includes static, viscoelastic, creep, fatigue, and fracture. Simplified models of biological structures. Creation of geometric models from medical imaging and computational modeling. Specific topics may include bone, cartilage, ligaments, tendon, teeth, and skin. Pre: 3054, 2074.

4444 (AOE 4054) (CEE 4444): STABILITY OF STRUCTURES
Introduction to the methods of static structural stability analysis and their applications .Buckling of columns and frames. Energy method and approximate solutions. Elastic and inelastic behavior. Torsional and lateral buckling. Use of stability as a structural design criterion. Pre: AOE 3024, CEE 3404. (3H,3C).

4524: INTRODUCTION TO WAVE MOTION
Introduction to fundamentals of wave propagation. Topics include wave speed and dispersion relations, group velocity, wavepackets, waveguides, wave reflections, effects of nonuniformity and nonlinearity. General phenomena will be illustrated through use of specific physical applications and well–known mode equations. Examples will be drawn from all areas of the physical sciences including solid and fluid dynamics, acoustics, geophysics, and electromagnetic field theory. Pre: MATH 4564. (3H,3C).

4574 (MSE 4574): BIOMATERIALS
Lectures and problems dealing with materials used to mimic/replace body functions. Topics include basic material types and possible functions, tissue response mechanisms, and considerations for long term usage. Integrated design issues of multicomponent materials design in prosthetic devices for hard and soft tissues are discussed. Must meet prerequisite or have graduate standing in the College of Veterinary Medicine. Pre: MSE 3054. (3H,3C).

4714: SCIENTIFIC VISUAL DATA ANALYSIS AND MULTIMEDIA
Classical and advanced methods of visual data analysis within scientific applications context; emphasis on examples of scientific investigation with visual tools, and new visual methods with computer graphics; visual data analysis of numerical experimental and analytical results including: gradients, function–extraction, chaos, nth–order tensor glyph representations, molecular synthesis. Pre: (MATH 1015, MATH 1016) or (MATH 1205, MATH 1206). (3H,3C).

4734 (AOE 4024): AN INTRODUCTION TO THE FINITE ELEMENT METHOD
The finite element method is introduced as a numerical method of solving the ordinary and partial differential equations arising in fluid flow, heat transfer, and solid and structural mechanics. The classes of problems considered include those described by the second–order and fourth–order ordinary differential equations and second–order partial differential equations. Both theory and applications of the method to problems in various fields of engineering and applied sciences will be studied. Pre: 2074, MATH 2224. (3H,3C).

ENGLISH

Lucinda Roy, Chair
Carolyn Rude, Graduate Program Chair

University Distinguished Professor: N. Giovanni
Alumni Distinguished Professor: L.H. Roy
NationsBank Clifford A. Cutchins III Professor: P.W. Graham
Edward S. Diggs Professor: E. Sullivan
Professors: F. D'Aguiar; J. Eska; E. Falco; V. Fowler; T.M. Gardner; C. Kiebuzinska; F. Oehlschlaeger; D.H. Radcliffe; C. Rude; L. Scigaj; R.W. Siegle; P. Sorrentino
Associate Professors: L.M. Anderson; A.J. Colaianne; J. Dubinsky; S. Fowler; L. Hatfield; B. Hausman; P. Heilker; S.M. Knapp; N.A. Metz; D.W. Mosser; K.T. Soniat; J.D. Stahl; K. Swenson; D.M. Welch
Assistant Professors: E.R. Brumberger; S. Carter-Tod; G. Chandler; J.H. Collier; C. Dannenberg; C. Evia; R. Hicok; J. Mann; D.G. Moss

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This department offers programs of study leading to the M.A. in English (thesis or non-thesis) and the MFA in Creative Writing.

Master of Arts in English
Our M.A. Program, revised in 2004 and focused on textual studies, is built on a three-course core (research, theory, and digital humanities/5014, 5024, and 5074). It focuses on the theoretical and practical aspects of locating and evaluating texts as well as calling special attention to the critique and production of digital discourse. Most of our students also do core work in the theory and practice of teaching composition. Our M.A. students typically move in one of three directions after leaving our program: doctoral study in literature, composition, or creative or professional writing; high school or instructor-level college teaching; writing- or document-related jobs in industry. Our core-based MA provides a platform for all three directions.

Courses in literature, linguistics, theory, and professional writing enable to students to tailor their programs according to their own interests and goals. Graduate students may also opt for a 9-hour graduate certificate in Women's Studies through the Women's Studies Program or a 9-hour graduate certificate in Professional Development through the Graduate Education Development Institute (GEDI).

The degree requirements include a capstone project, either an independent study (3 hours) or thesis (6 hours), to be completed in the second year of study.

The department offers financial support and teaching experience to many of its graduate students through graduate teaching assistantships. Graduate teaching assistants in English participate in a rigorous internship program that includes an orientation before classes begin, a graduate seminar (English 5054), and a practicum (English 5034).

MFA in Creative Writing
The MFA in Creative Writing is designed to be completed in three years. Students may select from among three options: Fiction, Poetry, and Playwriting. A minimum of 48 hours is required for this terminal degree. A series of creative writing workshops, courses in form and theory, new media writing, composition pedagogy, and literature and theory electives are designed for students wishing to pursue careers as writers or writer/scholars at the college level. Playwriting students will have an opportunity to work on the performance aspects of their original plays. Students also serve as Writers in Residence in area schools and/or work on as editors of a hypertext journal. A creative thesis and a final exam are required.

Of the 48 hours required for the degree, 36 must be distributed as follows:

- 15 hours of creative writing workshops, 9 of these in the designated specialty.
- 6 hours of form and theory courses.
- 3 hours in each of the following: New Media Writing, Composition Pedagogy, and Pedagogical Practices.
- A book-length creative thesis (a collection of poetry; a collection of short stories, a novel, or a full-length play)

The department offers financial support in the form of Knobler Graduate Scholar Awards (includes a stipend and tuition remission) and graduate assistantships. Graduate teaching assistants in the MFA program participate in a rigorous internship program that includes orientation before classes begin, graduate seminars (ENGL 5054) and a practicum (ENGL 5034). At the discretion of the program directors, credit will be awarded to those entering with graduate degrees in English or Creative Writing.

Required Courses for the MFA in Creative Writing:

5734, 5744, 5754, 5764, 6704, 6714, 6724; 5054, 5034

GRADUATE COURSES, M.A. (ENGL)

5014: INTRODUCTION TO LITERARY RESEARCH
This course introduces the materials and methods of research used in English Studies. Students learn how to locate primary texts, contextual documents, and critical scholarship, to evaluate their kinds and degrees of authority, and to incorporate and cite this material in original research. Graduate standing. (3H, 3C).

5024: CRITICAL THEORY IN ENGLISH STUDIES
This course introduces students to principal issues, concepts, terms, and methods currently employed in literary criticism and the interdisciplinary study of culture. Graduate standing. (3H,3C).

5034: PRACTICUM
Practical training in teaching composition at the university level. Required of all Graduate Teaching Assistants in English. Pass/Fail only. (3H,3C).

5054: COMPOSITION THEORY & PRACTICE
Theory and practice of teaching composition at the college level. Analysis and implementation of theories of teaching composition, including basic writing skills. (3H,3C).

5064: TOPICS IN LANGUAGE
Rotating topics in language study, exploring various theories of language and their bearing on literary interpretation, rhetoric, and textual criticism. Content will vary; may be repeated once for credit. (3H,3C).

5074: INTRODUCTION TO DIGITAL HUMANITIES
This course introduces students to the history and critical theory necessary to understand the broad import of digital technology for English Studies and to the knowledge and skills required to critique and and produce digital documents. Graduate standing. (3H, 3C).

5114: STUDIES IN MEDIEVAL LITERATURE
Rotating studies in medieval literature, focusing on particular themes, genres, works, or figures within their historical, social and literary context. Content will vary; may be repeated for credit. (3H,3C).

5124: STUDIES IN RENAISSANCE LITERATURE
Rotating studies in British literature from 1500 to 1660, focusing on literary traditions, themes, or representative writers. May be repeated once for credit. (3H,3C).

5134: STUDIES IN EIGHTEENTH–CENTURY LITERATURE
Rotating studies in English Literature of the eighteenth century, focusing on literary traditions, themes, or representative writers. Content will vary; may be repeated once for credit. (3H,3C).

5144: STUDIES IN NINETEENTH–CENTURY ENGLISH LITERATURE
Rotating studies in English literature of the nineteenth century, focusing on literary traditions, genres, themes, or representative writers. Content will vary; may be repeated once for credit. (3H,3C).

5154: STUDIES IN AMERICAN LITERATURE BEFORE 1900
Rotating studies in American literature before 1900, focusing on literary traditions, themes, or representative writers. Content will vary; may be repeated once for credit. (3H,3C).

5164: STUDIES IN BLACK AMERICAN LITERATURE
Rotating studies in Black American literature, focusing on its roots in folk and oral traditions; on key periods, such as the Harlem Renaissance; or on themes, genres, or selected figures. Content will vary; may be repeated once for credit. (3H,3C).

5174: STUDIES IN TWENTIETH–CENTURY TEXTS
Rotating studies in twentieth century literature in English. Typically, the course will concentrate on a kind of writing, a movement, a theme, or a critical issue. Content will vary; may be repeated once for credit. (3H,3C).

5224: STUDIES IN EARLY ENGLISH AUTHORS
Rotating studies in the works of such early writers as Chaucer, Shakespeare, or Milton, focusing on their relationship to history; on key texts; on themes or genres; or on critical approaches. Content will vary; may be repeated once for credit. (3H,3C).

5234: STUDIES IN LATER ENGLISH AUTHORS
Rotating studies in the works of one or two later English writers, such as Dickens, Hardy, Tennyson, Woolf, Joyce, Yeats, and others. Contents will vary; may be repeated once for credit. (3H,3C).

5244: STUDIES IN AMERICAN AUTHORS
Rotating studies which offer intensive treatment of one or two American authors, with particular attention to historical, biographical, cultural, and/or critical and theoretical contexts. Content will vary; may be repeated once for credit. (3H,3C).

5314: GENRE STUDIES
Rotating studies of particular genres–lyric, biography, literary criticism, speculative fiction–in relation to their social, intellectual, and literary contexts. Content will vary; may be repeated once for credit. (3H,3C).

5334: SPECIAL TOPICS IN LITERATURE
Approaches to the study of literature that cross the boundaries of genre, period, and nationality, exploring innovative combinations of texts, critical methods, and interpretive approaches. Contents will vary; may be repeated once for credit. X–grade allowed. (3H,3C).

5354: COMPARATIVE STUDIES IN LITERATURE
Rotating studies in global literature and theory, focusing on comparisons of authors, works, periods, or genres of different regions, countries, and/or cultures. Content will vary; may be repeated once for credit. (3H,3C).

5454: STUDIES IN THEORY
Rotating studies of the major issues, figures, and movements in literary and critical theory. Content will vary; may be repeated once for credit. (3H,3C).

5514: AMERICAN LITERATURE OF THE LATER NINETEENTH CENTURY
American literature from the Civil War to the end of the century, with emphasis on Whitman, Dickinson, Twain, James, and Crane. (3H,3C).

5534: STUDIES IN LITERARY HISTORY
Rotating studies in literary history. Topics, periods, and approaches will vary; may be repeated once for credit. (3H,3C).

5544: CURRENT TOPICS IN LITERARY STUDY
Special topics in frontier areas of literary study. Reserved for and taught by distinguished visiting faculty. Content will vary; may be repeated once for credit. (3H,3C).

5894: FINAL EXAMINATION
For non–thesis candidates who are required to register for their final examination and have completed their program of study. Not to be included in minimum 33 hours required for degree. Pass/Fail only. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ENGL)

The following 4000–level courses have been approved for graduate credit:

4024: LITERARY CRITICISM
Background of contemporary literary criticism. Axioms and procedures of significant and representative critics; focal points in critical theory (mimetic, formalist, expressive, and affective); application of critical values and methodologies to literary texts. (3H,3C).

4044: LANGUAGE AND SOCIETY
English language variation in the United States is considered from a current sociolinguistic perspective. Social, regional, ethnic, gender, and stylistic–related language variation are covered, along with models for collecting, describing, and applying knowledge about language variation. Students are exposed to a wide range of data on language variation, with emphasis on vernacular varieties of American English. Pre: 1106 or 1204H. (3H,3C).

4054: HISTORY OF THE ENGLISH LANGUAGE
Development of English including both its internal history (sounds, vocabulary, inflections, syntax) and its external history (political, social, and intellectual forces). Indo–European origins through the present, with special emphasis on the English Language in America. (3H,3C).

4064: MODERN ENGLISH LINGUISTICS
Study of language as a rule–governed system of knowledge, with special attention to the following: transformational analysis of the structure of English sounds, words, and sentences; the history of the language, the dialects of English, and the pragmatics of communication. (3H,3C).

4074: ENGLISH SYNTAX
This course introduces the grammatical structures of the English language and the processes by which we create and comprehend English sentences. Emphasis is on recent linguistic models. Topics include morphological structure, form– and structure–class taxonomy, phrase structure, transformational and generative approaches, language variation. Alternative models will be considered. Pre: 1106. (3H,3C).

4084: TOPICS IN LINGUISTICS
An advanced course in such areas of linguistics as phonetics, phonology, morphology, syntax, language change, dialectology, etc. Emphasis will be placed on the analysis of natural language data within contemporary theoretical frameworks. Individual sections will focus upon differing areas of linguistics (to be specified in the subtitle of the course). Repeatable with different content for a maximum of nine credits. Pre: 4064 or 4074. (3H,3C).

4114: CHAUCER
This course examines the life, work, and critical reception of Geoffrey Chaucer. Junior standing required. (3H,3C).

4124: INTRODUCTION TO OLD ENGLISH
Introduction to Old English grammar and reading of Old English poetry and prose. Senior standing required. (3H,3C).

4165,4166: SHAKESPEARE
The plays of Shakespeare. 4165: Shakespeare's early career (1590–1600), including history plays from HENRY VI to HENRY V, comedies from THE COMEDY OF ERRORS to THE MERRY WIVES OF WINDSOR, and early tragedies such as ROMEO AND JULIET and JULIUS CAESAR. 4166: the later career, including "problem plays" such as MEASURE FOR MEASURE, the great tragedies (HAMLET, KING LEAR, OTHELLO, MACBETH), and the romances such as THE TEMPEST. (3H,3C).

4214: MILTON
Milton's poetry from the early works, including COMUS, LYCIDAS, and the sonnets, to his major late works PARADISE LOST, PARADISE REGAINED, and SAMSON AGONISTES; with some attention to the important prose and to the historical context in which he wrote. (3H,3C).

4405,4406: THE ENGLISH NOVEL
4405: Development of the English novel to 1850, including such novelists as Defoe, Richardson, Fielding, Sterne, Austen, the Brontes, and Thackeray. 4406: Major novels from 1850 to World War II, including Dickens, Trollope, Eliot, Gaskell, Hardy, Woolf, Joyce, Lawrence, Huxley, and Waugh. (3H,3C).

4414: TOPICS IN SPECULATIVE FICTION
This variable content course offers an advanced exploration of deliberately anti–realistic narratives such as science fiction, utopian and dystopian fiction, and fantasy. May be taken twice with differing content. Junior standing required. (3H,3C).

4415,4416: AMERICAN NARRATIVE TO 1950
4415: The history of American narrative to 1865; 4416: The history of American narrative from 1865 to 1950; genres to be addressed may include diaries, journals, letters, autobiographies, narratives of captivity, essays, sermons, folktales, short fiction, and novels. Junior standing required. (3H,3C).

4424: DIGITAL LITERARY CULTURE
The interpretation of literary forms produced specifically for digital environments. Students will learn to analyze the design and rhetoric of hypertexts and hypermedia. Pre: 3354. (3H,3C).

4504: MODERN POETRY
British and American poetry from 1900 to World War II with emphasis on such figures as Pound, Williams, Stevens, Yeats, Sylvia Plath, Stevie Smith, and Eliot. (3H,3C).

4514: CONTEMPORARY POETRY
British and American poetry from World War II to the present, with emphasis on such figures as Bishop, Lowell, Ashbery, Heaney, and Hughes. (3H,3C).

4554: BRITISH DRAMA TO 1800
Plays from the Middle Ages through the 18th century (excluding Shakespeare). Includes works by the anonymous authors of the medieval mystery and morality plays and by such playwrights as Marlowe, Johnson, Webster, Ford, Dryden, Wycherly, and Goldsmith. (3H,3C).

4564: MODERN DRAMA
Plays by 19th and 20th century British, American, and continental dramatists, beginning with Ibsen and Shaw and culminating with Beckett and the contemporary Theatre of the Absurd. (3H,3C).

4624: STUDIES IN A BRITISH AUTHOR AFTER 1800
This course examines the life, work, and critical reception of a single major British author (or pair of closely associated authors) writing after 1800. May be taken up to 3 times with different content. Junior standing required. (3H,3C).

4634: STUDIES IN AN AMERICAN AUTHOR BEFORE 1900
This course examines the life, work, and critical reception of a single major American author (or a pair of closely associated authors) writing before 1900. May be taken up to three times with different content. Junior standing is required. (3H,3C).

4644: STUDIES IN AN AMERICAN AUTHOR AFTER 1900
This course examines the life, work, and critical reception of a single major American author (or pair of closely associated authors) writing after 1900. May be taken up to three times with different content. Junior standing is required. (3H,3C).

4664: CONTEMPORARY FICTION
Fiction since 1945 with emphasis upon the most recent two decades: the late modernist narratives of Bellow, Updike, and Percy; the new fiction of Barth, Hawkes, Barthelme; the postmodern fiction of Federman, Carter, Fowles, Katz, Sukenick. (3H,3C).

4674: STUDIES IN CONTEMPORARY CULTURE
Studies the emerging changes across arts media (including architecture, cyberculture, essay, fiction, film, painting, performance, photography, poetry, theatre, video) in relation to current cultural and social theory from a variety of disciplines (including architectural theory, art, history, literature, philosophy, psychoanalysis, and social sciences). (3H,3C).

4704: ADVANCED CREATIVE WRITING: FICTION
Intensive advanced workshop for fiction writers. Through a study of criticism and models for excellent fiction and through peer critiques, students can develop their talents at fiction writing to a high level. Pre: 3704. (3H,3C).

4714: ADVANCED CREATIVE WRITING: POETRY
Intensive advanced workshop for poetry writers. Paying close attention to established and experimental models and to criticism articulating the differences among these models, students will pursue their own writing in a workshop setting. Pre: 3714. (3H,3C).

4804: GRANT PROPOSALS AND REPORTS
This course prepares students to write effective proposals, reports, and informational articles. Students learn to define and write problem statements, program objectives, plans of action, evaluation plans, budget presentations, and summaries. In addition, they sharpen their teamwork, editing, writing, audience awareness, and design skills as they engage in collaborative projects with campus and/or non-profit organizations in the community. Prerequisite or consent of the instructor is required. Pre: 3804. (3H,3C).

4814: WRITING FOR THE WEB
This course prepares students to write and design complex documents for the World Wide Web, with a particular emphasis on communicating complex, technical, and scientific information. Students learn rhetorical principles, writing strategies, visual design factors, and technologies needed to create effective, usable web sites. They will develop sites in both individual and team settings, apply the principles of usability testing, and locate and use resources to help them keep pace with this rapidly changing field. Pre: 3804. (3H,3C).

4824: SCIENCE WRITING
Writing in and about the natural and social sciences. Students will write documents such as abstracts, research proposals, and ethnographies, analyze the development of disciplinary writing practices, and study non-fiction science writing for general audiences. Senior standing or instructor approval required. Pre: 1106 or H1204 or COMM 1016. (3H,3C).

4874: ISSUES IN PROFESSIONAL AND PUBLIC DISCOURSE
In this course, students will focus on the ways in which scientific, technical, and professional communication influence, and are influenced by, public discourse. Drawing on strategies of rhetorical criticism, students will gain an understanding of the persuasive value of style, arrangement, and delivery by investigating their professional roles in helping to structure public debate. Pre: 3804. (3H,3C).

Graduate Creative Writing Courses, MFA (ENGL)

5734: FORM AND THEORY OF FICTION
A graduate course for writers of fiction in which students are taught to analyze the forms and theories which underlie the development of the genre. Students will be asked to critique the theoretical assumptions which have been applied to the genre and study the history and conventions that have shaped the writing of fiction. They will be required to interrogate the forms and prevailing theories which have shaped major novelists and short story writers, and apply what they discover to the crafting of their own fiction. (3H,3C).

5744: FORM AND THEORY OF POETRY
A graduate course for practicing poets and writers in which students are taught to analyze the forms and theories which underlie the development of the genre. Students will be asked to critique the theoretical assumptions which have been applied to the genre and study the history and conventions that have shaped the writing of poetry. Students will analyze prosody; imitate metrical forms, such as the sonnet and the sestina; and adapt the techniques used by poetic masters. Students will study the works of a wide array of writers, from Chaucer to contemporary poets. They will be required to interrogate the forms and prevailing theories which have shaped the voices of poets through the ages. (3H,3C).

5754: FORM AND THEORY OF DRAMA
A graduate course for practicing playwrights and writers in which students are taught to analyze the forms and theories which underlie contemporary playwriting. Students will be asked to critique the theoretical assumptions which have been applied to the genre and study the history and conventions that have shaped playwriting and performance. Special emphasis will be placed on the interplay between theory and performance, and the influence of aesthetics on dramatic form and performance practices as students learn to adapt those approaches to their own playwriting. (3H,3C).

5764: NEW MEDIA CREATIVE WRITING
A graduate course in creative writing in a digital environment, which provides the experienced creative writer with an opportunity to develop a hypertext project. Students will learn a variety of techniques appropriate for writing designed to be read in a digital environment and adapt them to their own texts. Primary focus is on the composition of an original hypertext, but students are also required to analyze the work of influential "new media" writers and critics of the hypertext genre. (3H,3C).

6704: FICTION WORKSHOP
This advanced course in fiction writing provides those who wish to pursue careers in creative writing with the tools they need to develop as novelists and short story writers. Primary focus in on the writing and critiquing of original short stories and longer pieces of original fiction, while paying close attention to the work of established fiction writers who are acknowledged masters of their genres. This course may be repeated up to the maximum credit hours (15). Previous workshop experience is required. (3H,3C).

6714: POETRY WORKSHOP
This advanced course in poetry writing provides those who wish to pursue careers in creative writing with the tools they need to develop as poets. Primary focus is on the writing and critiquing of original poems, while paying close attention to the work of established poets who are acknowledged masters of their genres. This course may be repeated up to the maximum credit hours (15). Previous workshop experience is required. (3H,3C).

6724: PLAYWRITING WORKSHOP
This advanced course in playwriting provides those who wish to pursue careers in creative writing with the tools they need to develop as playwrights. Primary focus is on the writing and critiquing of original plays, while paying close attention to the work of established dramatists who are acknowledged masters of their genres, and to the aspects of playwriting that relate to theatrical production. This course may be repeated up to the maximum credit hours (15). Previous workshop experience is required. (3H,3C).

ENTOMOLOGY

Loke T. Kok, Head

Professors: J.R. Bloomquist; R.D. Fell; D.A. Herbert, Jr.; L.T. Kok; D.E. Mullins; D.G. Pfeiffer; P.B. Schultz; P.J. Semtner; J.R. Voshell, Jr.; M.J. Weaver; R.R Youngman
Associate Professors: S.L. Paulson; S.M. Salom
Assistant Professors: J.C. Bergh; C.C. Brewster; T.P. Kuhar; D.M. Miller; I. Sharakhov

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The entomology department has graduate programs leading to the M.S. (thesis or non–thesis) and Ph.D. Its purpose is to offer training in basic and applied entomology through a combination of graduate courses, research programs, and teaching experience. Graduate research programs may deal with a variety of entomological topics including basic biological studies (ecology, systematics, physiology, toxicology, morphology), environmental assessment and pesticide management, biological control, sustainable agriculture and integrated pest management, computer–aided decision making, and urban, aquatic and forest entomology.

Laboratories and equipment are available for graduate student research. These include facilities for rearing insects, such as constant temperature rooms, cabinets and greenhouse rooms for rearing plants, a beneficial insect quarantine laboratory, genetic stock center for cockroaches, and laboratory facilities for biochemical and physiological research. The department also has the largest collection of insects in Virginia. Five off–campus laboratories for research on specialized insect problems are located at research stations in diverse geographical, topographical, and agricultural sections of the state. Computing facilities on campus are accessible from many personal computers located in Price Hall. The department maintains a state–of–the–art computer–aided classroom which is well equipped with computers and software. Statistical analysis, weather records, systems models and numerous other software packages are available for student use.

SPECIAL DEGREE REQUIREMENTS

Each student's plan of study will be determined by a graduate advisory committee according to the student's background and area of desired specialization. The graduate advisory committee may require a student to make up deficiencies in undergraduate courses deemed necessary for a particular area of specialization. All graduate students are required to take courses in the following entomological subject areas: physiology, ecology and systematics. In addition, Ph.D. students are required to take courses in three of the following areas: morphology, behavior, toxicology, biotechnology, biological control, integrated pest management, sustainable agriculture, or expert systems All Ph.D. students are expected to have completed courses in calculus, organic chemistry, and physics and are required to correct deficiencies. All students must be well versed in statistics. Candidates for the Ph.D. degree must demonstrate breadth of experience in at least one area apart from their major area of study. This enrichment experience must be approved by their advisory committee and may take the form of foreign language, business, computer science or other pre–approved training. Students in the non–thesis M.S. program are required to complete an internship and a project paper in addition to course work.

GRADUATE COURSES (ENT)

5004: GRADUATE SEMINAR
Lectures and discussions by faculty and students on a current topic pertinent to research being conducted in the department. Critical evaluation of principles, theories, and methods will be emphasized. May be repeated. (1H,1C).

5014: INTRODUCTION TO ENTOMOLOGICAL RESEARCH
This course provides a general orientation to the field of entomology, with emphasis on training students for research careers. It is intended for all graduate students in entomology. Topics emphasized include: history of entomology, entomology as a science and profession, sources of literature and modern methods of information retrieval, illustration techniques, and presentation of research results. (1H,3L,2C).

5114: INSECT STRUCTURE & FUNCTION
A comparative study of the major structures and organ systems emphasizing modifications important in the success of insects. Designed for graduate and upper level undergraduate students in entomology and zoological biology. Pre: 3014. (2H,3L,3C).

5214: ARTHROPOD PEST MANAGEMENT
Principles and techniques designed to reduce pest levels below those causing injury of economic importance to agriculture and forestry. Course objectives are to provide students with background information which will enable them to formulate comprehensive approaches to pest problems and emphasize alternate methods of pest control and integrated approaches to pest problems. Appropriate for graduate students in entomology, plant protection, and related curricula. (2H,3L,3C).

5224: ARTHROPOD DISEASE CARRIERS
Classification and life history of Arthropods that affect the health of man and animals. Emphasis is on research problems dealing with these Arthropods, to include laboratory rearing, surveillance, and the design of laboratory and field experiments. Visits will be made to nearby commercial, federal, and state medical entomology facilities. Pre: 3254. (2H,3L,3C).

5254: URBAN & EXTENSION ENTOMOLOGY
Insects associated with man and animals in the urban environment; in depth coverage of household, structural, and turf insects, including biology, habits, and pest management programs design; consideration of target audience and control strategies; review of national and international urban areas with respect to insect pest/man interaction; and trends in urban pest management. Appropriate for majors and non–majors in entomology. Lecture and demonstrations. Pre: 3014. (2H,3L,3C).

5264: BIOLOGICAL CONTROL OF ARTHROPOD PESTS & WEEDS
Principles involved in the use of indigenous and introduced biological agents in the regulation of arthropod pests and weeds. Course objectives are to emphasize concepts important in biological control: population dynamics, host–parasite interactions, characteristics of parasitism and predation, principles involved in current biological approaches to pest control, and use of biological agents to control weeds. Suitable for students in entomology, plant protection, and related curricula. (2H,3L,3C).

5314: INSECT ECOLOGY
The relation of insects with their environment. Topics covered include: sampling, life history strategies, population regulation and growth, predator–prey relations, competition, trophic relations, production, distribution, dispersal, relation of physical factors, and role of insects. This course will give students a working knowledge of the principles and research techniques of insect ecology. (3H,3C).

5404: INSECT BIOSYSTEMATICS I
Principles of systematic entomology, speciation, phylogeny, and evolution; modern techniques in insect taxonomy; description, illustration of insects, and preparation of identification keys; phylogeny, classification, and biology of 24 orders of North American insects; non–insect arthropods; use of identification keys for both adults and immatures; and major sources of literature. A collection of adult and immature insects is required. Pre: 5114. (3H,3L,4C).

5414: INSECT BIOSYSTEMATICS II
Phylogeny, classification, and biology of 4 major orders (Coleoptera, Lepidoptera, Diptera, Hymenoptera), more important families, subfamilies, and some genera of North American insects that develop with complete metamorphosis; use of identification keys for these groups, for both adults and immatures; collecting, preservation, and mounting of the above groups of insects; and major sources of literature. A collection of adult and immature insects is required. Pre: 5114, 5404. (3H,3L,4C).

5904: PROJECT AND REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

6004: ADVANCED TOPICS IN ENTOMOLOGY
In–depth presentations and discussions on selected advanced topics in entomology. (Maximum 4 C per course). Variable credit course.

6154: INSECT PHYSIOLOGY
Detailed study of the physiology and biochemistry of insect organ systems. Topics include: circulation, digestion, respiration, excretion, hormonal regulation, pheromones, intermediary metabolism, and nerve and muscle physiology. Laboratories provide exposure to instrumentation and techniques used in physiological research. Pre: 5114, CHEM 2535, CHEM 2536. (3H,3L,4C).

6164: INSECTICIDE TOXICOLOGY
This course is designed to teach advanced graduate students the chemistry, toxicity, mode of action, and pharmacology of insecticides and related compounds, and to give them an opportunity to learn the methods employed in studying these compounds. The course is designed for entomology and other life science majors. Pre: 6154. (2H,3L,3C).

6254: POPULATION MODELLING OF INSECT SYSTEMS
Simulation models are being used to summarize the state of knowledge in insect systems, formulate new hypotheses about these systems, and predict future events. This course is designed to acquaint students with the basic methods of the systems approach, population/simulation model development, and model implementation. The techniques described in this course are applicable to problems in both basic (ecology, physiology, genetics) and applied areas (management). Pre: 5214 or 5314. (2H,3L,3C).

6354: INSECT BEHAVIOR
An examination of insect behavior using a comparative evolutionary approach. Topics covered include insect neurophysiology and neuroendocrinology as they relate to insect behavior, feeding and foraging behaviors, zoosemiotics and the evolution of insect communication systems, reproductive behaviors, insect social behavior, defensive behaviors, and thermoregulation. Pre: 5114, 5314. (2H,3L,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ENT)

The following 4000–level courses have been approved for graduate credit:

4254: INSECT PEST MANAGEMENT
Principles of insect pest management with application to the major insect pests found in Virginia. Pest management involves the utilization of all effective control practices in a program which is ecologically and economically efficient. This course is intended for all students with an interest in efficient agricultural production and in reducing losses to our most diverse competitor. One year of General Biology required. (2H,3L,3C).

4264 (PPWS 4264): PESTICIDE USAGE
An interdisciplinary study of pesticides used in urban and agricultural environments. Topics studied will include: classification, toxicology, formulation, application techniques, safety, legal considerations, environmental impact, and research and development of new pesticides. Pre: CHEM 2515 or CHEM 2536. (2H,3L,3C).

4354 (BIOL 4354): AQUATIC ENTOMOLOGY
Biology and taxonomy of insects and other macroinvertebrates most commonly encountered in freshwater environments. Selected aspects of biology, such as habitat, feeding, locomotion, and life history. Identification of individual taxa, mostly at family and genus level. Significance of these organism in aquatic ecology, pollution monitoring, and natural resource management.
Pre: (BIOL 1005, BIOL 1006), (BIOL 1015, BIOL 1016) or (BIOL 1105, BIOL 1106, BIOL 1115, BIOL 1116). (3H,3L,4C).

4484 (BIOL 4484) (FIW 4484): FRESHWATER BIOMONITORING
Concepts and practices of using macroinvertebrates and fish to monitor the environmental health of freshwater ecosystems. Effects of different types of pollution and environmental stress on assemblages of organisms and underlying ecological principles. Role of biological studies in environmental regulation. Study design, field and laboratory methods, data analysis and interpretation, verbal and written presentation of results. Pre: (BIOL 2804), (BIOL 4004 or BIOL 4354 or ENT 4354 or FIW 4424 or FIW 4614). (3H,3L,4C).

4524 (FOR 4524) (PPWS 4524): PEST AND STRESS MANAGEMENT OF TREES
Ecology of biotic and abiotic influences on forest and landscape tree health. Emphasis will be placed on developing a theoretical and practical understanding for managing pests and stresses of trees in both the forest and landscape setting. Insects and diseases of trees will be reviewed. Pre: FOR 3324 or PPWS 3104 or FOR 3354. (2H,3L,3C).

ENVIRONMENTAL DESIGN & PLANNING

Ron Wakefield, Director

Program Committee: M. Frascari (Architecture), R. Wakefield (Construction and Building Science), D. Kilper (Design), T. Luke (Public and International Affairs), J. Browder (Planning)

Web: http://www.caus.vt.edu/CAUS/EDP/

The College of Architecture and Urban Studies offers a college–wide Ph.D. prgram in Environmental Design and Planning. A goal of the program is to educate researchers, teachers, and advanced level practitioners in the areas of architecture, building science, construction, landscape architecture, interior design and planning, urban studies, and public and international affairs while advancing the knowledge base in these fields.

The college has a diverse faculty with a wide range of expertise. Students in the program have a variety of opportunities to conduct research in one or more of the fields of interest. The program has five streams in which students can pursue focused research. The streams are Architecture, Planning, Construction and Building Science, Public and International Affairs, and Design. There are also opportunities for students to pursue multidisciplinary research within or across the streams.

Areas of special opportunity for research currently include (but are not limited to) disadvantaged households within metropolitan settings; collaborative governance; economic development; energy and environmental policy/planning evaluation and control of indoor environments; evaluation research; health policy/planning; housing policy/planning; integrated land resource surveys; landscape aesthetics and design theory; political ecology; land use in Latin American historic districts; public management; construction management processes and materials; IT in constuction; sustainable Third World development; globalization and politics; theory and history of architecture; representation and architecture; and virtual environments technology and applications.

Prospective students are encouraged to contact the director, program, committee, or college faculty with questions related to the program.

Special Facilities

Special facilities in Blacksburg include a 9,000 square foot research and demonstration facility, an Environmental Systems Laboratory, and a fully equipped multimedia laboratory (shared with the College of Engineering). The college also operates the Washington–Alexandria Architecture Center in Northern Virginia and participates in the university's Center for European Studies and Architecture in Switzerland. Two streams of the Environmental Design and Planning Program, namelyArchitecture and Planning offer prgrams of study at the Washington–Alexandria Architecture Center.

Special Degree Requirements

Within broad constraints, students are given considerable freedom to develop individual programs of study in collaboration with advisory committees composed of faculty who share the students' interests. All students are expected to participate in a doctoral seminar that focuses primarily on epistemology and the nature of research, as well as teaching, viewed in the context of the design, building, and planning fields. In addition, students must satisfy core requirements in theory and research methods.

Graduate Courses (EDP)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

6005–6006: SEMINAR IN ENVIRONMENTAL DESIGN & PLANNING
Historical context for and nature of, research in fields encompassed by environmental design and planning; theoretical underpinnings and methodological approaches; current research directions; and selected case studies of research projects. (3H,3C).

6104: PLANNING THEORY SEMINAR
A doctoral–level seminar that traces the epistemology of major contemporary theories of planning so as to situate the activity of modern planning in an historical and intellectual context. Pre: UAP 5104 or UAP 5174 or UAP 5414. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ENVIRONMENTAL ENGINEERING

J. Little, Program Chair

Nick Prillaman Professor: J.T. Novak
W. Curtis English Professor: W.R. Knocke (Department Head)
Professors: G.D. Boardman; M. Edwards; T.J. Grizzard
Associate Professors: A.M. Dietrich; D.L. Gallagher; J. Little; N.G. Love
Assistant Professors: A. Godrej; L. Marr; P Vikesland

E–mail: bwingate@vt.edu
Web: www.cee.vt.edu/program_areas/environmental/

The Environmental Engineering Program of the Department of Civil and Environmental Engineering offers graduate study leading to the M.S. (thesis required) in environmental engineering and the Ph.D. in the environmental engineering option of civil engineering. Both the M.S. and the Ph.D. curricula have options in water pollution control, air pollution control, environmental toxicology, environmental microbiology, environmental chemistry, hazardous waste management, and water quality modeling. The goal of the programs is to educate and prepare engineers for careers in the various fields of environmental engineering design, water supply management, site remediation, environmental modeling, pollution control engineering, and public health protection.

The M.S. in environmental engineering is separately accredited by the Associated Boards of Engineering and Technology (ABET) and is open to students from all undergraduate engineering curricula. It is specifically designed to build upon undergraduate degrees in civil, chemical, agricultural, mechanical, and mining engineering. The program objectives are to:

- Apply science and mathematics to the analysis of environmental engineering problems.
- Recognize the social, political and environmental contexts of environmental engineering.
- Employ modern technology for analysis and design of environmental engineering systems.
- Practice engineering in a professional environment through practical application of skills for conducting technical analysis, communicating orally and in writing, and applying prevailing standards of professional and ethical behavior.
- Maximize individual potential, including lifelong growth, development, and professional activities.
- Conduct data analysis and data evaluation for environmental processes or systems.

The purpose of the core curricula is to develop an understanding of the applicable chemical, physical, biological, and mathematical modeling fundamentals and then teach the student how to apply them for treatment process design and environmental management. Specialization can be in water treatment, municipal and industrial waste water treatment, environmental toxicology, environmental microbiology, land disposal of wastes, groundwater pollution control, hazardous waste management, air pollution control, surface water eutrophication control, non–point pollution control, solid waste management, water quality modeling, environmental chemistry, and bioremediation.

The Ph.D. program is designed to build directly upon the M.S. in environmental engineering, but also is open to students with master's degrees in other engineering disciplines. Areas of specialization are the same as for the M.S. degree, but the programs of study are more individualized. The Ph.D. is a research degree, but applied aspects of the degree program are maintained.

Resources available for teaching and research include modern, well–equipped laboratories and sophisticated, analytical equipment such as atomic absorption units, gas, ion, and high performance liquid chromatographs GC/mass spectrometer, spectrophotometers, and organic carbon analyzers on campus and a large monitoring and analytical laboratory at a major field research site located near Washington, D.C. Excellent computer and pilot–scale, treatability/demonstration facilities also are available.

GRADUATE COURSES (ENE)

The majority of the appropriate courses are listed under the Department of Civil and Environmental Engineering. Additional listings are under the Departments of Biological Systems Engineering, Crop and Soil Environmental Sciences, Biochemistry, Biology, Chemical Engineering, Chemistry, Mechanical Engineering, and Statistics.

ENVIRONMENTAL PROGRAMS

Environmental programs encompasses a broad array of subject matter, approaches, and issues regarding the natural environment and the sustainability of the biosphere in the face of human development. Considerable attention is currently devoted to environmental programs at Virginia Tech, in instructional programs, research, and outreach. More than three dozen centers, institutes, and laboratories–on campus and across the commonwealth–have environmental studies as a major focus, and well over 200 faculty members have environmental interests.

Although Virginia Tech offers no single, comprehensive, graduate degree program in environmental studies, a wide variety of environmentally related degree programs (and options within degree programs) are available at the graduate level. Interested students should look under the following program headings for more information:

Agricultural and Applied Economics
Architecture
Biochemistry
Biological Systems Engineering
Biology
Chemistry
Civil and Environmental Engineering
Crop and Soil Environmental Sciences
Economics
Entomology
Environmental Design and Planning
Environmental Engineering
Environmental Sciences and Engineering
Fisheries and Wildlife Sciences
Forestry
Geography
Geological Sciences
Landscape Architecture
Natural Resources
Plant Pathology, Physiology, and Weed Science
Urban Affairs and Planning
Veterinary Medical Sciences
Wood Science and Forest Products

ENVIRONMENTAL SCIENCES & ENGINEERING

John Novak, Chair

Advisory Committee: G. Boardman; D. Gallagher; C. Zipper; R. Reneau; R. Jones; F. Benfield

E–mail: bwingate@vt.edu
Web: www.cee.vt.edu/program_areas/environmental/

Interdisciplinary activities in the College of Engineering concerned with the definition and solution of environmental problems are coordinated through the Environmental Engineering Division of the Department of Civil and Environmental Engineering. Of particular interest are science and engineering solutions to such problems as water pollution, solid waste management and disposal, air pollution, hazardous waste management, environmental chemistry, bioremediation, toxicology, and soil pollution. The goal of the programs is to educate and prepare scientists for careers in environmental fields such as environmental chemistry, water quality management, hazardous waste management, air quality management, solid waste management, public health controls, and water quality modeling.

Affiliated faculty members come from a variety of departments, including aerospace and ocean engineering, biological systems engineering, chemical engineering, civil engineering, mechanical engineering, materials engineering, and mining engineering. In addition, faculty members outside the College of Engineering are affiliated with the program, including members of the crop and soil environmental sciences, biology, chemistry, forestry and wildlife, and statistics departments.

The Environmental Engineering Division administers interdisciplinary graduate degree program leading to the M.S. in environmental sciences and engineering. The program is primarily designed for qualified students with undergraduate degrees in one of the natural sciences who wish to obtain technically oriented training. The degree is considered to be intermediate between the sciences and engineering. The natural sciences students should have strong backgrounds in mathematics, including differential equations, and have had courses in chemistry and physics. Degree candidates may elect a thesis under the supervision of any faculty member affiliated with the Environmental Sciences and Engineering Program.

SPECIAL DEGREE REQUIREMENTS

There are core course requirements for all students which must be satisfied to obtain a graduate degree. The core courses differ, however, depending upon the branch of science of the student's undergraduate degree and the student's desired area of specialization. All plans of study must be approved by the student's advisory committee and the program chairman. Each applicant is considered on the basis of previous academic performance, Graduate Record Examination (GRE) scores, letters of reference, and prior research and/or professional achievements.

GRADUATE COURSES (ESEN)

Most of the courses are listed under the Department of Civil and Environmental Engineering. Other course listings are provided under the Departments of Engineering (General), Aerospace and Ocean Engineering, Biological Systems Engineering, Chemical Engineering, Crop and Soil Environmental Sciences, Biochemistry, Biology, Chemistry, and Statistics.

FINANCE, INSURANCE, & BUSINESS LAW

Vijay Singal, Head

SunTrust Professor of Finance: G.E. Morgan
SunTrust Professor of Banking: J.M. Pinkerton
J. Gray Ferguson Professor of Finance: V. Singal
R. B. Pamplin Professors of Finance: G.B. Kadlec; A.J. Keown
R.V. and A.F. Oliver Professor of Investment Management: R. Kumar
Professors: J.S. Hiller; D.M. Patterson; M.I. Schneller; D.K. Shome; G.R. Thompson
Associate Professors: R.S. Billingsley; V.A. Bonomo; J.C. Easterwood; A. Mozumdar
Assistant Professor: M. Cliff; S. Mansi; H. Gulen; A. Outchinnikov; B. Remmers
Instructors: S.D. Smith; C. Giles
Career Advisor: Dilip K. Shome (231–3607)

E–mail: fin@vt.edu
Web: http://www.cob.vt.edu/finance/

The Department of Finance, Insurance and Business Law offers graduate studies leading to two advanced degrees: the Ph.D. and the M.B.A. (with specialization in finance). The Ph.D. degree requires dissertation on an approved research topic in finance. The objective of the doctoral program in finance is to prepare the student for a career in academe or at the research level of private and public organization and to publish in top scholarly journals. This is a research–oriented degree wherein the student must display a deep understanding of both financial theory and practice through the completion of an original piece of research (the dissertation). Strong methodological training is necessary to successfully complete the program. The M.B.A. is a non–thesis degree program that allows for specialization in finance through the selection of appropriate course electives. In addition, M.B.A. students may pursue concentrations in in investment and financial services management, and corporate financial management. More details about the M.B.A. program are available at http://www.mba.vt.edu.

GRADUATE COURSES (FIN)

5004: FUNDAMENTALS OF LEGAL ENVIRONMENT OF BUSINESS
Examines the legal environment in which businesses operate. In particular, torts, contracts, agency, government regulation, and forms of business will be covered. (Not open to those with previous legal environment coursework.). (3H,3C).

5014: COMMERCIAL LAW
This course examines those topics related to legal concepts of commercial transactions. Specifically addressed will be: collection of debts, sale of goods problems (such as warranties, checks, product liability), notes and the banking system, secured transactions, and bankruptcy. Pre: 3055. (3H,3C).

5024: PRINCIPLES OF FINANCE
Explores the basic concepts underlying the finance function, relevant to finance and non–finance majors. It provides an understanding of the firm's decision–making framework in the context of the economic environment (financial markets) in which the decisions are made. The specific topics covered, at a basic level, include

investment decision under uncertainty, valuation, risk and return, market efficiency, portfolio theory, asset pricing, cost of capital, capital investment decisions, and futures and options markets. Pre: STAT 5624, ECON 5504, ACIS 5104. Blacksburg, NVC and extended campus. (3H,3C).

5034: INTERNET LAW & POLICY
Intensive examination of public and private regulation of the Internet at the local, national, and international levels. The broad areas covered are Internet as a communication medium; privacy, security and trust; intellectual property; and electronic commerce. Specific topics include freedom of speech, encryption, and distance education. The course will examine private means of regulation, national, and state policies and international perspectives of Internet law. Pre: Graduate standing or consent of instructor. (3H,3C).

5044: ASSET VALUATION
Focuses on techniques for the valuation of non–financial assets such as projects, business units, private and public firms. Specific topics include method of comparables, discounted cash flow methods and the real options approach to valuation. Pre: 5024. Blacksburg campus only. (1H,1C).

5054: OPTIONS & FUTURES
This course provides an introduction to Derivative Securities like Options, Futures, and Forwards. The specific topics covered will include the payoffs and profits of Puts, Calls, and Forward contracts, one period binomial option pricing model, the use of Black–Scholes option pricing model, the relationship between the Spot and Forward prices, and an introduction to Real Options. Pre: 5024. Blacksburg campus only. (1H,1C).

5064: EQUITY MARKETS
Examines the role and functioning of the equity markets. Specific topics include the market structure and securities trading, overview of investment companies, and equity valuation models with brief overview of statistical properties of equity returns. Pre: 5024. Blacksburg campus only. (1H,1C).

5074: INTEREST RATES
Analysis of the macroeconomic and macro–financial environment of interest rate determination. Attention will be paid to the role of both monetary policy and market forces. The course will also review and analyze the basic determinants of valuing fixed income instruments. Pre: 5024. Blacksburg campus only. (1H,1C).

5104: CORPORATE FINANCE
Provides a broad coverage of the major policy making areas of a corporation. The course covers topics in capital investment policy, financing and capital structure policies, dividend policy, financial statement analysis, financial forecasting, and the basics of working capital management. Pre: 5024. Northern Virginia and Extended campus only. NVC and extended campus only. (3H,3C).

5114: INTEREST RATES & FIXED INCOME SECURITIES
Analysis of the macroeconomic environment of interest rate determination and monetary policy. Description and analysis of several classes of fixed income securities. Measurement and management of interest rate risk. Introduction to arbitrage–free term structure modeling and applications to the pricing and hedging of debt securities. Pre: 5024. NVC and extended campus only. (3H,3C).

5124: INVESTMENT ANALYSIS & PORTFOLIO MANAGEMENT
Examines the role and functioning of securities markets. Specific topics include the equity market, fixed–income securities market, and mutual funds. The course presents portfolio and capital market theory, the efficient markets hypothesis, institutional organization, and security valuation techniques. Pre: 5024. NVC and extended campus only. (3H,3C).

5134: INVESTMENT BANKING IN A GLOBAL ENVIRONMENT
Examines advanced topics confronting investment banks as intermediaries in the raising capital and corporate restructuring processes. The topics include the U.S. and international structure and regulation of investment banking, global market strategies, intermediation theories, corporate going public and raising capital in a global market, corporate restructuring transactions, investment banking innovations, municipal financing, and ethics. The course contains a strong analytical component and also uses case studies. Pre: 5024. NVC and extended campus only. (3H,3C).

5144: FINANCIAL INSTITUTION MARKETS & MONEY
Theoretical explanation of why financial markets exist with attention to the functions of financial institutions within those markets. The course considers the money and capital markets in the U.S., focusing on: (1) the theoretical determinants of interest rates; (2) the decision to participate in financial markets; (3) current topics in financial institutions and markets. Pre: 5104. NVC and extended campus only. (3H,3C).

5154: COMMERCIAL BANK MANAGEMENT
Emphasis on the major issues facing managers of financial institutions focusing primarily on commercial banks. Topics include asset, liability, and capital management, the interaction of the regulatory environment with managerial decisions, and international banking. Pre: 5104. NVC and extended campus only. (3H,3C).

5164: ADVANCED CORPORATE FINANCE
Covers advanced topics in the basic policy making areas of corporations and special topics in corporate finance. The advanced topics are presented in the framework of the more current theories of corporate finance. The course also has a strong applied component in the form of case studies and computer applications. Pre: 5104. NVC and extended campus only. (3H,3C).

5174: CORPORATE RISK MANAGEMENT
Identification of domestic and global risk management problems of corporations. Introduction to the characteristics of derivative contracts and markets. Applications of derivative contracts to the solution of corporate risk management problems. Use of real–world examples and cases highlight the practical approach taken in this course. Must have prerequisite or consent of instructor. Pre: 5024. NVC and extended campus only. (3H,3C).

5184: CURRENCIES & GLOBAL FINANCE
Explores the international economic environment, including analyses of exchange rates, international monetary systems, contemporary currency regimes, and current financial crises. Examines a firm's exposure to various kinds of exchange risks and the methods and financial instruments used to manage those risks. Introduces global opportunities open to firms for raising capital, foreign investment in financial assets, and managing currency and interest rate risk. Blacksburg, NVC and extended campus. Pre: 5024. (3H,3C).

5204: MANAGING CORPORATE CAPITAL INVESTMENT & CAPITAL STRUCTURE
Explores value creation through capital investment and capital structure choices. The capital investment and capital structure policies of a corporation have a very significant impact on its value and this course explores how these policies are established in the framework of modern finance theory. The course has a theoretical component and an applied component in which the case method is used. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5214: FIXED INCOME SECURITIES
Description and analysis of several classes of fixed income securities. Measurement, management, and pricing of interest rate risk and credit risk. Valuation of embedded options. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5224: PORTFOLIO MANAGEMENT
This course focuses on portfolio management and asset pricing. Specific topics include portfolio theory, asset pricing models (Capital Asset Pricing Model, Arbitrage Pricing Theory, among others), market efficiency and performance evaluation. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5234: VENTURE CAPITAL & INVESTMENT BANKING
Explores the venture capital cycle of fund-raising, investing in portfolio firms, and exiting the investment. Focuses on the role of investment banking in the exiting of investments by taking the portfolio firms public through initial public offerings. Comprises a conceptual component and an applied component in which the case method is used. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5244: MANAGING CORPORATE RISK WITH DERIVATIVES
Identification of domestic and global risk management problems of corporations. Application of derivative contracts to the solution of corporate risk management problems. Use of real world examples and cases of risk management. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5254: FINANCIAL INSTITUTION RISKS & STRATEGIES
Emphasis on the major issues facing managers and owners of financial institutions, primarily commercial banks. Topics include the risks and rewards associated with granting credit, managing liquidity, interest rates/currency positions, technology, and sovereign borrowers. The role of capital adequacy and the interaction of other regulatory aspects of the environment with managerial strategies and owner interests are emphasized throughout the course. Students run a simulated bank for the full semester. Pre: 5024, 5044, 5064, 5074. Blacksburg campus only. (2H,2C).

5264: MERGERS & ACQUISITIONS & CORPORATE RESTRUCTURING
Focuses on the major aspects of merger and acquisition transactions: deal strategy, deal analysis and deal design. Additionally, it explores value creation through other forms of corporate restructuring, such as divestitures or sell-offs, spin-offs, equity carve-outs, leveraged recapitalizations and leveraged buyouts. The course uses the case methods as the primary mode for teaching. Pre: 5024, 5044, 5054, 5064, 5074. Blacksburg campus only. (2H,2C).

5274: DERIVATIVE PRICING MODELS
Stochastic processes and arbitrage arguments used in pricing and managing the risk of options, forwards, futures, and swaps. Models applicable to standard European and American options as well as exotic options. Binomial, finite-difference, and Monte Carlo methods for numerical pricing. Models of the term structure are developed for pricing interest rate derivatives. Mortgage-backed securities including strips and collateralized mortgage obligations. Must have prerequisite or consent of instructor. Pre: 5174. NVC and extended campus only. (3H,3C).

5604: FINANCIAL & ECONOMIC ENVIRONMENT OF BUSINESS
Provides an understanding of the financial and economic environment in which the financial decisions of the firm are made. Studies the basic principles and concepts underlying the finance function. The specific topics covered are financial assets and markets, financial intermediaries, interest rates, time value of money, risk and return, diversification and capital asset pricing model, valuation of stocks and bonds and market efficiency. Executive MBA students only. (2H,2C).

5614: FINANCIAL MODELING & CORPORATE FINANCE
Provides coverage of the major financial decisions facing a corporate manager in a modeling framework. The specific topics covered are analysis of financial statements, financial planning, cost of capital and capital budgeting, capital structure, working capital management, dividend policy, and international financial management. Executive MBA students only. (2H,2C).

5624: VALUATION & CORPORATE RESTRUCTURING
Explores value creation through corporate restructuring. Provides detailed coverage of alternative valuation methods and explores the major asset and liability restructurings undertaken by a firm. The specific topics covered are valuation techniques, mergers and acquisitions, spin-offs, divestitures/asset sales, leveraged recaps, and leveraged buyouts. Executive MBA students only. (2H,2C).

5634: LEGAL & ETHICAL ISSUES IN THE HIGH TECHNOLOGY ENVIRONMENT
Intensive exploration of legal and ethical issues that affect the operation of business in the high technology, networked environment. Studies public and private regulation of business, emphasizing the networked environment. Explores the interrelationship of ethics and law, the duties of directors and managers, and decision-making under uncertain regulatory parameters. Included within these areas are; participating in the regulatory process, intellectual property, ethical frameworks, Internet privacy and security, and international perspectives. Executive MBA students only. (1H,1C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: INTRODUCTION TO FINANCIAL THEORY
Examines the basic principles of finance theory. The course covers the theories of choice under certainty and uncertainty. The criteria for choice under uncertainty are used to develop asset valuation models and theoretical frameworks for the firm's capital investment, capital structure, and dividend decisions. The course also deals with the basics of information theory and the theory of efficient capital markets. Pre: ECON 5005. (3H,3C).

6115,6116: CORPORATE FINANCE
Analysis of financial decisions in the corporate firm under uncertainty and in the presence of agency costs, information asymmetries, incomplete markets, and taxation. Pre: 6004. (3H,3C).

6125,6126: INVESTMENTS
Advanced treatment of equity, debt, and speculative markets. Topics include security return distributions, market efficiency, mean-variance portfolio theory, capital asset pricing, arbitrage pricing, option pricing models, and futures markets. Theory and empirical evidence are examined. Pre: 6004. (3H,3C).

6134: EMPIRICAL RESEARCH METHODS
In-depth examination of the methods and techniques used for empirical research in finance. Alternative procedures for estimation of risk, return, and abnormal performance will be examined. Methodological issues related to bid-ask bounce, non-synchronous and infrequent trading will be discussed. The course will also provide an exposure to the financial databases like CRSP, COMPUSTAT, TAQ, and IBES, which are commonly used for empirical research in finance. Pre: 6004 or 6125. (3H,3C).

6144: ADVANCED TOPICS IN FINANCE
Advanced topics of contemporary interest in finance. The course can be focused on a single area such as financial derivatives and risk

management, mergers and acquisitions, investment banking, global financial markets, or financial regulation, or can reflect a combination of topics from several areas. Pre: Three credits in 6000 level FIN courses and consent of instructor. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

FISHERIES & WILDLIFE SCIENCES

D.J. Orth, Head

Professors: J.D. Fraser; E.M. Hallerman; L.A. Helfrich; E. McLean; B.R. Murphy; J.J. Ney; R.J. Neves; D.J. Orth; D.F. Stauffer; D.L. Trauger; M.R. Vaughan
Associate Professors: P.L. Angermeier; J.M. Berkson; S. Craig; C.A. Dolloff; C.A. Haas; S.L. McMullin; J.A. Parkhurst
Assistant Professors: P.A. Flebbe; M.S. Kelly; A.D. Lemly
Adjunct Professors: W. Hershberger; T.J. Newcomb; E.P. Smith; S.A. Smith; J.R. Walters
Senior Research Associate: J.L. Waldon
Career Advisors: *Fisheries*, J.J. Ney (231–7292); *Wildlife*, J.A. Parkhurst (231–9283)

Web: www.fw.vt.edu/fisheries/

The Department of Fisheries and Wildlife Sciences offers M.S. and Ph.D. programs. The comprehensive curriculum covers fisheries and wildlife biology and ecology, conservation biology, habitat analysis, aquaculture and human dimensions of natural resource science and management. Faculty specialties include endangered species management, coldwater stream management, conservation genetics, trophic ecology, recycling aquaculture systems, wildlife physiology and ecotoxicology, habitat analysis and management, geographic information systems, human dimensions, policy and administration. M.S. programs stress preparation for professional careers in public agencies and private organizations with fisheries and wildlife responsibilities; doctoral programs stress preparation for research and leadership positions in public agencies and for university faculty positions.

The department hosts cooperative units with the U.S. Geological Service Biological Resources Division, the U.S. Forest Service, and the National Marine Fisheries Service. These cooperatives provide students with access to lands, waters, animals, facilities, and equipment throughout the nation. The department maintains facilities in Cheatham Hall for laboratory analysis, small–scale aquatic experiments, small–animal holding, computer analysis, and geographic information systems. The latest computer technology is available through CEARS: Center for Environmental Application of Remote Sensing. The department is affiliated with the Conservation Management Institute, an outreach and research organization dedicated to improving natural resource conservation worldwide. A newly renovated 11,000 sq. ft. aquaculture laboratory provides state–of–the–art facilities for endangered species and food–fish aquaculture. Center Woods is an off–campus woodlot housing captive animal facilities for bear and other animals. Most student research, however, is conducted in field locations; most projects are in Virginia and adjacent states, but current projects also occur in Alaska, California, Florida, New York, North Dakota, West Virginia, and the countries of Belize, China, Cuba, Kenya, Mexico, India, and Taiwan.

SPECIAL DEGREE REQUIREMENTS

All graduate students must conduct M.S. or Ph.D. research projects, in addition to course work chosen in consultation with an advisory committee. Research projects are designed

in a student–written research working plan that is approved by the advisory committee. In almost all cases, students are funded on research contracts or teaching assistantships, both of which may require substantial work outside of degree requirements. Most graduates are expected to satisfy certification requirements for either the American Fisheries Society or The Wildlife Society; this may require additional course work for students entering the program from other disciplines. All students must deliver at least two seminars and write a thesis or dissertation and a semi–technical manuscript about their research. Doctoral students are required to take a diagnostic exam within the first semester in residence and must teach at least one semester, regardless of funding source. All students are expected to participate in the professional and collegial life of the department and their professional specialty by attending seminars and professional meetings, participating in student organizations, and serving on departmental and professional committees.

GRADUATE COURSES (FIW)

5004: GRADUATE SEMINAR
Advanced exploration of special topics in fisheries and wildlife, through literature reviews, guest speakers, student/faculty presentations, and small group projects. Topics and format vary depending on interests of faculty and graduate students. May be repeated. Pass/Fail only. (1H,1C).

5114: FISHERIES & WILDLIFE CONSERVATION GENETICS
Population genetics of terrestrial and aquatic animals as applied to fisheries and wildlife management, endangered species management, and ecosystem protection. Discussion of genetic variability and analytic techniques, population genetic processes, and practical applications. (3H,3C).

5214: VERTEBRATE POPULATION & HABITAT ANALYSIS
Application of quantitative methods to data collected on wild vertebrates. Philosophy and principles of study design and hypothesis testing. Habitat sampling design and analysis for terrestrial and aquatic systems. Population estimation including indices, distance measures, open– and closed–population mark–recapture estimators. Current approaches to estimating survival and reproductive parameters. Integrating population and habitat data to assess resource preference. Principles of habitat modeling and community measures. Even years. Pre: An introductory graduate–level statistics class. Pre: 4444. (3H,3L,4C).

5224: WILDLIFE POPULATION DYNAMICS
Advanced course in wild animal population dynamics with emphasis on research concerning theories of population regulation. Discussion topics include characteristics of population growth, age and sex composition in relation to population growth, general features of population fluctuations, and natural control and regulation of bird, reptile, mammal, and amphibian populations. Pre: 4414. (3H,3C).

5344: WILDLIFE PHYSIOLOGY, NUTRITION, & TOXICOLOGY
Emphasis on research concerning physiological mechanisms involved in the responses of wild animals to their environment, particularly those involved in the regulation of wild animal populations. Topics include: social stress; nutrition, reproduction, and survival relationships; pesticides, heavy metals, and other contaminants; and seasonal cycles. Pre: 2314 or ALS 2304 or BIOL 3404. (3H,3C).

5414: ENDANGERED SPECIES MANAGEMENT
History, philosophy, and practice of endangered species management with emphasis on management in the United States. Biology of extinction, rationale for preservation, endangered species legislation, status surveys, management goals, habitat protection, recovery plans. Pre: 4414 or 4614 or BIOL 4404. (3H,3C).

5424: ADVANCED WILDLIFE MANAGEMENT
Advanced methods and approaches to wildlife resource management, including analysis and design of managerial system. Emphasis is on formulating objectives and selecting strategies. Computer–aided instruction is used, including simulations of realistic systems allowing students experience in practical decision–making, and field trips. Pre: 4444. (2H,3L,3C).

5444: ROLE OF SCIENCE IN NATURAL RESOURCE MANAGEMENT
Advanced study of alternative views on the role of the individual scientist within resource management. Synthesis and application of fundamental fish and wildlife coursework applied to complexities associated with real world issues. Case studies from fisheries management, wildlife management, and conservation biology. Delineating student's individual career goals. Pre: Graduate standing. (2H,2C).

5514: FISH POPULATION DYNAMICS & MODELING
Theory and application of fish population models for managing recreational and commercial fisheries. Estimation of basic fish population statistics (abundance, mortality, growth). Development and application of models for age–structured populations, bioenergetics, growth, stock–recruitment, yield, predation, and competition. Pre: 4714. (3H,3L,4C).

5614: ADVANCED ECOLOGY OF FISHES
Relationship of fishes to their physical, chemical, and biological environments in natural and perturbed aquatic ecosystems. Diversity in form and function, feeding and reproductive strategies, and individual and social behavior are considered for their management implications as they relate to population adaptation, production, and man's influence on the environment. Features approaches and techniques used to conduct advanced research in the ecology of fishes. (3H,3C).

5624: FISH HEALTH
Pathology, diagnosis, causes, control, prevention, and treatment of infectious and nutritional diseases and water quality related health problems of fish. Laboratory focuses on isolation, culture, and identification of common pathogenic microorganisms. Intensive 5–day format. (1H,1C).

5734: FISHERIES & WILDLIFE PLANNING
Advanced study of public fisheries and wildlife management institutions and their operations. Major emphasis on agency ogranization and philosophy, strategic and tactical planning, decision–making techniques, inter–governmental operations, and public participation programs. Day–long and possible overnight field trips are required. Consent required. Pass/Fail only. (2H,2C).

5814: STREAM HABITAT MANAGEMENT
Application of stream ecology, fish biology, hydrology, and hydraulics to the protection, restoration, and enhancement of stream habitats and fauna. Major emphasis on stream habitat evaluation, regulated stream flow, biotic, integrity, and watershed management. Pre: BIOL 4004. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (FIW)

The following 4000–level courses have been approved for graduate credit:

4414: WILDLIFE POPULATION ECOLOGY
Natural and man–induced regulation of wild bird and mammal populations. Population growth and fluctuation of ungulates, microtines, hares, carnivores, raptors, songbirds, waterfowl, and upland game birds. Estimation of mortality, natality and movement. Pre: 4214. (3H,3C).

4434: WILDLIFE HABITAT ECOLOGY & MANAGEMENT
Relationship of wildlife species to their habitats. Factors influencing distribution and abundance of wildlife populations. Vegetation succession and structure, habitat classification, modeling wildlife habitat relationships and management of habitats in forests, agricultural lands, rangelands, riparian/wetland and urban areas. Pre: 2114, 3364. (3H,3C).

4444: ROLE OF SCIENCE IN NATURAL RESOURCE MANAGEMENT
Alternative views of the role of the individual scientist within resource management. Synthesis and application of previous fish and wildlife coursework applied to complexities associated with real world issues. Case studies from fisheries management, wildlife management, and conservation biology. Defining student's individual career goals. Pre: 4414. (3H,3C).

4454: VERTEBRATE PEST MANAGEMENT
Management of vertebrate pest species. Causes and prevention of damage by vertebrate pest species to: food and fiber plants, animal production, structures, human transportation systems, and health of humans and domestic animals. Senior standing required. (3H,3C).

4464: HUMAN DIMENSIONS OF FISHERIES & WILDLIFE
Values, attitudes and opinions of people toward fish and wildlife. Social, economic, legal and political aspects of fisheries and wildlife management. Roles of professionals and the public in fish and wildlife policy processes. Contemporary fish and wildlife policy issues. Senior standing required. Pre: 2114. (3H,3C).

4484 (BIOL 4484) (ENT 4484): FRESHWATER BIOMONITORING
Concepts and practices of using macroinvertebrates and fish to monitor the environmental health of freshwater ecosystems. Effects of different types of pollution and environmental stress on assemblages of organisms and underlying ecological principles. Role of biological studies in environmental regulation. Study design, field and laboratory methods, data analysis and interpretation, verbal and written presentation of results. Pre: BIOL 2804 and BIOL 4004 or ENT/BIOL 4354 or FIW 4424 or FIW 4614. (3H,3L,4C).

4514: PRINCIPLES OF AQUACULTURE
Requirements of aquatic organisms in captivity. Husbandry of fish and invertebrates, including nutrition, water quality, and disease control. Design of fish rearing facilities. Two day–long field trips required. Pre: 2114. (2H,3L,3C).

4524: GENETICS FOR AQUACULTURISTS
Genetics of sex determination, qualitative and quantitative traits in aquatic organisms. Selective breeding and biotechnology–based methods of genetic improvement. Case studies. Pre: 4514, BIOL 2004. (3H,3C).

4534: ECOLOGY & MANAGEMENT OF WETLAND SYSTEMS
Introduction to the variety of wetland systems found in North America, though emphasis will focus on Eastern and Mid–Atlantic wetland systems. Origin and processes of formation of wetlands, functions and values of wetlands, wetland delineation, wetland classification, regulatory processes affecting wetlands. Objectives of, and management techniques used to protect and/or manipulate wetland systems for wildlife and other human needs. Pre: BIOL 3204. (2H,3L,3C).

4714: FISHERIES MANAGEMENT
History, theory, and practice of fisheries management. Emphasis on basic strategies used in effective management and setting management objectives. Synthesis of fish population dynamics and manipulation, habitat improvement, and human management to achieve objectives. Case studies of major fisheries. Taught odd years. Pre: 3514. (3H,3L,4C).

FOOD SCIENCE & TECHNOLOGY

S. S. Sumner, Head

Distinguished Professor: G.J. Flick, Jr.
Professors: S.E. Duncan; M.L. Jahncke; J.E. Marcy; M.D. Pierson; S.S. Sumner; B.W. Zoecklein
Associate Professors: J. D. Eifert; W.N. Eigel; S.F. O'Keefe
Assistant Professors: R.C Williams
Research Associate Professor: M.L Storey
Research Assistant Professor: R.A. Forshee
Professor Emeritus: N.G. Marriott
Associate Professor Emeritus: P.P. Graham
Adjunct Faculty: B. Blakistone; R.E. Croonenberghs; C.R. Hackney; S.E. Miller

E–mail: fstinfo@vt.edu
Web: www.fst.vt.edu/

The department offers graduate work leading to the M.S. and Ph.D. degree. Programs are built around courses in food science and technology, supported by courses in chemistry, biochemistry, microbiology, mathematics, statistics, engineering, and biology. Areas of research which offer opportunities for graduate education include food biochemistry and chemistry, food microbiology, packaging, food engineering, and new product and process development.

Individual graduate programs are planned with the advisor to prepare student for opportunities in industry, academia, and government.

All M.S. students are expected to assist with the teaching of departmental courses for a minimum of one academic semester, and Ph.D. candidates are required to assist in teaching for a minimum of two academic semesters.

Food Safety Research

Microorganisms are of significance in food systems because they have both adverse and beneficial effects – they can cause spoilage and illness, but they are also used to produce a variety of foods through fermentation. At Virginia Tech, food microbiology research is concerned with basic and applied studies of foodborne pathogens, microbiological spoilage, prevention and control of contamination during processing, thermal and non–thermal processing, and method development to detect microorganisms and their toxins. Recently, food safety research has focused on control of major foodborne pathogens in primary agriculture production and processing through the application of new and traditional processing technologies, antimicrobials, sanitation, HACCP based strategies and analytical methodology.

Food Chemistry and Sensory Research

The food chemistry and biochemistry emphasis in food science and technology allows graduate students to focus on interactions of food components at both basic and applied levels. Understanding of molecular reactions, food composition, component interactions, and physical properties of food systems can be applied to characterizing changes in food quality attributes, such as texture, color, flavor, and nutrition; separation of food components to enhance functional characteristics; development or assessment of analytical processes; and evaluation of toxic or contaminating substances. Recently, food chemistry research has focused on cause, effects, and controls of oxidative reactions in food systems, flavor and lipid chemistry, enzymatic activity, and physiochemical properties of food systems.

Food Packaging and Processing Research

An emphasis in food processing and packaging allows graduate students in food science and technology to use many of the specialized disciplines of food science in practical applied and basic research. Principles of food engineering, food microbiology, and food chemistry are combined in the food processing and packaging program. Students are engaged in such unit operations as thermal processing, aseptic processing, computer data acquisition and control, dehydration, modified atmosphere packaging, filtration, sanitation, and nondestructive evaluation methods. Students have the opportunity to determine how processing and packaging affect the foods we produce and to investigate new methods of food processing and packaging.
Research emphases includes active packaging as well as aseptic and modified atmosphere packaging, and integrates polymier chemistry, engineering and food science. Advanced and process, including high pressure, sous–vide, aseptic, ultraviolet, and microwave technologies are used for improving food quality, shelf–life, safety and for product development. Practical application of processing and packaging for small industries and developing countries is considered.

Enology and Viticulture Research

Research in enology is focused primarily in the area of grape and wine flavor components in addition to evaluation of vineyard management and processing alternatives. The influence of grapevine canopy management on the incidence of fruit rot metabolites and their effect on native grape aroma components is currently being investigated. Viticultural and enological practice affecting grape phenols and their polymerization and stabilization is also investigated. The evaluation of new cultivars and the wines produced from those cultivars attempts to provide practical information to enhance the growth and development of the Virginia wine industry.

Center for Food and Nutrition Policy

The Center for Food and Nutrition Policy is an independent research and education center affiliated with Virginia Tech and located in Alexandria, VA with a convenient proximity to USDA and FDA headquarters. This allows students exceptional opportunities for internships and training with USDA and FDA in regulatory affairs. The mission of CFNP is to advance rational, science–based food and nutrition policy. Through its research, outreach, and teaching programs, the Center examines complex, and oftentimes contentious, issues facing government policymakers, regulators, agribusinesses, food manufacturers, the media, and consumers. CFNP is recognized as a center of excellence in food and nutrition policy by the Food and Agriculture Organization of the United Nations.

GRADUATE COURSES (FST)

5004: GRADUATE SEMINAR
Special topics, critical reviews, and discussions of current literature throughout a wide range of subject areas in food science and technology. May be repeated. Pass/Fail only. (1H,1C).

5014 (HNFE 5014): SENSORY EVALUATION OF FOOD
Principles of sensory evaluation including experimental methods, applications, and statistical analyses. Pre: 4524 or STAT 2004. (2H,3L,3C).

5024: REGULATORY AFFAIRS
History, development, and enforcement of laws and regulations that affect the food processing industry and food consumers. Impact of legal and regulatory issues on food quality, safety, formulation, labeling, marketing, grading, product and process development, international trade, and processor employees. Roles and responsibilities of consumers and industry in the development of and compliance with food laws and regulations. Two of the four prerequisites listed are required. Odd years. Pre: 4405, 4504, 4524, 4604. (3H,3C).

5204: ADVANCED MEATS
Study of factors influencing meat animal carcass composition and its processing characteristics. The effect of post–mortem treatment of muscle on the subcellular fractions as related to final meat quality, including glycolysis, rigor mortis, and cold–induced toughness of fresh and processed meats will be studied. Pre: BCHM 4115. (2H,3L,3C).

5404: FOOD PACKAGING
Examines the role of food packaging in the preservation of foods in today's society. Food packaging materials will be discussed with emphasis on their interaction with food products. Specific applications of packaging materials to food groups will be discussed. Procedures to develop a new food package are incorporated in class activities. food industry. Pre: 4405. (3H,3C.

5514: FOOD ENZYME TECHNOLOGY
Characteristics, mechanisms, and applications of soluble enzymes currently used in food processing. Immobilized enzyme technology to include production of enzymes, immobilization techniques, changes in enzymes properties, and scale–up to commercial food application. Pre: BCHM 5115, CHEM 2536. (3H,3C).

5604: ADVANCES IN FOOD MICROBIOLOGY
Critical review of current topics in food microbiology. Foodborne pathogens, toxins, analytical methodology, food spoilage, inhibition and destruction of bacteria, standards, and fermentations. Pre: 4604, BCHM 5124. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (FST)

The following 4000–level courses have been approved for graduate credit:

4014: FOOD PROD DEVELOPMENT
Application to the food industry of principles and standard practices of research and product development; functionality of food ingredients; students will work in teams to design and develop a new food product. Pre: 4604. Co: 4404, 4505. (3H,3C).

4204: MARINE FOOD PRODUCTS
Fundamentals of the science and technology associated with harvesting, processing, packaging, preservation, storage, distribution, marketing, and safety of marine food products of commerce. An off–campus intensive course for students in education, business, and the physical or biological sciences. Course enrollment is limited to 20 students. Instructor consent required. (2H,3L,3C).

4405,4406: FOOD PROCESSING
Basic principles, unit operations, and equipment involved in the commercially important food processing methods and unit operations; materials and containers used in food packaging; food laws, regulations, and standards. Pre: BIOL 2604 for 4405; 3304 for 4406. 4405: (3H,3L,4C) 4406: (1H,3L,2C) 4405: I; 4406: II.

4504: FOOD CHEMISTRY
Consideration of the chemical constituents of foods with emphasis on their role in determining the nutritive value, functional properties, storage characteristics and acceptability of fresh and processed foods. Pre: CHEM 2536, BCHM 2024. (3H,3C).

4514: FOOD ANALYSIS
Sampling techniques and theory and practice of chemical and physical methods of food analysis for determination of food composition; application of analytical methods to quality control and food law regulation problems. Pre: 4504. (2H,3L,3C).

4524: FOOD QUALITY ASSURANCE
Functions of quality control departments in monitoring safety and quality of food as well as compliance with government regulations. Description of federal regulatory agencies. Development of specifications, food standards and critical control points. Selection of analytical methods. Acceptance sampling and control charts. Microbiological quality control. Pre: 4405, 4604, STAT 3616. (3H,3C).

4604 (BIOL 4604): FOOD MICROBIOLOGY
Role of microorganisms in foodborne illness and food quality, spoilage, and preservation. Control and destruction of microorganisms in foods. Pre: BIOL 2604, BIOL 2614. (3H,3L,4C).

4614: FOOD SANITATION
Applications of sanitation principles to food products and processing facilities with emphasis on regulatory programs, sanitation systems, cleaning and sanitizing compounds, and monitoring procedures for evaluation of effectiveness of the system. Pre: 4604. (2H,2C).

FOREIGN LANGUAGES & LITERATURES

Andrew S. Becker, Chair

Professors: J.E. Bixler; P.A. Mellen; J.C. Ulloa
Associate Professors: A.S.Becker; S.W. Farquhar; A.A. Fernández-Vázquez; N. Milman; T.L. Papillon; J.L. Shrum; R.L. Shryock
Assistant Professors: J.A. Folkart; M.Guèye; S.P. Johnson; J. Noob; M.E. Panford; F.G. Teulon; H. Witthoeft
Career Advisor: S.P. Johnson (231-9859)

E-mail: RWills@vt.edu
Web: www.fll.vt.edu/

Several courses are offered to serve the needs of graduate students majoring in other disciplines. This department does not offer its own graduate degree program, but rather collaborates with History and Geography in the Area Studies M.A. and with Teaching and Learning for an M.A. in Curriculum and Instruction. The courses listed below are available to graduate students and may complement their work in their particular fields.

MASTER OF ARTS IN AREA STUDIES

Coordinator: J. Bixler (Foreign Languages and Literatures)

Area Studies is a collaborative program sponsored by the departments of Foreign Languages & Literatures, Geography, and History. An option within the established graduate program in History, this interdisciplinary degree offers concentrations in Western Europe and Latin America. A diversified curriculum with courses in history, culture and civilization, literature, geography, development, political science, economics, architecture, and urban affairs and planning prepares students for doctoral studies in the Humanities and Social Sciences and for a variety of careers in inernational education, development, government, and commerce.

Students normally complete their degree program in four semesters. Graduate Teaching Assistantships are available. Area Studies students are encouraged to study abroad as part of their course of study.

FOREIGN LANGUAGE GRADUATE COURSES (FL)

5024 (GEOG 5024) (HIST 5024): AREA STUDIES METHODS
Introduction to recent theories and methods in history, foreign languages and literary studies, and geography, with a focus on issues that have facilitated exchanges between the three disciplines. Practical aspects of Area Studies research are highlighted with particular reference to Latin America, the Caribbean, and Europe. The formulation of research problems using interdisciplinary approaches is given special attention. Graduate standing required. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable study course.

ADVANCED UNDERGRADUATE COURSES (FL)

The following 4000-level courses have been approved for graduate credit:

4104 (MGT 4104): GLOBAL CULTURE
This course will examine problems of cultural differences using an interdisciplinary approach combining Business Studies with Cultural Studies in the humanities and social sciences. It will address issues related to living and working with people from other countries or cultures, whether domestically or abroad. It will also explore the impact of globalization on various aspects of culture. Junior standing required. (3H,3C).

FRENCH GRADUATE COURSES (FR)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (FR)

The following 4000-level courses have been approved for graduate credit:

4154: ADVANCED COMPOSITION & STYLISTICS
Intensive work in written French. Development of the student's ability to write clear, correct, and articulate French in a variety of modes (e.g., epistolary style, the formal and informal essay). Writing intensive, taught alternate years. Pre: 3106. (3H,3C).

4314: STUDIES IN FRENCH LITERATURE
In-depth study of a selected topic in French literature, such as an author, a group of authors, a literary movement or genre during a specific period of French literary history (i.e., Voltaire, the Pleiade, Romanticism, the nouveau roman). May be repeated for credit with different content. Pre: 3105, 3106, 3305, 3306. (3H,3C).

4324: SPECIAL TOPICS IN FRENCH LIFE, LITERATURE & LANGUAGE
In-depth study of a selected topic in French culture or language as manifested in creative and historical literature, music, art, film, etc., such as phonetics, translation techniques, or the staging of dramatic works in French. May be repeated for credit with different content. Pre: 3105, 3106 or 3205, 3206. (3H,3C).

GERMAN GRADUATE COURSES (GER)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (GER)

The following 4000-level courses have been approved for graduate credit:

4154: ADVANCED COMPOSITION & STYLISTICS
Intensive advanced work in written German. Development of the student's ability to write clear, correct, and articulate German in a variety of modes. Style analysis. Writing intensive, taught alternate years. Pre: 3106. (3H,3C).

4304: AGE OF GOETHE
Major writers of the age of Goethe: Goethe, Schiller, and Holderlin; the development of German Classicism. Taught alternate years. Pre: 3106, 3306. (3H,3C).

4314: STUDIES IN 19TH–CENTURY LITERATURE
Variable–content course devoted to the study of 19th century drama, lyric, and prose. May be repeated for credit with different content. Taught alternate years. Pre: 3106, 3306. (3H,3C).

4324: STUDIES IN 20TH–CENTURY LITERATURE
A variable–content course devoted to the study of major literary works of the 20th–century. May be repeated for credit with different content. Taught alternate years. Pre: 3106, 3306. (3H,3C).

4334: SPECIAL TOPICS IN GERMAN LIFE, LITERATURE, & LANGUAGE
Variable–content course devoted to the study of various aspects of German culture, literature, and language. May be repeated for credit with different content. Taught alternate years. Pre: 3106, 3306. (3H,3C).

LATIN GRADUATE COURSES (LAT)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (LAT)
The following 4000–level courses have been approved for graduate credit:

4004: DIRECTED STUDIES IN LATIN PROSE COMPOSITION
Application of Latin grammar structure to the translation of English into Latin. Original compositions are written in Latin. (Will be offered during the academic year whenever there is sufficient enrollment and available staffing). One 3000–level course in Latin required. (3H,3C).

SPANISH GRADUATE COURSES (SPAN)

5224: TOPICS IN SPANISH CIVILIZATION
In–depth analysis of the enduring institutions, ideas, and significant intellectual currents that have contributed to the formation of modern Spain. Taught in Spanish, the course integrates selected cultural manifestations in literature, art, architecture, music, theater, and film. Not a variable content course. Pre: Graduate standing, and advanced language skills in Spanish. IV–Offered only during the Intensive Second Language Institute; counts towards the Area Studies M.A. only with additional research component. (3H,3C).

5234: SPANISH AMERICAN INSTITUTIONS & CONCEPTS
In–depth analysis of the enduring cultural institutions and ideas that inform Spanish–American perceptions of reality and their development into modern times. Selected topics include: the cultural contributions of the Spanish, indigenous and African legacies; religions and syncretism; militarism and caudillismo; aesthetics; cultural regions; idiosyncrasies; and concepts of time and space. Essay and prose fiction readings will be complemented by lectures, discussions, and films. Taught in Spanish. Pre: Graduate standing and advanced language skills in Spanish. (3H,3C).

5344: SPANISH–AMERICAN LITERATURE & THE REPRESENTATION OF HISTORY
This is a special topics variable–content course that allows the student to explore different geographical regions of Spanish America and the ways that authors have used literature to preserve, recreate, revise, subvert, and even contradict their countries' official history. All discussion conducted in Spanish. May be repeated for credit up to three times. Pre: minimum oral proficiency of "Advanced" on the ACTFL scale; and graduate standing. (3H, 3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (SPAN)
The following 4000–level courses have been approved for graduate credit:

4104: ADVANCED GRAMMAR AND STYLE
Analysis of and practice with advanced grammatical and stylistic concepts, including idiomatic and colloquial usage. Intended to help advanced students achieve high levels of proficiency in writing and speaking Spanish. Taught alternate years. X–grade allowed. Pre: 3106. (3H,3C).

4124: SPANISH TRANSLATION: THEORY AND TECHNIQUE
Introduction to translation theories and application of these theories to different types of texts, including literature, business correspondence, commercial advertising, and legal documents. Includes translation from English to Spanish and from Spanish to English, as well as a thorough review of Spanish grammar and idiomatic language. Pre: 3106. (3H,3C).

4304: STUDIES IN MEDIEVAL AND GOLDEN AGE LITERATURE
A variable content course devoted to Hispanic literature of the Middle Ages and of the Golden Age. The texts selected are studied not only for their aesthetic value but also for their historical and cultural significance. May be taken twice for credit with different content. Pre: 3314. (3H,3C).

4314: STUDIES IN 18TH AND 19TH CENTURY LITERATURE
A variable content course devoted to Hispanic literature of the 18th and 19th centuries. The texts selected are studied not only for their aesthetic value but also in terms of their historical and cultural significance. May be taken twice for credit with different content. Taught alternate years. Pre: 3314 or 3324. (3H,3C).

4324: STUDIES IN 20TH CENTURY LITERATURE
A variable content course devoted to Hispanic literature of the 20th century. Texts are selected not only for their aesthetic value but also in terms of their historical and cultural significance. May be taken twice for credit with different content. Taught alternate years. Pre: 3314 or 3324. (3H,3C).

4334: SPECIAL TOPICS IN HISPANIC LIFE, LITERATURE, AND LANGUAGE
Broad central themes of Hispanic culture as manifested in creative and historical literature, music, art, film, etc., or in language, such as the history of the Spanish language, translation techniques, or the staging of dramatic works in Spanish. Historical and/or national boundaries are crossed whenever the nature of the topic permits. May be repeated for credit with different content. Taught alternate years. X–grade allowed. Pre: 3314 or 3324. (3H,3C).

FORESTRY

UNIVERSITY EXEMPLARY DEPARTMENT *

Harold E. Burkhart, Head

University Distinguished Professor: H.E. Burkhart
Julian Cheatham Professor: G.J. Buhyoff
Charles Nettleton Professor: R.M. Shaffer
Shelton Short Professor: J.R. Seiler
Professors: W.M.Aust; J.A. Burger; R.B. Hull; J.E. Johnson; J.M. Kelly; R.G. Oderwald; M.R. Reynolds, Jr.[1]; J.W. Roggenbuck; S.M. Zedaker
Associate Professors: G.S. Amacher; U. Egertsdotter; T.R. Fox; J.R. Kirwan; S.P. Prisley; J. Sullivan; R.H. Wynne
Assistant Professors: C.A. Copenheaver; S.R. Lawson; M.J. Mortimer; P.J. Radtke; R. Visser
Adjunct Faculty: D.C. Chojnacky; K.H. Johnsen; P.D. Keyser; D.L. Loftis; J.L. Marion; F.D. Merry; J.A. Scrivani; J.M. Vose
Affiliated Faculty: S.D. Day, L. Travis
Courtesy Appointments: R.H. Jones (Biology); R.D. Meller (Industrial and Systems Engineering); P.A. Miller (Landscape Architecture); S.M. Salom (Entomology)
Senior Research Associate: R.L. Amateis
Career Advisors: H.E. Burkhart (231–5483); R.G. Oderwald (231–5297)

[1] Joint with Statistics.

E-mail: forestry@vt.edu
Web: www.cnr.vt.edu/forestry/

The Department of Forestry administers graduate programs leading to the M.F., M.S., and Ph.D. The M.F. (master of forestry) degree is usually a terminal, professional, non–research degree, intended to give the candidate additional post–baccalaureate education in forestry. Graduate research program concentrations are available in silviculture, soils, ecology, physiology, genetics, management/economics, outdoor recreation, forestry operations, forest biometrics, remote sensing, and computer applications including geographic information systems and expert systems. The demand for individuals with advanced education in all areas of forestry is strong. This is especially true for people with advanced knowledge and skills in applying new technologies to solving forestry problems.

SPECIAL FACILITIES

Exceptional facilities are available in Julian N. Cheatham Hall, which houses studies in forest resources. The Department of Forestry also administers the Industrial Forestry Operations Harvesting Laboratory. Students have available to them ample laboratory space for research projects, and desk space is usually provided.

The Center for Environmental Applications of Remote Sensing (CEARS) laboratory is physically and administratively housed within the college, but is shared with other colleagues and constituencies, both on campus and off. The laboratory is equipped with UNIX work stations; networked Windows NT work stations; an NT server, small– and large–format digitizers; and a complete suite of GIS, image processing, and associated software.

The department sponsors, with industry, two research cooperatives: the Loblolly Pine Growth and Yield Research Cooperative and the Industrial Forestry Operations Research Cooperative. A Cooperative Park Studies Unit of the National Biological Service is also housed in Julian Cheatham Hall. Graduate student research is commonly conducted with these cooperative units.

Laboratories for basic studies in physiology, nutrition, and genetics of forest trees are located in Cheatham Hall. Research equipment includes refrigerated centrifuges, ultracentrifuge, liquid scintillation counter, atomic absorption unit, growth chambers, and other commonly required instrumentation.

The department operates the Reynolds Homestead Forest Resources Research Center, a 710–acre research unit located in the Virginia Piedmont. It is equipped with a laboratory, greenhouse, slat house, nursery bed, and ample field space. In addition, a 1200–acre demonstration forest of the Appalachian hardwood and mixed pine–hardwood type (the Fishburn Forest) is adjacent to the Virginia Tech campus.

SPECIAL DEGREE REQUIREMENTS

Each student's program of study is determined by a graduate advisory committee according to the student's background, goals, and area of desired specialization. Those students without a prior background in forestry will be required to make up deficiencies in undergraduate courses deemed necessary for a particular area of specialization. All students must acquire competency in statistics. A thesis is required for the M.S. degree. Although M.F. candidates do not complete a thesis, they must do a degree paper, which counts for three to six hours of credit. The Ph.D. degree requires an extensive research project that culminates in a dissertation.

Candidates for the M.S. and Ph.D. in the College of Natural Resources may be required to gain teaching experience in the classroom or laboratory.

GRADUATE COURSES (FOR)

5004: GRADUATE SEMINAR
Special topics, critical reviews, and discussions of pertinent literature throughout a wide range of subject areas in forestry. May be repeated. Pass/Fail only. (1H,1C).

5104 (GEOG 5104): SEMINAR IN REMOTE SENSING & GEOGRAPHIC INFORMATION SYSTEMS
Interdisciplinary seminar devoted to current research in the fields of remote sensing, Geographic Information Systems, and related topics. Seminars, workshops, and presentations conducted by students, faculty, and visitors. Pre: Graduate standing. Pass/Fail only. (1H,1C).

5214: ADVANCED FOREST INVENTORY
An advanced course in forest inventory and sampling. Topics include the foundations of point, plot, and probability proportional to prediction sampling, application of Bayesian and James–Stein methods, and unequal probability sampling in the forest setting. Pre: 3215 or 3216 or STAT 4524. (3H,3C).

5224: FOREST BIOMETRY
Theory and practice involved in the measurement and modeling of the growth and yield of forest trees and stands Pre: 3215, 3216, STAT 5606, STAT 5616. (3H,3C).

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

5254: REMOTE SENSING OF NATURAL RESOURCES
Philosophy and rationale of remote sensing as a part of the resource management process; comparisons of analogic and digital sensors; sensor selection and proper use; accuracy assessment; signature development; and identification of factors which affect the quality of remotely sensed information. Pre: 4214 or GEOG 4354. (2H,3L,3C).

5264 (GEOG 5364): GIS APPLICATIONS IN NATURAL RESOURCE MANAGEMENT
Acquiring and using publicly available natural resources data sources. Methods and algorithms to terrain modeling and landscape metrics. Evaluation of the impacts of data errors and variability on analysis results, including sensitivity analysis of GIS–based resource assessments. Special issues related to temporal data and the management of natural resources information systems. Pre: 4214 or GEOG 4084. (2H,3L,3C).

5334 (PPWS 5334): PLANT WATER RELATIONS
Properties and status of water in the plant and thermodynamics in relation to water and solute movement; measuring water deficits and drought tolerance; and transpiration and stomatal action. (2H,3L,3C).

5354: ADVANCED FOREST SOILS
Current topics in forest soils with emphasis on soil–site relationships, managing soil water, tree roots and nutrient uptake, diagnosis and correction of nutrient deficiencies, effect of atmospheric deposition on forest soils, and modeling and simulation of nutrient and water movement in forest soils. Pre: 4354. (2H,3L,3C).

5374: ADVANCED FOREST ECOLOGY
Advanced topics in forest ecology, including: forest populations, forest community dynamics, forest community structure and analysis, forest productivity on a global scale, ecology of forest landscapes, spatial heterogeneity, and hierarchy issues in ecology. Pre: 3314, MATH 2016, STAT 5606, STAT 5616. (2H,3L,3C).

5384: FOREST BIOLOGY AND ECOLOGY FOR EDUCATORS
This online course is designed to provide educators with an understanding of the specifics of forest ecology and tree biology. Topics include identification of approximately 80 commonly found tree species, tree growth and development, woody plant reproduction and propagation, carbon and water uptake, dormancy and coldhardiness, site productivity and forest succession, forest soils, and silvicultural practices in managed forests. This class is offered online during a 10–week period that extends over both Summer I and II sessions. This course is not available to graduate students enrolled in Forestry programs. (3H,3C).

5415,5416: ADVANCED FOREST RESOURCE MANAGEMENT & ECONOMICS
5415: Application of microeconomics to solving forest resource problems. Emphasis on forest products demand and supply analysis, forest products marketing, forest capital theory, and interregional and international trade in forest products. 5416: Impacts of economic and physical variables upon forest appraisal and management decisions. Valuation of nonmarket goods and economics of multiple–use. Application of operations research tools in evaluating forest management alternatives in public and private forest planning. Pre: 3414, 4424. (3H,3C).

5434: OPERATIONAL PROBLEMS IN FOREST RESOURCE MANAGMENT
Timber and multiple use management cases will be used to demonstrate the application of forest management, economic, biometric, and silvicultural principles to operational management problems. Microcomputer applications are emphasized. Course is designed for any graduate student in forestry. Consent required. Pre: 5415, 5416, 5224. (3H,3C).

5454: WILDLAND RECREATION THEORY
Theoretical approach to understanding wildland recreation behavior. Emphasis given to such concepts as motivation, attitudes, conflict, behavior change, satisfaction, and personal and social b nefits. 9 credits of Recreation course work required. (3H,3C).

5464: BEHAVIORAL RESEARCH STRATEGIES IN WILDLAND RECREATION
Overview of research applications in wildland recreation. Experimental, observational, and survey research approaches will be critically examined. Formulation of research questions and strategies of research design will be emphasized. At least one course in statistics required. Pre: 5454. (3H,3C).

5474: WILDLAND RECREATION ECONOMICS
Application of economic theory to wildland recreation resource management, primarily from the public sector view: market allocation of resources, market failures, supply–demand interaction, valuation of nonmarket goods, benefit/cost analysis. Not for credit for forest management/economics students. 6 credits of Economics and 9 credits of Recreation course work required. (2H,2C)

5484: WILDERNESS MANAGEMENT
Principles and practices for managing wilderness and back country areas. Emphasis given to visitor management to protect resources and provide wilderness experiences. 9 credits of Forest, Wildlife, and/or Recreation Management required. (3H,3C).

5494: NATURAL RESOURCE RESEARCH PROCEDURES
An examination of concepts and philosophies of science and research as applied to forestry and related renewable natural resource research programs. Emphasis is on scientific procedure, ethics, and responsibility. Attention is also paid to the specifics of establishing research projects, contracts, and grants and carrying them out. Consent required. (2H,2C).

5614 (WOOD 5614): FOREST PRODUCTS MARKETING & MANAGEMENT STRATEGIES
Examination of forest products markets, industry structure, distribution channels, and strategic management trends. Case studies demonstrate the impact of these factors on decision–making in the forest products industry. Pre: 4614 or 3424. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (FOR)

The following 4000–level courses have been approved for graduate credit:

4114: INFORMATION TECHNOLOGIES FOR NATURAL RESOURCE MANAGEMENT
An introduction to computer information systems used in natural resources management. Course will introduce students to the theory and applications of database management systems (DBMS) and geographic information systems (GIS). Uses, challenges, and limitations of these technologies in natural resource management applications will be discussed. Students will receive extensive hand–on instruction in the use of current software packages for DBMS and GIS. Pre: 2154, (3216 or STAT 3005). (2H,3L,3C).

4354: FOREST SOILS AND HYDROLOGY
Principles of forest soils and hydrology and applications to forest management. Forest soil development, relationships of soil and hydrologic properties to tree growth, and the management of soil and soil water to enhance fiber production. Pre: 3314. (2H,3L,3C).

4364: ADVANCED SILVICULTURE AND FOREST VEGETATION MANAGEMENT
Advanced topics in silviculture with an emphasis on species silvical differences; forest vegetation management and control, herbicides used in forestry, their chemistry, toxicology, application technology; environmental considerations; tree improvement, individual tree growth, and stand dynamics as affected by intermediate silvicultural operations; implications of atmospheric deposition. Pre: 3324. (3H,3C).

4374: FORESTED WETLANDS
Classifications, jurisdictional delineation, and management options of forested wetlands. Relationship of hydrology, soils, and vegetation to ecosystem processes, societal values, and management with regard to environmental and legal considerations and best management practices. Emphasis is on forested wetlands in the southern U.S., but national and international wetlands are included. Pre: CSES 3114 or CSES 3134. (3H,3C).

4524 (ENT 4524) (PPWS 4524): PEST AND STRESS MANAGEMENT OF TREES
Ecology of biotic and abiotic influences on forest and landscape tree health. Emphasis will be placed on developing a theoretical and practical understanding for managing pests and stresses of trees in both the forest and landscape setting. Insects and diseases of trees will be reviewed. Pre: (3324 or PPWS 3104), (3354). (2H,3L,3C).

4714: HARVESTING SYSTEMS EVALUATION
Principles and techniques for evaluating harvesting machines and systems design, application, productivity, and financial performance. Pre: 3216, 3424, 3714, 3734. (3H,3C).

GENETICS, BIOINFORMATICS, AND COMPUTATIONAL BIOLOGY

D. R. Bevan, GBCB Steering Committee Chair

Steering Committee: R. Avery; C. Gibas; R. Grene; L. Heath; I Hoeschele; R. Laubenbacher; M.A. Saghai Maroof

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The new research paradigm exemplified by the Human Genome Project requires a new academic training paradigm, one that creates team–oriented researchers who may be specialists in one area but who are literate in several other disciplines. For example, researchers in the mathematical, statistical, or computer sciences also require sufficient knowledge in biology to understand the questions in order to develop appropriate analytical methods and computer tools. Similarly, life scientists need sufficient grounding in mathematics, statistics, and computer science to be educated users of these quantitative methods and tools, and to conceptualize new tools. The interdisciplinary Ph.D. program in Genetics, Bioinformatics, and Computational Biology is designed to provide a combination of discipline–specific and cross–disciplinary course work, as well as a multidisciplinary research environment maintained by program faculty and distinguished by a high level of collaboration among disciplines.

Program faculty members come from a variety of departments, including Animal and Poultry Sciences; Biochemistry; Biology; Computer Science; Crop and Soil Environmental Sciences; Human Nutrition, Foods and Exercise; Mathematics; Plant Pathology, Physiology, and Weed Science; Science and Technology Studies; Statistics; and the Virginia Bioinformatics Institute.

SPECIAL DEGREE REQUIREMENTS

For the GBCB program, four specialty tracks are defined: life sciences, computer science, statistics, and mathematics. A student will select one of the specialty tracks as his/her primary track, which will typically be consistent with the student's undergraduate training. The other tracks will be denoted the secondary tracks for that student. A core curriculum that is common to all students also has been defined.

In an interdisciplinary program such as this one, which requires considerable coordination among several academic units, it is important to insure that students receive as broad an exposure to the disciplines as is practical. Course require–ments are designed to provide much of that exposure. In addition, students in the program will be conducting dissertation research projects that cross the boundaries of traditional disciplines. To complement coursework, and to assist students in developing their dissertation research projects, additional focused research experiences may be required. These research experiences may include lab rotations. Before a student selects a Graduate Advisory Committee, decisions related to this aspect of the program will be made in consultation with the program Steering Committee.

GRADUATE COURSES (GBCB)

5004: SEMINAR IN GENETICS, BIOINFORMATICS, AND COMPUTATIONAL BIOLOGY
Review and discussion of current topics and literature in genetics, bioinformatics, and computational biology by students, Virginia Tech faculty, and outside speakers. Students give formal presentations of research results or current literature. May be repeated. Pre: Graduate status in the Program in Genetics, Bioinformatics, and Computational Biology or in a department that offers the Bioinformatics Option. (1H,1C).

5314 (PPWS 5314): BIOLOGICAL PARADIGMS FOR BIOINFORMATICS
This course is an intensive introduction to the central paradigms of molecular cell biology for bioinformatics. Material from cell molecular biology and genetics will be presented, and placed in a genomics context. The course prepares students in mathematical disciplines to interact in teams in the pursuit of bioinformatics research. Pre: Senior or graduate standing in mathematically based disciplines such as computer science, statistics, mathematics or engineering. (3H,3C).

5515,5516 (MATH 5515, 5516): MATHEMATICAL METHODS FOR MODELING AND SIMULATION OF BIOLOGICAL SYSTEMS
Introduction to mathematical techniques for modeling and simulation, parameter identification and analysis of biological systems. Emphasis on both theoretical and practical issues and methods of computation, with concrete applications. Suitable for students from the mathematical and life sciences who have a basic foundation in multivariate calculus and ordinary differential equations. 5515: Continuous models and methods. 5516: Discrete models and methods. (3H,3C).

5844 (CSES 5844): PLANT GENOMICS
Comprehensive overview of genomics and its applications. Topics include: molecular markers, map construction, map-based cloning, quantitative trait loci, and functional genomics. Even years. Pre: Knowledge of general principles of genetics and molecular biology. (3H,3C).

5874: PROBLEM SOLVING IN GENETICS, BIOINFORMATICS, AND COMPUTATIONAL BIOLOGY
Research practicum in genetics, bioinformatics, and computational biology. Emphasis on the multidisciplinary and collaborative nature of research in genetics, bioinformatics, and computational biology. Exposure to the scientific method, the nature of research tools, strategies for publishing, and opportunities for research careers in genetics, bioinformatics, and computational biology. Permission required. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

A sampling of supporting courses specifically aimed at students studying genetics, bioinformatics, and computational biology is given below. Many additional relevant courses, which students may select in consultation with their advisory committee, are offered in various departments.

GRADUATE COURSES:

BCHM 5024: Computational Biochemistry for Bioinformatics
BIOL 5075–5076: Bioinformatics Methods in Research
CS 5045–5046: Computation for Life Sciences
CS 5124: Algorithms in Bioinformatics
CSES 5844: Plant Genomics
MATH 5515–5516: Mathematical Methods for the Modeling and Simulation of Biological Systems
PPWS 5314: Biological Paradigms for Bioinformatics
STAT 5564: Statistical Genetics
STAT 5615–5616: Statistics in Research
STS 5444: Issues in Bioethics

GEOGRAPHY

Lawrence S. Grossman, Head

Professors: J.B. Campbell; L.W. Carstensen; L.S. Grossman; J.L. Scarpaci
Associate Professors: S.R. Brooker–Gross
Assistant Professors: L.M. Kennedy; K.N. Kolivras; L.M. Resler
Professors Emeritus: C.M. Good; R.W. Morrill; B.C. Richardson
Instructor: J.D. Boyer
Adjunct Lecturer: J. Crawford
Research Associate: P. Sforza
Career Advisors: J.B. Campbell; L.W. Carstensen (231–7557)

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The M.S. in geography is designed to prepare students for a variety of careers in business, government, research and planning organizations, teaching, or for doctoral studies. The program provides students with both a well–defined research focus and maximum flexibility to explore individual interests by taking supporting courses in cognate disciplines. The geography curriculum involves the completion of 30 semester credit hours, of which six hours are devoted to thesis research and preparation. A non–thesis option is also available. Each student must complete a two–course core: GEOG 5014 and a choice of one among GEOG 4084, 4354, or 5034.

Both geography majors and students with degrees in majors other than geography are encouraged to apply. Graduate assistantships and tuition support are available for qualified students. The Department of Geography's Sidman P. Poole Endowment provides funds for graduate student research on a competitive basis.

The department has excellent facilities for research and teaching, including a GIS lab and a Remote Sensing Lab. The Biogeography Laboratory has new Leica stereomicroscopes and image analysis capability. Geography participates in several interdisciplinary centers relevant to student geospatial research: Virginia Tech's Center for Environmental Applications of Remote Sensing (with Forestry), established with NASA support; the Center for Geospatial Information Technology (with fifteen departments); and the Center for Wireless Telecommunications (with Electrical Engineering and Finance).

There are several areas of faculty strength to facilitate student research. Training in GIS and Remote Sensing enables students to apply these techniques to a variety of problems in environmental and human geography and to work in collaboration with faculty and students in several allied disciplines. Biogeographic research may focus on paleoenvironmental studies, vegetation dynamics, human impacts on biota, or related topics, and may include the use of GIS or remote sensing, if desired. Biogeographic fieldwork focuses on tropical and alpine environments. Students interested in medical geography can take advantage of ongoing research projects on health in immigrant communities and relationships between disease and climate. Those focusing on international development can specialize in agrarian issues, peasantries, political ecology, heritage tourism, urbanization, and social policy. Students involved in historical issues can work on changing land–use patterns, colonial environmental history, and historic preservation. Opportunities for foreign research are especially strong in the Caribbean and Latin America.

Graduate Courses (GEOG)

5014: GEOGRAPHIC THEORY & RESEARCH
Study of how physical geography, human ecological concerns, and the spatial perspective have been synthesized into a unified academic discipline. Formulation of geographic research problems, including collection, organization, and analysis of geographic data. (3H,3C).

5024 (FL 5024) (HIST 5024): AREA STUDIES METHODS
Introduction to recent theories and methods in history, foreign languages and literary studies, and geography with a focus on issues that have facilitated exchanges between the three disciplines. Practical aspects of Area Studies research are highlighted, with particular reference to Latin America, the Caribbean, and Europe. The formulation of research problems using interdisciplinary approaches is given special attention. Graduate standing required. (3H,3C).

5034: ANALYSIS OF SPATIAL DATA
Methods of describing and analyzing spatial distributions, including spatial autocorrelation, quadrat analysis, trend surface analysis, and methods of map comparison. Applications to student research problems. (3H,3C).

5104 (FOR 5104): SEMINAR IN REMOTE SENSING & GEOGRAPHIC INFORMATION SYSTEMS
Interdisciplinary seminar devoted to current research in the fields of remote sensing, Geographic Information Systems, and related topics. Seminars, workshops, and presentations conducted by students, faculty, and visitors. Pre: Graduate standing. Pass/Fail only. (1H,1C).

5134: URBAN ECONOMIC GEOGRAPHY
Geographical perspectives on economic activities within the urban sphere. Classical location theory, recent models of locational decision–making, interconnections between economic actors in a global setting. Analysis of the urban economic landscape. (3H,3C).

5144 (HIST 5144): THE TRANSATLANTIC WORLD
Comparative and interdisciplinary study of encounters and exchanges between Europe, Africa, and the Americas. Surveys the literature on selected topics from the onset of European colonization until the present time. (3H,3C).

5204 (SOC 5644) (UAP 5204): GEOGRAPHY OF THIRD WORLD DEVELOPMENT
Geographical, historical, and ecological perspectives on Third World development. Applicability of development theory to particular case studies. Problems in planning and constraints on economic development. (3H,3C).

5244 (CSES 5244): ADVANCED SOIL INTERPRETATION USING GIS & DSS
Use of Geographic Information System (GIS) software to compile digital maps, imagery, and natural resource data and decision support systems (DSS) to produce interpretative maps from digital soil data as part of a research proposal and project. Field trip and class attendance required. Pre: CSES 4124, GEOG 4084 or BSE 4344 or CEE 4204. (2H,3L,3C).

5264 (UAP 5264): GLOBAL CHANGE & LOCAL IMPACTS
All jurisdictions, national, regional, or local, function in an interconnected global market. Understanding the structure and interactions within that global market and the impacts therein is the focus of UAP 5264. Thematic topics include a review of welfare state functions, privatization, decentralization, and nonprofit organizations and their relation to global market dynamics. Upon completion of the courses, students will have an understanding of how global forces influence local areas and how local leaders have developed strategies to cope with their position in an increasingly global market. (3H,3C).

5314: ADVANCED SPATIAL ANALYSIS IN GEOGRAPHIC INFORMATION SYSTEMS
Theory and application of geographic information systems. Spatial data handling and analysis to facilitate decision–making through the communication of geographic information. Development of such systems from existing data sources using both packaged and student produced software systems. Pre: 4084. (2H,3L,3C).

5364 (FOR 5264): GIS APPLICATIONS IN NATURAL RESOURCE MANAGEMENT
Acquiring and using publicly available natural resources data sources. Methods and algorithms to terrain modeling and landscape metrics. Evaluation of the impacts of data errors and variability on analysis results, including sensitivity analysis of GIS–based resource assessments. Special issues related to temporal data and the management of natural resources information systems. Pre: 4084 or FOR 4214. (2H,3L,3C).

5424: TOPICS IN POLITICAL GEOGRAPHY
Territorial basis of political systems, political processes, and political behavior from local to global scales; evolution of contemporary political geographic patterns, territorial divisions, and process of partitioning the earth. (3H,3C).

5434: TOPICS IN REGIONAL GEOGRAPHY
Selected topics concerning development and change in a specific region such as Sub–Saharan Africa, the Caribbean, Appalachia, or the European Community. Spatial, ecological and historical perspectives, including examination of pertinent social theory. Can be taken up to three times provided the subject material is different. (3H,3C).

5654 (SOC 5654): THE GLOBAL DIVISION OF LABOR
Theory and research on the globalization of the division of labor during the recent past as well as over the past several centuries. Examines the development of the capitalist world–system including the role of technological forces; the roles of transnational corporations and states in the global economy; the effects of globalization on work and quality of life in the U.S., other developed countries, and the Third World; analyses of globalization in the manufacturing and service sectors; and possible solutions for problems associated with globalization. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (GEOG)

The following 4000–level courses have been approved for graduate credit:

4044 (BIOL 4044): BIOGEOGRAPHY
A survey of the field of biogeography. A study of the factors influencing the distribution of plants and animals approached from ecological, historical, and cultural perspectives. Human influence on biotic patterns, such as crop domestication, habitat alteration, species introductions and extinctions, management issues, and environmental change, is a primary focus. Pre: 1104 or BIOL 2804. (3H,3C).

4074: MEDICAL GEOGRAPHY
Geographic patterns of disease and health care at various scales. Ecological, holistic approach to health problems emphasizes interrelationships of population–habitat–culture. Mapping of disease patterns and health services delivery and utilization. Field experience included. 3 hours of Geography required. (3H,3C).

4084 (GEOS 4084): INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS
Use of automated systems for geographic data collection, digitization, storage, display and analysis. Basic data in GIS applications. Overview of GIS applications. Group homework projects to develop proficiency in the use of current GIS software. Prior experience with personal computers recommended. (3H,3C).

4204: GEOGRAPHY OF RESOURCES
Environmental problems of Industrialized and Third World. Human impact on the environment, population–resource relationships, the relationship between resources and economic development, food production and the problem of world hunger, and energy–related issues. (3H,3C).

4244: GEOGRAPHY OF EUROPE
Overview of the physical geography, places, and peoples of Europe, past and present. Evolving cultural landscapes of Europe. Colonial linkages to other regions. Economic globalization and uneven development in the European Union. Comparative intracontinental regional case studies. One GEOG course at 2000 level or above, or consent. (3H,3C).

4324: ALGOTRITHMS IN GEOGRAPHIC INFORMATION SYSTEMS
Computational methods in automated mapping and map analysis. Visual Basic programming and algorithm design for spatial display and analysis under both raster and vector data models. Requires regular use of the departmental microcomputer and UNIX workstation laboratory. Variable credit course. Pre: 4084, CS 1044.

4354 (GEOS 4354): INTRODUCTION TO REMOTE SENSING
Theory and methods of remote sensing. Practical exercises in interpretation of aerial photography, satellite, radar, and thermal infrared imagery. Digital analysis, image classification, and evaluation. Applications in earth sciences, hydrology, plant sciences, and land use studies. (2H,3L,3C).

4384: THE ARC/INFO GEOGRAPHIC INFORMATION SYSTEM
Use of the Arc/Info software system for basic data tasks such as database development, digitization, storage, display and analysis under the UNIX operating system. Individual application projects will be developed throughout the semester in consultation with the instructor. Pre: 4314 or 4324. (1H,6L,3C).

4764 (SOC 4764) (UAP 4764): INTERNATIONAL DEVELOPMENT POLICY AND PLANNING
Examination of major development theories and contemporary issues and characteristics of low–income societies (industrialization, urbanization, migration, rural poverty, hunger, foreign trade, and debt) that establish contexts for development planning and policy–making. Junior standing required. (3H,3C).

4834 (CSES 4834): SOIL CHARACTERIZATION AND INTERPRETATION
Soil characteristics that influence land use and environmental quality evaluated by methods specified by the National Cooperative Soil Survey Program. Influence of spatial soil variability on soil–interpretation accuracy. Interpretative–class criteria for agricultural and urban land uses appraised. Pre: CSES 3114. (1H,6L,3C).

4844 (CSES 4844) (ENSC 4844): SOIL INTERPRETATION USING GIS AND DSS
Use of Geographic Information System (GIS) software to compile digital maps, imagery, and natural resource data. Digital data will be downloaded from the Internet and verified in the field with GPS units. Decision support systems (DSS) will be used to produce interpretative maps from digital soil data. A hypothesis, proposal, and GIS project will be created and project results presented in class. Attendance required on daylong field trips to GIS application sites. Pre: 4084, CSES 4124, or BSE 4344 or CEE 4204. (2H,3L,3C).º

GEOSCIENCES

R. J. Bodnar, Chair
J. D. Rimstidt, Administrative Chair

E-mail: geosciences@vt.edu
Web: www.geol.vt.edu

The Department of Geosciences offers graduate programs leading to the master of science and doctor of philosophy in geosciences covering the fields of aqueous/environmental geochemistry, earthquake seismology, exploration geophysics, hydrogeosciences, petrogenesis and isotope geology, mineralogy, petrology, ore deposits, paleontology, sedimentology, stratigraphy, structural geology, and active tectonics/geomorphology. Graduate programs are flexible, and students with degrees in majors other than the geosciences are encouraged to apply. Individual student programs are established through close cooperation between the student and his or her advisory committee. The specific course requirements for the M.S. and Ph.D. are as follows: 30 credits are required for the M.S., including a maximum of 12 credits from (allowable) 4000–level courses and a minimum of 12 credits from 5000– and 6000–level courses. Also, a minimum of 6 credits of 5994–level courses can be counted. Ninety credits are required for the Ph.D., including unlimited credits from (allowable) 4000–level courses and a minimum of 27 credits from 5000 and 6000– level courses. The minimum number of credits for 5994–level research credits or 7994–level research credits is 30. Students must take at least 15 credits at the 5000– and 6000–level (not including thesis or dissertation hours) at Virginia Tech. A preliminary examination must be taken as part of the Ph.D. program. The number of transfer credits is equal to the number of credits taken at Virginia Tech for a MS or Ph.D. All transfer credits must be at a "B" or higher grade to transfer.

Specific research fields of faculty members are described in a separate publication, the “Graduate Announcement.” This information can also be found on our webpage at *www.geol.vt.edu.* General areas of active research include regional geology, sedimentology, structural geology, tectonics, stratigraphy, hydrogeosciences/groundwater, invertebrate paleontology, paleoecology, earthquake seismology, regional seismicity, active tectonics/geomorphology, exploration seismology, crystal structure analysis, crystal chemistry, fluid inclusions, mineral synthesis and stability, isotope chemistry and geologic assessment of nuclear waste, igneous and

metamorphic petrology, sulfide geochemistry, gold chemistry, sedimentary petrology, and modeling of ore deposits and minerals.

SPECIAL FACILITIES

Major items of equipment include a Scintag fully automated powder X–ray diffractometer and two 4–circle single–crystal X–ray diffractometers, including an Xcalibur diffractometer system from Oxford Diffration and a customized Eulerian–cradle design from Huber Diffraktionstechnik GmbH. Diamond anvil cells are available for high–pressure diffraction experiments. In addition, a Cameca SX–50 four–spectrometer microprobe equipped with image analysis capability and a CamScan scanning electron microscope with an energy dispersive analysis system are available. Micro–Raman and FTIR spectrometers, two scanning tunneling microscopes and facilities for optical research at elevated temperatures. In addition, facilities are available for high temperature–high pressure investigations of mineral equilibria and for fluid inclusion studies of ores and rocks. Also operational is an isotope geochemistry and petrogenesis laboratory, equipped with both a single collector (35–cm instrument), as well as a new multicollector (VG 54) mass spectrometer for trace elements and isotopic studies. Facilities for geophysics include state–of–the–art 3–D seismic data processing, interpretation, and modeling hardware and software along with portable seismic, geoelectrical gravity and magnetic, and ground penetrating radar equipment. The department also operates a Worldwide Standard Seismography Station and regional telemeter network for earthquake monitoring.

GRADUATE COURSES (GEOS)

5104: SEISMIC DECONVOLUTION
Synthetic seismograms. Finite discrete linear operators for seismic applications. Analysis of single– and multi–channel real seismic data. Statistical determination of seismic wavelets and their arrival times. Deconvolution. Analysis of seismograms using digital computer. Consent required. Pre: 4136. (3H,3L,4C).

5114: THEORETICAL SEISMOLOGY
Vibrations and waves, principle of the seismograph, elastic waves in unbounded media and body and surface waves in a half–space and a layered half–space. Seismic ray theory for spherical media. Consent required. Pre: MATH 4564, ESM 5014. (3H, 3C).

5134: SEISMIC MIGRATION
Imaging of acoustic energy by wave field extrapolation. Overview of wave theory and principles of extrapolations. Forward and inverse extrapolation. Migration in wavenumber–frequency domain. Summation approach to migration. Finite difference approach to migration. Comparison between different approaches. Consent required. Pre: MATH 4564, MATH 4574. (3H, 3L, 4C).

5144 (MATH 5144): INVERSE THEORY & APPLICATIONS
Overview of inverse theory, utilizing geophysical examples to illustrate the concepts of model construction, parameter estimation, resolution, and non–uniqueness. Emphasis is on the linear problem, concluding with an overview of nonlinear inversion. Pre: MATH 2214, MATH 2224. (3H,3C).

5204: TERRIGENOUS DEPOSITIONAL SYSTEMS
Bedforms and primary sedimentary structures, secondary sedimentary structures including trace fossils, facies, facies sequences facies models, analysis of Holocene sedimentary environments, and paleoenvironmental interpretation of ancient sedimentary rocks, sedimentation and tectonics. Pre: 3204. (3H, 3C). Alternate years.

5214: CARBONATE DEPOSITIONAL SYSTEMS & SEQUENCE STRATIGRAPHY
Classroom, laboratory and field examination of the temporal and spatial makeup and controls on mineralogy and constituent composition of sedimentary carbonates, sequence stratigraphy of carbonate platforms, paleoclimatic significance of carbonates succession. Introduction to porosity evolution and cementation of carbonates in marine, meteoric and burial realms. Pre: 3204. (2H,3L,3C).

5224: CLASTIC PETROGRAPHY & DIAGENESIS
Formation of terrigenous particles by weathering, clay mineralogy, clay diagenesis, tectonic control on framework grain composition, quartz arenites and silicretes, feldspathic sandstone's, lithic sandstones, greywackes, and controls on sandstone diagenesis. Pre: 3204, 3504, GEOL 4504. (3H, 3L, 4C).

5314: PALYNOLOGY
Classification, biology, paleoecology, and biostratigraphic applications of microscopic plant fossils ranging from marine algae (dinoflagellates, etc.) to terrestrial flora (fernsthrough angiiosperms). Pre: Consent of instructor. (2H,3L,3C).

5324: SYSTEMATIC PALEOZOOLOGY I– THE LOWER INVERTEBRATES
Systematics and morphology of major fossil groups of Sarcodina, Porifera, Cnidaria, Mollusca, Brachiopoda, and Bryozoa. Two semesters of biology required. Pre: 3604. (2H,3L,3C).

5344: BIOSTRATIGRAPHY
Use of fossils for determining time relationships in sedimentary rocks. Sediment accumulation rates, evolutionary rates, problems of correlation, zonal and the issue of time resolution. Pre: 3204, 3604. (3H, 3C).

5354 (STS 5354): THE FOSSIL RECORD OF EVOLUTION
Application of the fossil record to the study of evolution. Role of paleontology in documenting evolutionary change and in testing and establishing aspects of modern evolutionary theory. Pre: 3604. (3H, 3C).

5364: PALEOECOLOGY
Growth, functional morphology, and interpretation of modes of life of fossil organisms; formation of fossil assemblages, paleocommunity reconstruction and interpretation, and evolution of ecologic relations biosphere. Pre: 3204 and 3604. (3H, 3C).

5374: QUANTITATIVE PALEOBIOLOGY
Use of quantitative methods in paleontology. Analysis of paleontological data. Modeling the macroevolutionary process. The role of quantification in establishing a rigorous science of paleontology. Consent required. Pre: 3604; Co: STAT 5605, STAT 5606. (3H, 3C) II.

5384: (BIOL 5384): MORPHOMETRICS
Study of shape and size in fossil and modern organisms with strong focus on quantitative methods and digital image analysis. Covers analytical methods (multivariate methods, Fourier analysis, geometric morphometrics), image processing, and software training (SAS, SAS/IML, and Imaging Software). Pre: 5374, STAT 5004. (2H,3L,3C).

5404: APPALACHIAN GEOLOGY
Geology and tectonics of the Appalachians with emphasis on the Valley and Ridge, Blue Ridge, and Piedmont provinces. Evaluation of current orogenic models. Exercises in writing proposals on problems of Appalachian geology. Weekend field excursions to provide an overview of typical terranes. Pre: 3104, 3204, 3404, 3704; (3H, 3L, 4C).

5414: TECTONICS
Overview of modern plate tectonic theory through lectures, reading original articles in the professional literature, and class discussions. Pre: 3104, 3204, 3404, 3704. (2H, 2C).

5424: STRUCTURAL PETROLOGY
Examination of the processes by which rocks deform due to tectonic stresses, and recognition and interpretation of the microstructures that record these processes. Consent required. Pre: 3504, 3704. (2H, 3L, 3C).

5504: CRYSTALLOGRAPHY & CRYSTAL CHEMISTRY
Crystallography and crystal chemistry of rock-forming minerals. Pre: 3504. (3H, 3L, 4C).

5514: ADVANCED OPTICAL TECHNIQUES
Advanced methods of optical crystallography, particularly spindle stage methods, plus new methods of determining the principal refractive indices and orientation of crystals in petrographic thin sections will be described and applied. Pre: 3504. (3H,3C).

5524: X-RAY CRYSTALLOGRAPHY
Principles of x-ray diffraction used in the characterization of crystalline solids by photographic and spectrometric methods. Pre: 3504. (2H, 3L, 3C).

5525, 5526: ELECTRON MICROPROBE
Theory and practice of qualitative and quantitative elemental microanalysis using electron-excited x-rays. Consent required. Pass/Fail only. (1H, 1C).

5604: ORE MINERALOGY & MICROSCOPY
In-depth study of ore minerals as major phases in ore deposits and as petrologic indicators. The theory and application of reflected light microscopy in the identification and analysis of textures of ore minerals and their synthetic analogs. Pre: 3504. (2H, 3L, 3C).

5615, 5616: PETROGENESIS
Systematic study of selected isotopes and trace elements. Application of data to modern petrologic and tectonic environments and their ancient analogs. Numerical modeling of crust/mantle processes, use of analytical facilities (solid source mass spectrometer, x-ray fluorescence spectrometer) to general isotopic and chemical data. Application of new data to interpretation of regional petrology and tectonics. Weekend field trips may be required. Pre: 3704. (3H, 3L, 4C).

5704: THEORETICAL PETROLOGY
Fundamentals of chemical thermodynamics and their application to rock and mineral systems. Material will include solid-solid and solid-vapor equilibria at elevated pressures and temperatures, properties of real gasses, modeling of solid solutions, the phase rule and composition space, and Schreinemaker's analysis. Calculus required. (3H,3C).

5714: IGNEOUS PETROLOGY
Advanced analysis of the origin and evolution of magmatic rocks, including discussion of phase equilibria of melt-crystal systems, thermodynamics and structures of melts, physics and fluid dynamics of melt segregation and movement, physical and chemical interactions with wallrock, and case studies of magmatic provinces with specific illustrations of igneous processes. Pre: 3704, 5704. (2H, 3L,3C).

5724: METAMORPHIC PETROLOGY
Classical and quantitative methods for the study of the origin of metamorphic rocks. Emphasis is placed on the synthesis of observational, analytical, theoretical, and experimental data towards the fundamental understanding of the petrology of metamorphic rock systems in a geologic framework. Pre: 3704, 5704. (2H, 3L, 3C).

5734 (CSES 5734): CLAY MINERALOGY
Structure, composition, classification, identification, and properties of clay minerals; emphasis on characteristics of mixed-phase systems in sediments and soils. Even years. Pre: CSES 5634 or GEOS 3504. (3H,3L,4C).

5744: FLUID INCLUSIONS TECHNIQUES
The study of fluid inclusions in rocks and minerals from sedimentary, metamorphic, igneous, and ore-forming environments. Basic fluid inclusion principles and techniques and characteristics of inclusions from these various geologic environments will be described. Consent required. (2H, 3L, 3C).

5754: FLUIDS IN THE EARTH'S CRUST
The physical and chemical properties of various fluids of geologic interest and the interaction of these fluids with minerals, rocks, and melts in the earth's crust are considered. Consent required. (3H, 3C).

5804: QUANTITATIVE HYDROGEOLOGY
Rigorous mathematical and physical concepts of fluid flow in porous geological media. The course will focus on the mechanics of groundwater flow in one, two, and three spacial dimensions. Boundary conditions and analytical solutions to subsurface and vadose-zone flow problems will be explored and solved analytically. The mechanics of horizontal and vertical deformation of aquifers due to applied pumping stress will be taught from first principles. Includes problems dealing with steady and transient groundwater flow, Biot's equations and three-dimensional consolidation theory. Pre: 4114, MATH 2214 or MATH 2514. (3H,3C).

5814 (CEE 5354): NUMERICAL MODELING OF GROUNDWATER
Theory and practice of numerical techniques are developed and applied to fluid flow and transport in ground-water flow systems. Governing equations are formulated using FD and FE techniques with appropriate BC's and IC's. Additional topics include: model conceptualization and grid design in multidimensional systems; practical applications of numerical models including calibration, validation, and prediction; concepts and techniques of advective transport using particle tracking and dispersive transport. Introduction to MODFLOW, MODPATH, MT3D, and others. Pre: 4114 or CEE 4314. (3H,3C).

5974: INDEPENDENT STUDY
Pass/fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6104: ADVANCED TOPICS IN GEOPHYSICS
Advanced analysis of one or more topics of geophysics using the most recent techniques, interpretations, and data. Can be taken up to three times provided the subject material is different. Consent required. Variable credit course.

6194: SEMINAR IN GEOPHYSICS
Critical review of recent published works on selected topics in geophysics. Consent of instructor required. Pre: 5114, 5134. (2H, 2C).

6204: ADVANCED TOPICS IN SEDIMENTOLOGY
Advanced analysis of one or more topics in sedimentology using the most recent techniques, interpretations, and data. Can be taken up to three times provided the subject material is different. Consent required. Variable credit course.

6304: ADVANCED TOPICS IN PALEONTOLOGY
Advanced analysis of one or more topics in paleontology using the most recent techniques, interpretations, and data. Can be taken up to three times provided the subject material is different. Consent required. Variable credit course.

6404: ADVANCED TOPICS IN STRUCTURE/TECTONICS
Current ideas and research problems in structural geology and tectonics. Can be taken up to three times provided the subject material is different. Consent required. Variable credit course. Pre: 3404.

6504: ADVANCED TOPICS IN MINERALOGY
Current research in the major mineral groups subdivided by crystallographic, crystal chemical, or petrogenetic affinities. May be repeated up to three times. Variable credit course. Pre: 5504.

6604: ADVANCED TOPICS IN GEOCHEMISTRY
Advanced analysis of one or more topics of geochemistry using the most recent techniques, interpretations, and data. Can be taken up to three times provided the subject material is different. Variable credit course. Pre: consent.

6704: ADVANCED TOPICS IN PETROLOGY
Advanced analysis of one or more topics of petrology using the most recent techniques, interpretations, and data. Can be taken up to three times provided the subject material is different. Consent required. Variable credit course.

6804: ADVANCED TOPICS IN HYDROGEOLOGY
Advanced analysis of one or more topics of hydrogeology. Can be taken up to three times provided the subject material is different. Pre: Consent of instructor. Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (GEOS)

The following 4000–level courses have been approved for graduate credit:

4124: SEISMIC STRATIGRAPHY
Overview of seismic data acquisition and processing methods, seismic wavelets, static and dynamic corrections, and seismic velocities; seismic reflection data interpretation; seismic reflection responses Seismic mapping; seismic stratigraphy and seismic lithology. Consent required. Pre: 3104. (2H,3L,3C).

4154: EARTHQUAKE SEISMOLOGY
Seismicity and its causes in the context of plate tectonics; determination of earthquake location, size and focal parameters; seismogram interpretation; seismometry; hazard potential; use of earthquakes in determining earth structure. Pre: 3104, MATH 2214, MATH 2224, PHYS 2305. (2H,3L,3C).

4164: POTENTIAL FIELD METHODS IN EXPLORATION GEOPHYSICS
Theory and application to engineering, environmental, and resource exploration. Gravity, magnetics, electrical resistivity, self potential, induced polarization, ground–penetrating radar, magnetotellurics, electromagnetic induction. Pre: 3104, MATH 2214, MATH 2224, PHYS 2306. (3H,3L,4C).

4174: EXPLORATION SEISMOLOGY
Theory and application of seismic methods to engineering, environmental and resource exploration: reflection seismics, refraction seismics, and tomography. Data acquisition, digital filtering, data corrections, imaging, interpretation, and forward modeling. Pre: (3104, MATH 2224, PHYS 2305, PHYS 2306). (3H,3L,4C).

4324 (BIOL 4324): PLANT EVOLUTION (WRITING INTENSIVE)
Geological history, comparative morphology, evolution and systematics of pre–vascular and vascular plants. Focus on evolution of communities, adaptive construction of tissues and organs, and ecology of reproduction. Pre: BIOL 2304. (2H,6L,4C).

4404: ADVANCED STRUCTURAL GEOLOGY
Basic principles of rock behavior under applied, non–hydrostatic stress (experimental and tectonic) and analysis of the geometrical patterns produced. Alternate years. Pre: 3404. (2H,3L,3C).

4554: GEOLOGIC ASPECTS OF NUCLEAR AND TOXIC WASTE DISPOSAL
Review of the geochemical characteristics of radionuclides and other toxic, inorganic materials and how these characteristics affect safe disposal of these materials in the natural environment. Examination of the effects of near–surface geologic processes such as groundwater movement and geologic hazards on long–term storage of nuclear wastes, with application to evaluation of current and proposed disposal sites. Pre: 3404, CHEM 1036. (2H,3L,3C).

4634: ENVIRONMENTAL GEOCHEMISTRY
Application of quantitative methods of thermodynamic and physicochemical analysis to the study of the distribution and movement of chemical elements in surface and near–surface geological environments. Emphasis on practical approaches to environmental geochemistry. Pre: MATH 1205, CHEM 1036. (2H,3L,3C).

4644: ORGANIC GEOCHEMISTRY
Composition, origin and distribution of organic matter in the geological environment; the carbon cycle; terminology and structure of organic molecules; metamorphism of organic materials; formation and composition of coal, oil, natural gas; organic geochemistry of the oceans; role of organics in ore formation; organic compounds in natural waters; abiogenic organic compounds in magmatic rocks and fluids. Pre: 1004 or 2104, 1014 or 1024, CHEM 1036. (3H,3C).

4714: VOLCANOES AND VOLCANIC PROCESSES
Study of characteristics and mechanisms of voclanic phenomena, including magma dynamics, origin and chemistry of lavas, physics of eruptions, and characteristics of volcanic products, particularly pyroclastic deposits. Includes focus on volcanism as a general planetary process, on terrestrial tectonic settings of volcanism and on volcanic hazards. Pre: 3704. (2H,3L,3C).

4804: GROUNDWATER HYDROLOGY
Physical principles of groundwater flow, including application of analytical solutions to real–world problems. Well hydraulics. Geologic controls on groundwater flow. Pre: (1014), (PHYS 2205 or PHYS 2305), (MATH 1206). (2H,3L,3C).

GERONTOLOGY

K.A. Roberto, Director
R. Blieszner, Associate Director

Professors: K.R. Allen; J. Beamish; R. Blieszner; J.R. Bohland; T.M. Calasanti; N. Castagnoli; R.H. Cox; H.J. Crawford; E.A. Flanagan; M.J. Furey; R.C. Goss; W.G. Herbert; M.E. Houston; J.C. Lee; J.A. Mancini; F. Piercy; K.A. Roberto; J. Ryan; E.D. Schlenker; K. Singh; B. Snizek; M. Uysal; J.H. Williams; D.T. Zallen

Administrative Faculty: J.E. Dooley; S. Dwyer

Associate Professors: C.F. Baffi; M.A. Bell; J.R. Bloomquist; A. Bouguettaya; J.B. Crockett; L. Dudley; J.M. Emmel; D.W. Harrison; B.G. Klein; I. Leech; M. Nussbaum; K.J. Redican; S. Schofield–Tomschin; S.D. Sheetz; E.J. Smith; J.A. Yardley

Adjunct Associate Professor: D.R. Southard

Assistant Professors: K.L. Babski–Reeves; M. Dolbin–MacNab; J. Callahan; K. Caroll; B. Davy; A.L.. Few; D. Gracanin; C. Hayhoe; T.L. Henderson; S.E. Jarrott; M. Keeling; B.G. Klein; K. Knowlton; J. Leiferman; T.E. Lockhart; M. Madigan; S. Nichols–Richardson; E. Serrano; T.L. Smith–Jackson; K.M. Stadler; M.L. Stevenson; H.M. Suthers–McCabe; E.M. Van Aken

Instructor: A. Galway

Research Associates: A.H. Glass; K.L. Wilcox

Research Scientist: I. Bradburn

E-mail: carthur@vt.edu

Web: www.gerontology.vt.edu

Gerontology is the study of aging which includes examining the process of aging; the physical, social, economic, emotional, and political ramifications of aging; and the changes that individuals and populations experience as they grow older. As the world's population ages and the number of elderly citizens increases, the demand for graduates with a background in gerontology, coupled with a strong program in a traditional discipline, is expanding dramatically.

The Center for Gerontology is the central organizational unit for gerontological research, instruction, and outreach on the Virginia Tech campus. It is a member of the Association for Gerontology in Higher Education. The potential for interdisciplinary graduate study in gerontology is demonstrated by the variety of instructional programs represented by the participating faculty. These faculty members are involved in diverse basic and applied research projects in such areas as family support mechanisms, factors influencing health care decisions, exercise and nutritional status, managing chronic disease, intergenerational relations, housing satisfaction, family and friendship patterns, consequences of cognitive impairment, the needs of rural elders, care management, body mechanics, elder–computer interactions, and the elderly leisure and tourism service market.

Graduate students with a concentration in gerontology have a number of opportunities for participation in activities outside the classroom that can complement their course work, enhance their professional development, help finance their education, and provide direct experience in applied settings. Students are encouraged to participate in gerontological research being conducted by participating faculty members. Involvement in such projects can lead to direct research experience and, in some cases, provide financial assistance, course credit, and thesis or dissertation research topics. The Gerontology Research Forum, presentations by noted authorities on aging issues, provides an informal setting for learning about and discussing current issues in gerontology. The Center for Gerontology sponsors the Beta Sigma Chapter of Sigma Phi Omega, national honor society in gerontology. Sigma Phi Omega members participate in activities related to gerontology education, research, and service. Graduate students are encouraged to meet with faculty in informal monthly research seminars. Students also may participate in field studies carried out in conjunction with cooperating agencies throughout the region, including the Virginia Tech Adult Day Services. The field work is tailored to the specific career and educational goals of each student and may include research, administrative, or clinical experience. In addition, the Center for Gerontology offers a limited number of graduate assistantships to qualified persons.

A Graduate Certificate in Gerontology Program is administered by the Center for Gerontology and offered either in conjunction with a master's or doctoral degree or as a non-degree program. Degree candidates who are seeking certification in gerontology typically study in areas such as adult development and aging, architecture, biology, business administration, clothing and textiles, counseling, engineering/human factors, exercise physiology/cardiac rehabilitation, family studies, health, housing, interior design, neurobiology, nutrition, psychology, public administration, and sociology. Non-degree candidates are upgrading their professional knowledge and skills in gerontology. The Certificate is designated a Program of Merit by the Association for Gerontology in Higher Education.

Graduate Certificate in Gerontology

Course Requirements (15 cr.)

Area 1.	HD 5104	Adult Development and Aging I
Area 2.	HD 5114	Adult Development and Aging II
or		
	SOC 5714	Aging in Social Context
Area 3.	EDHL 5704	Health of the Elderly or
	HNFE 5624	Nutrition and Aging or
	HNFE 5664	Physiological Aspects of Aging
Area 4.	HD 5144	Seminar in Gerontology (1 cr.)
Area 5.	XXXX 5964	Practicum/Field Study (2 cr.)
Area 6.	Elective(s) 3 cr. selected from courses above or:	
	AHRM 4674	Housing Management for the Elderly
	AHRM 6604	Housing for an Aging Society
	HD 4114	Community–Based Services for Older Adults
	HD 5124	Social Policy and Aging
	HD 5134	Contemporary Issues in Aging
	HD 6114	Theory and Research in Aging

Up to six hours of transfer credit can be approved. If the student writes a thesis or dissertation, it must be on an age-related topic. Students can normally fit the requirements for the certificate into their program of graduate study so that the time needed to complete the graduate degree in their basic discipline is not extended by simultaneously pursuing the certificate. Students interested in the Graduate Certificate in Gerontology should confer with the associate director of the Center for Gerontology prior to submitting a program of study to the Graduate School. Additional information regarding opportunities for graduate study in gerontology at Virginia Tech may be obtained from the Center for Gerontology.

AHRM 4674: Housing Management for the Elderly
AHRM 6604: Housing in an Aging Society
EDHL 5334: Health of the Elderly
HD 4114: Community Based Services for Older Adults
HD 5104: Adult Development and Aging I: Individual Development
HD 5114: Adult Development and Aging II: Interpersonal Issues
HD 5124: Social Policy and Aging
HD 5134: Contemporary Issues in Aging
HD 5144: Seminar in Gerontology
HD 6114: Theory and Research in Aging
HNFE 5624: Nutrition and Aging
HNFE 5664: Physiological Aspects of Aging
SOC 5714: Aging in Social Context

GOVERNMENT & INTERNATIONAL AFFAIRS

Timothy W. Luke, Chair

University Distinguished Professor: T.W. Luke
Edward S. Diggs Professor in the Social Sciences: E. Weisband
Professors: I.A. Luciak; R.C. Rich; J. Rothschild; G. Toal
Associate Professors: W. Dunaway; A. Ebrahim; D.J. Milly
Assistant Professor: C. Clement

Government and International Affairs (GIA) is a program in the School of Public and International Affairs in the College of Architecture and Urban Studies (CAUS). GIA offers the master of public and international affairs (MPIA) and the PIA stream of the Ph.D. in the CAUS EDP program (see Environmental Design and Planning). These degrees are offered in both Blacksburg and Alexandria.

PUBLIC AND INTERNATIONAL AFFAIRS

The master of public and international affairs (MPIA) is offered through the Government and International Affairs program in the School of Public and International Affairs. The interdisciplinary MPIA curriculum is designed as a coherent program of study that will enable public, private or nonprofit leaders to respond to new public challenges. Two major trends lend this program its distinct focus: first the globalization of production and markets and its many implications; and second, the need for more collaborative and democratic forms of governance in resolving social problems. The consequences of these two trends will continue to shape the foreseeable future. Effective leadership, be it in the public, private or nonprofit sectors, will require persons capable of understanding the impact of global forces on local, regional and national economies and able to create effective alliances across sectors (public, private, and non-profit) of our economy and among diverse citizen groups.

The 36-credit-hour curriculum is guided by the following instructional principles:

1. Theory and application must be an integral part of the professional education.
2. Comparative conceptual frameworks are emphasized throughout the curriculum to emphasize global perspectives.
3. Inquiry and active learning instructional strategies are explored and used where appropriate.
4. The synthesis course provides an opportunity for students to develop new or alternative frameworks for integrating the core concepts provided in the curriculum and to develop a common culture for the program.

MPIA CURRICULUM

Total Credit Hours Required: 36

COMMON CORE (18 CREDIT HOURS)

UAP 5164: Collaborative Governance and Civil Society
UAP 5224 Research Design
PSCI 5444: International Politics
UAP 4184: Community Involvement
UAP 5634: Global Change and Local Processes
UAP 5754: Professional Development Colloquium (1 hr)
UAP 5804 Practicum Problem (2 hrs)
or UAP 5904 Project and Report (3 hrs)
or UAP 5994 Research and Thesis (6 hrs)

AREA CORES (6 HOURS REQUIRED)

Students must select three hours from each of the following area core courses.

PUBLIC AND NONPROFIT MANAGEMENT (3 HOURS REQUIRED FROM LIST)

UAP 5514 : Public Budgeting and Management
PAPA 6314: Public Budget Processes and their Policy Implications
UAP 4244: Nonprofit Organization and Management
UAP 5444: Strategic Planning and Management

INQUIRY AND ASSESSMENT (3 HOURS REQUIRED FROM LIST)

UAP 5474: Program Evaluation
UAP 5484: Advanced Research Methods
UAP 5494: Advanced Quantitative Techniques
PSCI 1515: Research Methods
PSCI 5214: Contemporary Political Theory

AREAS OF CONCENTRATION
(12 APPROVED HOURS IN ONE OF FOLLOWING AREAS)

PUBLIC AND NONPROFIT FINANCE AND BUDGETING
GLOBAL CHANGE AND IMPLICATIONS
ENVIRONMENTAL MANAGEMENT
COLLABORATIVE POLICY AND MANAGEMENT
INFORMATION TECHNOLOGY AND SOCIETY

GRADUATE COURSES (SPIA)

5454 (PSCI 5454): ADVANCED TOPICS IN INFORMATION TECHNOLOGY & PUBLIC POLICY
In-depth study and critical evaluation of selected complex issues related to information technology, society, governance, and public policy. Focused attention is given to theoretical and methodological foundations of the area of inquiry and to specific domains of policy making and implementation. Topics will be selected from IT-related issues in such areas of concern as: cities, local communities, nonprofit organizations, governments, and global networks. May be repeated on a different topic. Must meet prerequisite or have permission of instructor. Pre: UAP 5564. (3H,3C).

5554 (PSCI 5554): CULTURE, POLITICS & SOCIETY IN NETWORK ENVIRONMENTS
Historical origins, institutional foundations, and theoretical interpretations of cultural, political, and social interaction through computer-mediated communication are examined. Particular attention is given to new types of discourse, sources of power, and structures of society at all geographical levels in global computer and communications networks. (3H,3C).

GRADUATE SCHOOL

Karen P. DePauw, Vice Provost for Graduate Studies and Dean of the Graduate School

Roger J. Avery, Senior Associate Dean

Some course are offered by the Graduate School or are combinations of other academic units (interdisciplinary).

GRADUATE COURSES (GRAD)

5004: GTA TRAINING WORKSHOP
A three-day orientation to the role of a GTA at Virginia Tech and review by experienced faculty and GTAs of essential guidelines for effective classroom and laboratory communication and management. Microteaching component completes the program. Pass/Fail only. (1H,1C).

5104: PREPARING THE FUTURE PROFESSORIATE
The purpose of the course is to provide doctoral students with an understanding and contextual knowledge of the professoriate and issue facing higher education. These topics include the changing nature of faculty roles and expectations, changing nature of the students/learners, increasing role of technology and distance education in higher education, paradigm shifts in the academe, ethical issues, and external forces influencing the college/university. Graduate standing required. (3H,3C).

5114: PEDAGOGICAL PRACTICES IN CONTEMPORARY CONTEXTS
This seminar will engage participants in an interdisciplinary exploration of pedagogical practices for different courses taught in different contexts. This course will examine teaching to diverse groups with inclusive pedagogy, integrating gloval contexts with innovative e-learning components, and using problem-based learning across the disciplines. Participants will discover ways to negotiate the changing demographics of contemporary teaching sites, and undertake an overview of the uses and benefits of electronic portfolios both as a teaching tool and as a professional development tool. Graduate standing required. (3H,3C).

5944: GRADUATE COOPERATIVE EDUCATION PROGRAM
Administrative registration to designate full-time registration for master's level students. (0C).

5984: SPECIAL STUDY
Variable credit course.

6864: DEFENDING MASTERS STUDENT
For defending Masters Students. (1H,1C).

7864: DEFENDING DOCTORAL STUDENT
For defending Doctoral students. (1H,1C).

7944: GRADUATE COOPERATIVE EDUCATION PROGRAM
Administrative registration to designate full-time registration for doctoral level students. (0C).

INTERDISCIPLINARY GRADUATE COURSES (GBCB)

5004: SEMINAR IN GENETICS, BIOINFORMATICS, AND COMPUTATIONAL BIOLOGY
Review and discussion of current topics and literature in genetics, bioinformatics, and computational biology by students, Virginia Tech faculty, and outside speakers. Students give formal presentations of research results or current literature. May be repeated. Pre: graduate status in the Program in Genetics, Bioinformatics, and Computational Biology or in a department that offers the Bioinformatics Option. (1H,1C).

5314 (PPWS 5314): BIOLOGICAL PARADIGMS FOR BIOINFORMATICS
This course is an intensive introduction to the central paradigms of molecular cell biology for bioinformatics. Material from cell molecular biology, and genetics will be presented, and placed in a genomics context. The course prepares students in mathematical disciplines to interact in teams in the pursuit of bioinformatics research. Pre: Senior or graduate standing in mathematically–based disciplines such as computer science, statistics, mathematics or engineering. (3H,3C).

5515,5516 (MATH 5515, 5516): MATHEMATICAL METHODS FOR MODELING AND SIMULATION OF BIOLOGICAL SYSTEMS
Introduction to mathematical techniques for modeling and simulation, parameter identification and analysis of biological systems. Emphasis on both theoretical and practical issues and methods of computation, with concrete applications. Suitable for students from the mathematical and life sciences who have a basic foundation in multivariate calculus and ordinary differential equations. 5515: Continuous models and methods. 5516: Discrete models and methods. (3H,3C).

5844 (CSES 5844): PLANT GENOMICS
Comprehensive overview of genomics and its applications. Topics include: molecular markers, map construction, map–based cloning, quantitative trait loci, and functional genomics. Even years. Pre: Knowledge of general principles of genetics and molecular biology. (3H,3C).

5874: PROBLEM SOLVING IN GENETICS, BIOINFORMATICS, AND COMPUTATIONAL BIOLOGY
Research practicum in genetics, bioinformatics, and computational biology. Emphasis on the multidisciplinary and collaborative nature of research in genetics, bioinformatics, and computational biology. Exposure to the scientific method, the nature of research tools, strategies for publishing, and opportunities for research careers in genetics, bioinformatics, and computational biology. Permission required. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

INTERDISCIPLINARY GRADUATE COURSES (MACR)

5015,5016: MACROMOLECULAR FUNDAMENTALS LABORATORY I AND II
The course will cover fundamentals and experimental techniques for the synthesis and characterization of polymeric materials. MACR 5015 includes statistical experimental design, step–growth and chain–growth polymerization, molecular modeling, thermal properties of polymers, molecular weight analysis, morphology, and melt and solution rheology. MACR 5016 includes static and dynamic mechanical analysis, rubber elasticity, spectroscopy, surface analysis, fracture behavior, and basic polymer processing. Must meet pre–requisites or equivalent. Pre: CHEM 4534 or CHEM 4634 or CHE 4104. (2H,3L,3C).

5024: WRITING SKILLS IN MACROMOLECULAR SCIENCE AND ENGINEERING
This course focuses on methods and critiques for preparing technical abstracts, conference proceedings, technical industrial reports, refereed journal manuscripts and resumes. (2H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

HISTORY

Daniel B. Thorp, Chair

Distinguished Professor: J.I. Robertson, Jr.
Professors: L.J.Arnold; F.J. Baumgartner; W.C. Davis; A.R. Ekirch; R.F. Hirsh; W.L. Ochsenwald; C.A. Shifflett
Associate Professors: M.V. Barrow, Jr.; G.R. Bugh; B. Bunch-Lyons; E.T. Ewing; H. Farrar; T.C. Howard; K.W. Jones; A. Nelson; J.D. O'Donnell Jr.; P. Schmitthenner; N.L. Shumsky; D.B. Thorp; P.R. Wallenstein
Assistant Professors: M. Mollin; H.M. Schneider; R. Stephens
Adjunct Professor: B.J. Reeves

E-mail: histgrad@vt.edu
Web: http://www.history.vt.edu

Graduate instruction in history is designed to prepare students for many careers that require training beyond the baccalaureate level. These may include teaching, archival or museum work, publishing, and governmental service. An advanced degree in history also is useful as pre-legal or pre-business preparation.

Graduate offerings in history lead to the degree of M.A., with or without thesis. Students may focus in one of four tracks: U.S. History; Race, Class, and Gender in History; History of Science and Technology; and Atlantic World Studies, or they may pursue an Area Studies specialty, all with intensive training in the computing skills involved in historical teaching, research, and writing. Detailed information about the requirements and content of the program is available from the department.

Graduate Courses (HIST)

5024 (FL5024) (GEOG 5024): AREA STUDIES METHODS
Introduction to recent theories and methods in history, foreign languages and literary studies, and geography with a focus on issues that have facilitated exchanges between the three disciplines. Practical aspects of Area Studies research are highlighted with particular reference to Latin America, the Caribbean, and Europe. The formulation of research problems using interdisciplinary approaches is given special attention. Graduate standing required. (3H,3C).

5104: HISTORICAL METHODS
Introduction to methods and approaches in history for all graduate students. Choosing research topics, canvassing depositories, use of computer techniques in history, art and craft of historical writing. (3H,3C).

5114: U.S. TO 1877
American history, from European discovery through Reconstruction. Emphasis on major themes and developments in the emergence of the United States: exploration and settlement; encounters among Europeans, Africans, and Native Americans; achievement of political independence; territorial expansion and political conflict; immigration, industrialization, and urbanization; Civil War, emancipation, and Reconstruction. (3H,3C).

5124: U.S. SINCE 1877
Introduction to main themes in U.S. history beginning with post-Civil War industrialization. An intensive readings course emphasizing the social, cultural, political, economic, and military changes in the century after Reconstruction. (3H,3C).

5144 (GEOG 5144): THE TRANSATLANTIC WORLD
Comparative and interdisciplinary study of encounters and exchanges between Europe, Africa, and the Americas. Surveys of literature on selected topics from the onset of European colonization until the present time. (3H,3C).

5205, 5206 (STS 5205, 5206): MAIN THEMES IN THE HISTORY OF SCIENCE & TECHNOLOGY
Methods and concepts in the history of science and technology. 5205: research methods, interpretive approaches, and contemporary issues in the history of science; 5206: research methods, interpretive approaches, and contemporary issues in the history of technology. X-grade allowed. (3H,3C).

5254: TOPICS IN MODERN EUROPEAN HISTORY
Advanced intensive research seminar in the development of European history since the Enlightenment. Variable content course. May be repeated with different topics for credit. (3H,3C).

5264: READINGS IN LATIN AMERICAN HISTORY
Variable topics readings course in Latin American history focusing on intersecting themes such as race/class/gender and environment/technology/culture, and emphasizing the most recent trends in the historiography. Students will be expected to write a literature review of recent secondary sources. Variable content course. May be repeated for a mazimum of six hours. (3H,3C).

5274: TOPICS IN LATIN AMERICAN HISTORY
Variable topics research seminar in Latin American history. Emphasis will be placed on planning a research agenda and analyzing primary sources–visual, oral, and written–within the context of recent trends in the historiography. Students will be expected to write an original article length research paper based on primary sources. May be repeated with a different topic for a maximum of 6 credits. (3H, 3C).

5404 (STS 5404): DEVELOPMENT OF MODERN AMERICAN SCIENCE
Development of the sciences and the community of scientists in the American national context. Emphasis on scientific, institutional, and social events from 1830s through 1980s, including the circumstances surrounding the creation of nuclear weapons and the emergence of "big science." An interdisciplinary perspective, exploring traditional and contemporary historiographical and methodological issues and approaches. (3H,3C).

5504: MODERN EUROPEAN HISTORY
Major problems and interpretations of European history from the 18th century to the present. Comparative and theoretical approaches to understanding social movements and transformation, social class and ethnicity, and the politics of culture and "exceptional histories" such as Germany and Russia. (3H,3C).

5524: EMERGENCE OF THE PACIFIC CENTURY
Description and analysis of the emergence of the "Pacific Century." The phrase connotes the emerging Pacific Rim and the growing importance of cultural, political, and especially economic relations between North America and East Asia, as Japan and also China, Taiwan, Korea, and other parts of the region undergo rapid industrialization. (3H,3C).

5534: IMPERIALISM, NATIONALISM, & DECOLONIZATION
Imperialism, nationalism, and their legacies in the twentieth century. Concentration on imperialism and nationalism as categories of historical analysis. Critical examination of the imperial and colonial experiences and of the expansion and transformation of the nation-state system as a consequence of decolonization and global restructuring. (3H,3C).

5545,5546: STUDIES IN HISTORY OF ENGLAND AND BRITISH EMPIRE
Survey of major secondary literature and introduction to primary sources for study of English history. 5545: Early Modern England, 1540–1783; 5546: England and the Empire since 1783. (3H,3C).

5564: AFRICAN AMERICAN WOMEN IN UNITED STATES HISTORY
This course is designed to explore the historical, socio–cultural and political forces that have contributed to the development of an African American female experience in the United States. Taught chronologically beginning with the colonial period, emphasis will be given to the evolution of significant themes, relying on race, class, gender, and regionalism as critical modes of analysis. Graduate standing required. (3H,3C).

5604: WAR AND REVOLUTION IN AMERICA
War and revolution in American society. Emphasis on common themes and unique features of three wars in the American experience: the American Revolution, Civil War, and Vietnam War. Concentration on similarities and differences in these three conflicts regarding military strategy; political, economic, diplomatic racial factors; race and social class; foreign involvement; and public response. (3H,3C).

5614: COLONIAL–EARLY NATIONAL AMERICA
Development of America from 1607 to 1828. Emphasis upon social, economic, cultural, and political changes as well as different patterns of regional growth. (3H,3C).

5624: JACKSONIAN AMERICA & THE CIVIL WAR
This graduate seminar focuses first on the social, economic, and political events which led to Civil War, and then on various aspects of the war itself. Special emphasis also will be placed on the major political and military leaders of the period. (3H,3C).

5634: BIRTH OF MODERN AMERICA, 1870–1920
The transformation of America from a preindustrial, rural, agrarian society into a modern, technologically–advanced, urban, industrial nation. The social, political, and cultural components of that transformation are studied. (3H,3C).

5644: MODERN AMERICA SINCE 1920
The transformation of the United States from a powerful but isolated industrial nation with minimal military forces into its current role as industrial and military superpower. (3H,3C).

5654: AMERICAN CITIES
Urbanization and urban life in the United States. Emphasis on the transformation of the United States from a rural agrarian to an urban industrial nation and on the nature of urban life in the nineteenth century. Analysis of the twentieth century urban revolution and the development of the post–modern city. (3H,3C).

5674: CIVIL RIGHTS MOVEMENT
This course will explore the modern U.S. Civil Rights Movement, 1930s–1960s, a combination of litigation, direct action, and political efforts that sought to eliminate the various facets of Jim Crow, particularly segregation and disfranchisement, from the nation in general and the South in particular. (3H,3C).

5684: THE U.S. SOUTH
A reading colloquium on the history of the south during various periods of its history. Emphasis upon the emergence of the south as a separate and distinct region and the basis of southern identity from the years of slavery to the present. (3H,3C).

5694: AMERICAN ENVIRONMENTAL HISTORY
Examination of the important ways Americans have shaped and been shaped by the natural environment from the time of European contact with the New World to the present. Emphasis on the evolution of environmental concern in the nineteenth and twentieth centuries. (3H,3C).

5704: AFRICAN–AMERICAN NATIONALISM, 1829–PRESENT
Intensive study of divergent paths towards racial and national identity within the African–American community since 1829. Topics include assimilationism, racial separatism, black nationalism, and Afrocentricity. (3H,3C).

5724: ORAL HISTORY
Introduction to oral history as an important methology in the historical profession. The focus is on the usefulness of the oral tradition in recording the experiences of previously "silent" segments of the population, i.e., those who left few written recods. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5914: RACE & SLAVERY IN COMPARATIVE PERSPECTIVE
Race and slave societies in the modern world. Emphasis on major themes and developments since the seventeenth century. Comparative and theoretical approaches to understanding slavery in North and South America, the Caribbean, Russia, and South Africa. Concentration on similarities and differences in the slave trade, the origins of racial slavery, and the evolution of slavery as a system of racial oppression. (3H,3C).

5934: GENDER IN U.S. HISTORY
Theoretical approaches to understanding the role of gender in political, economic and social life and in popular culture. Survey of major themes and developments since the seventeenth century. Concentration on the development of biological and sociological explanations of gender differences and similarities, and on the evolution of gendered politics and work and family relationships. Emphasis given to class, race, ethnic differences and differences in sexual orientation. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6224 (STS 6224): SCIENCE, TECHNOLOGY & THE ENLIGHTENMENT
Science, technology, and medicine and their social and cultural interrelationships in the eighteenth and early nineteenth centuries. The modern agenda; nature, knowledge, and progress. Early social science. (3H,3C).

6234 (STS 6234): ADVANCED TOPICS IN THE HISTORY OF MODERN SCIENCE, TECHNOLOGY & MEDICINE
Variable topics in history of science, technology, and medicine after 1800, such as the atomic age; space science; science, technology, and institutions; scientific and technological medicine; and environmental history. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

HORTICULTURE

J. Nowak, Head

Professors: B.L. Appleton; J.G. Latimer; J. Nowak; R.E. Veilleux; G.E. Welbaum; T.K. Wolf; R.D. Wright
Associate Professors: T.J. Banko; E.P. Beers; J.R. Harris; A.R. McDaniel; R.F. McDuffie; A.X. Niemiera; V. Shulaev; S.B. Sterrett; J.M. Williams
Assistant Professors: A.D. Bratsch; G.K. Eaton; S.J. Martino-Catt; H.L. Scoggins; J. Tokuhisa
Adjunct Faculty: J. L. Shuman

E-mail: potato@vt.edu
Web: www.hort.vt.edu/

The horticulture department offers graduate study leading to the M.S. (with thesis) and Ph.D. Emphasis may involve vegetable crops, fruit crops, floriculture, woody nursery and landscape crops. Areas of specialization include growth regulation, functional genomics, breeding and genetics, tissue culture, molecular biology, nutrition, physiology, rhizosphere management, urban horticulture, and hort therapy.

Facilities in the department include laboratories equipped for physiological, biochemical, analytical, histological, morphological, and molecular investigations; greenhouses; an urban horticulture center for research on establishment of landscape species; and a research farm with a field laboratory housing refrigerated storage rooms. Extensive computer facilities are available for data analyses and preparation of posters for presentation. Through collaboration with the Virginia Bioinformatics Institute, graduate students have access to tools for genomic analysis, including DNA microarrays and sequencing, computational genetics, and biological database systems.

Opportunities for graduates with advanced degrees in horticulture include research, teaching, and extension with state and private institutions. Positions may be available with the U.S. Department of Agriculture or other federal and state agencies. Commercial research organizations and industries engaged directly with production, processing, or distribution of horticultural commodities also offer employment opportunities for graduates.

In addition to the graduate programs in horticulture offered on the Blacksburg campus, a non-thesis graduate program is available at the Hampton Roads Agricultural Research and Extension Center (HRAREC) in the Norfolk-Virginia Beach area. Known as the off-campus master's in horticulture, the program offers a single graduate course each semester for students in one of Virginia's most populous areas. It is intended primarily for those already employed in the horticultural industry to earn a master's degree on a part-time basis. Courses are taught by faculty at HRAREC with occasional visits from on-campus faculty in particular specializations. Students will be eligible for the M.S. after satisfactorily completing 30 credit hours.

Special Degree Requirements

Incoming students should have completed an undergraduate program emphasizing courses in the plant sciences (including but not limited to plant taxonomy, plant physiology, entomology, plant pathology, and genetics), chemistry, physics, and mathematics. Individual graduate plans of study are developed by the student and the advisory committee to provide a solid foundation in horticulture as well as in one or more associated disciplines: plant physiology, plant pathology, botany, biochemistry, genetics, statistics, soil science, social science, and agricultural economics. Each program is based on the student's background, interest, and particular research problem.

Graduate Courses (HORT)

5004: SEMINAR
Formal presentation and discussion of current problems, programs, and research studies in horticulture. May be repeated. (1H,1C).

5104: INTRODUCTION TO GRADUATE STUDIES & RESEARCH
Introduction to topics and processes important during and following graduate study in a Land Grant institution. Topics include philosophy of the Land Grant institution, the scientific process, experiment station project proposals, literature reviews and library information retrieval systems, function of statistics in research, manuscript preparation, oral and poster paper presentation, peer review of manuscripts, grant proposals, and thesis and dissertation preparation. Pass/Fail only. (2H,2C).

5304: GENETICS & BREEDING OF HORTICULTURAL CROPS
Special topics in breeding and genetics, such as incompatibility, unreduced gametes, cytoplasmic male sterility, polyploidy and tissue culture, are covered, and the impact of each on breeding of horticultural crops is assessed. Laboratories involve hybridization, anther culture, embryo culture, and cytogenetics. Pre: CSES 4144. (2H,3L,3C).

5404: PLANT TISSUE CULTURE
The use of aseptic techniques for the culture and manipulation of plant cells, tissues, and organs with emphasis on developmental, physiological, and genetic applications. Pre: PPWS 3514. (2H,3L,3C).

5504: NUTRITION OF HORTICULTURAL CROPS
Principles of mineral nutrition for the production and utilization of fruits, vegetables, and ornamentals; functions of mineral nutrients, correction of deficiencies and imbalances associated with physiological disorders of usable plant parts; and interactions of mineral nutrients with environmental and cultural factors. Pre: CSES 3114, PPWS 3514. (3H,3C).

5524 (PPWS 5524): ADVANCED PLANT PHYSIOLOGY & METABOLISM I
Plant metabolism and its regulation, cell and organ structure and function. Current understanding of photosynthesis, respiration, nitrogen fixation, mineral nutrition, water and ion transport in plant cells and tissues, ecophysiology and responses of plants to the environment. Pre: Undergraduate major in Biology or related discipline. (3H,3C).

5534 (PPWS 5534): ADVANCED PLANT PHYSIOLOGY & METABOLISM II
Presentation of the current understanding of metabolic and functional relationships among primary and secondary metabolites and storage products and their impact on the whole plant. Biosynthesis of phytohormones. Mechanisms controlling responses to phytohormones including: impact on carbon/nitrogen partitioning, senescence, development of higher plant structures such as vascular tissue and flowers. Pre: Undergraduate major in Biology or related discipline. (3H,3C).

5604: PHYSIOL CROP PLANTS
Growth and phasic development of crop plants. Emphasis on cellular and metabolic aspects of germination, organ formation, flowering, fruiting, senescence, and the role of environment and bioactive substances. Consent required. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: ADVANCED TOPICS IN HORTICULTURE
In–depth presentations and discussions in a specific area of advanced horticulture. Topics will vary, and course may be taken for credit more than once. Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (HORT)

The following 4000–level course has been approved for graduate credit:

4545–4546: SMALL SCALE & RESIDENTIAL LANDSCAPE DESIGN
Development of graphic skills with concentration on a variety of media and techniques. Basic theory and principles on design of small scale and residential landscapes with emphasis on spatial composition, user needs, ecology, and uses of plant materials and light construction. Pre: 3325, 3544. (2H,6L,4C).

HOSPITALITY & TOURISM MANAGEMENT

James R. Lang, Head

Professors: M.A. Khan; K.W. McCleary; B.J. Mihalik; S.K. Murrmann; M.D. Olsen; M. Uysal; P.A. Weaver
Assistant Professors: N.G. McGehee
Instructors: P. Couture
Lecturers: H. Feiertag; J.E. Sexton
Adjunct Faculty: P.W. Kipp; J.D. McAlister; C.A. Reed; E. Tse

E-mail: htmdept@vt.edu
Web: www.cob.vt.edu/htm

The Hospitality and Tourism Management Department is one of six departments within the Pamplin College of Business. Its graduate programs leading to the M.S. (thesis and non–thesis) and Ph.D. are offered on the Blacksburg campus. An M.B.A. concentration in Hospitality and Tourism Management is offered at the Northern Virginia Center, which is located in the Washington, D.C. metropolitan area. Degree candidates and their advisory committees plan individual graduate programs pursuant to the students' career goals and degree requirements. The Ph.D. degree is a research–oriented degree with plans of study built around a nucleus of courses in research methodology, statistics, and theory development. They are supported by courses in hospitality and tourism management, as well as those from other business and social science disciplines. It is possible to specialize in areas such as finance, franchising, hotel and food service operations, human resources, marketing, strategy, and tourism. Research work is undertaken selecting a specific topic in the hospitality and tourism management area.

The graduate program offered by the department is recognized by our peers as one of the premier programs of its kind in the nation. Graduates are prepared for challenging careers in teaching, research, and/or work in the hospitality and tourism industries.

One of the most important dimensions of the graduate program is its focus on a variety of disciplines in the hospitality and tourism arena. The department provides extensive opportunities for graduate students and faculty to do research on significant industry problems.

GRADUATE COURSES (HTM)

5024: INTERNATIONAL SERVICE MANAGEMENT
Overview of the contemporary issues in the international business environment facing multinational service firms in the hospitality industry. These issues include such topics as: global strategy formulation and implementation; technology challenges; diversity in customers and employees; political and legal concerns; and effective organizational structures for long term survival. (3H,3C).

5414: CHAIN MANAGEMENT IN THE HOSPITALITY INDUSTRIES
The organization, administration and evaluation of existing and changing practices, concepts and theories in chain management in the hospitality industries. Pre: 5424, 5444, 5514, 5534. (3H,3C).

5424: HUMAN RESOURCE MANAGEMENT
This course focuses upon the attainment and retainment of employees within the hospitality industry. Topics include the processes, practices and legal considerations involved in the employment of people in hospitality organizations. Pre: MGT 3334. (3H,3C).

5444: FINANCIAL MANAGEMENT IN THE HOSPITALITY SERVICE INDUSTRIES
Fundamentals of financial management as applied to hotel, restaurants, institutions and similar service organizations. Pre: FIN 3104. (3H,3C).

5454: HOSPITALITY & TOURISM MARKETING STRATEGY & POLICY
Examination of the role of marketing within the strategic planning of hospitality service organizations. Pre: MKTG 3104. (3H,3C).

5464: FRANCHISING IN HOSPITALITY MANAGEMENT
Role of franchising in hospitality management. Contemporary issues related to franchising in different segments of hospitality industry, including franchise concept development, franchisor–franchisee relationship, franchise agreements, operational problems, and international franchising. (3H,3C).

5514: CONTEMPORARY PROBLEMS IN THE HOSPITALITY INDUSTRY
Consideration and analysis of relevant industry problems and issues facing management personnel in the hospitality industries. Computer literacy required. (3H,3C).

5534: STRATEGIC MANAGEMENT & COMPETITIVE STRATEGY IN THE HOSPITALITY INDUSTRIES
To enable students to develop a comprehensive understanding of the concepts of strategic management and competitive strategy as applied to the hospitality industries. Pre: 4534. (3H,3C).

5544: RESEARCH METHODS FOR HOSPITALITY APPLICATIONS
The use of business research methods in the scientific investigation of hospitality related problems. The foundations of research, research design, data collection techniques, sampling issues, statistical techniques and the analysis and reporting of data will be studied. Pre: STAT 5634. (3H,3C).

5614: CURRENT ISSUES IN TRAVEL & TOURISM MANAGEMENT
Current issues in the management of travel and tourism services. Environmental trends, planning and development, policy formulation, social and economic impact, and marketing of travel and tourism. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: GRADUATE SEMINAR
Presentation and critical discussion of current literature and major topics in hospitality and tourism management. The seminar provides a forum for the discussion of research and research problems in hospitality and tourism management and the presentation of research by graduate students. Provides students an opportunity to prepare and present current work related to their thesis and dissertation activities. May be repeated. (1H,1C).

5964: FIELD STUDY
Variable credit course. X–grade allowed.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6414: CONCEPT OF SERVICE IN THE HOSPITALITY SERVICE INDUSTRIES
Seminar in the concept of service and its management. Pre: 5514. (3H,3C).

6424: HUMAN RESOURCES MANAGEMENT IN THE SERVICE INDUSTRY
Examination of research and writings in the area of human resources management in service industries. Issues and opportunities in human resources management distinctive to hospitality service organizations. Pre: 5424 or MGT 5704. (3H,3C).

6434: THEORY DEVELOPMENT FOR HOSPITALITY & SERVICE MANAGEMENT
Seminar in theory construction in the areas of hospitality, tourism and service. Emphasis on the identification of relevant interdisciplinary paradigms and theory and the evaluation of social science research. Six graduate credits of hospitality and tourism courses required. Alternate years. (3H,3C).

6444: ADVANCED QUANTITATIVE METHODS FOR HOSPITALITY APPLICATIONS
Methodologies and techniques for analysis, reporting, and critiquing hospitality issues using advanced concepts and quantitative methods in the scientific investigation of problems related to hospitality. Pre: STAT 6634. (3H,3C).

6454: HOSPITALITY MARKETING RESEARCH PROBLEMS
Research designs and methodologies for the solution of hospitality industry marketing problems. Analysis and interpretation of marketing research studies. Pre: 5454 and STAT 5634. (3H,3C).

6534: ADVANCED SEMINAR IN STRATEGIC MANAGEMENT IN THE HOSPITALITY INDUSTRY
This seminar is designed to provide an in–depth exploration of the literature and research which has been developing in the context of the hospitality and tourism industry, specifically as it applies to the hotel, restaurant and tourism sectors. Specific methodological approaches encountered in an industry–specific environment will be identified and evaluated. The current state of theory development will be assessed and key issues relevant to further theory building will be explored. The course will be in a seminar format where students will be expected to develop a comprehensive and in–depth understanding of the body of knowledge relative to strategy in the hospitality and tourism industry. Must have the prerequisite or equivalent. Pre: 5534. (4H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSE (HTM)

The following 4000–level course has been approved for graduate credit:

4424: EVENTS MANAGEMENT
Management of special events in the hospitality and tourism industry. Students will explore organizational functions necessary for producing special events, as well as analyzing the factors that influence an event's success, such as organizational structure, risk management and the impact of tourism activity. Junior standing in HTM is required. (3H,3C).

4534: HOSPITALITY MANAGEMENT POLICY
Integrates business principles and practices related to hospitality management. Cases involving hospitality industry organizations are analyzed extensively. Senior standing required. Pre: 3444, 3524. Co: 4414, 4454, 4464. (3H,3C)..

HUMAN–COMPUTER INTERACTION

F. Quek, Director

Professors: W. Barfield; J. K. Burton; J. B. Campbell; H. J. Crawford; R. W. Ehrich; E. A. Fox; H. R. Hartson; J. T. Head; P. K. Shires; W. E. Snizek; W. Tranter; T. M. Wildman; R. C. Williges; R. A. Winett
Associate Professors: M. Abrams; R. J. Beaton; G. L. Downey; J. M. de la Garza; V. Hardcastle; N. M. A. Hauenstein; B. R. Hertel; B. M. Kleiner; R. D. Kriz; J. H. McLain Kark; G. McMillan; J. F. Moore; A. M. Prestrude; M. Sanders; R. S. Schulman; C. A. Shaffer; E. E. Wiedegreen
Assistant Professors: D. Bowman; J.M. Dubinsky; S. Edwards; D. Hix; D.S. McCrickard; C.L. North; S. M. Nussbaum; M.A. Pérez-Quiñones; S. D. Sheetz; D. P. Tegarden

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Human–Computer Interaction (HCI) is the region of intersection between the social and behavioral sciences, on the one hand, and information technology, on the other. It provides a challenging test domain for applying and developing social theory, and a stringent source of constraint for creating and evaluating new information systems. HCI researchers analyze and design specific user interface technologies (e.g., for real-time collaboration over networks). They study and improve the cognitive and organizational processes of technology development (e.g., task analysis, design rationale). They integrate and evaluate new applications of technology in human activities (e.g., distance learning, data visualization in virtual environments). They increase the chance that new information technology can actually be used by people for real purposes.

The Center for Human–Computer Interaction is the central organizational unit for human–computer interaction research, instruction, and outreach within Virginia Tech. The center seeks to leverage and integrate diverse HCI activities throughout the university. It is a member of the Human–Computer Interaction Consortium, the international organization of leading academic and industrial centers.

The potential for interdisciplinary graduate study in human–computer interaction is demonstrated by the variety of instructional programs represented by participating faculty: Accounting and Information Systems, Teaching and Learning, Philosophy, Veterinary Medicine, Psychology, Engineering Science and Mechanics, Sociology, Communication Studies, the Center for Interdisciplinary Studies, Computer Science, Industrial and Systems Engineering, Civil and Environmental Engineering, and Near Environments (Interior Design). Faculty associated with the Center for Human–Computer Interaction are involved with basic and applied projects in such areas as multimedia information systems, digital libraries, visualization of scientific data and processes, virtual environments, input and output devices, electronic conferencing, instructional technology, computer-supported cooperative work, community computing, user interface design, scenario-based design, usability evaluation methods and tools, design rationale, and task analytic notations.

Graduate students with a concentration in human–computer interaction have many opportunities for participation in activities outside the classroom that can complement their course work, enhance their professional development, and provide direct experience in applied settings. Students are encouraged to participate in human–computer interaction research being conducted by participating faculty members. Involvement in such projects can lead to direct research experience and, in some cases, provide financial assistance, course credit, and thesis or dissertation topics. The Center for Human–Computer Interaction sponsors a seminar series involving presentation by noted authorities on human–computer interaction from both inside and outside Virginia Tech. Students also may participate in cooperative education and intern programs to carry out field studies and develop industrial experience.

A Graduate Certificate in Human–Computer Interaction Program is administered by the Center for Human–Computer Interaction and offered in conjunction with either a master's or doctoral degree in most departments.

Graduate Certificate Requirements

Master's students complete 9 hours and doctoral students 15 hours of course work for the certificate. At least two of the courses taken must be outside the student's degree program requirements and home department. If the student writes a thesis or dissertation, it must be related to human–computer interaction. Students can normally fit the requirements for the certificate into their program of graduate study so that the time needed to complete the graduate degree in their basic discipline is not extended by simultaneously pursuing the certificate. Students interested in the Graduate Certificate in Human–Computer Interaction should confer with the director of the Center for Human–Computer Interaction prior to submitting a program of study to the Graduate School.

Graduate Courses

The following graduate courses (3H, 3C, unless noted otherwise) are offered through participating departments. For descriptions, see respective departments.

CEE 5064: Knowledge-Based Expert Systems
CS 4624: Multimedia, Hypertext, Information Access
CS/ISE 5714: Usability Engineering
CS 5724: Models And Theories of Human-Computer Interaction
CS 5734: Computer-Supported Cooperative Work
CS 6724: Advanced Topics in Human-Computer Interaction
EDCI 6664: Advanced Instructional Technology
ESM 4714: Visual Data Analysis and Multimedia
ISE 5604: Human Information Processing
ISE 5605: Human Factors Systems Design I
ISE 5694: Macroergonomics
ISE 6604: Human Factors of Visual Display Systems
ISE 6614: Human Computer Systems
PSYC 5354: Information Processing
STS 5424: Computers in Society

HUMAN DEVELOPMENT

Fred P. Piercy, Department Head

Professors: K.R. Allen; R. Blieszner; M. Boucouvalas; V.R. Fu; J.A. Mancini; E. McCollum; P.S. Meszaros; F.P. Piercy; K. Roberto; S.M. Stith
Associate Professors: J.A. Arditti; M.J. Benson; G.W. Bird; S.W. Johnson; K.H. Rosen; A.J. Stremmel; A. Wiswell
Assistant Professors: A.L. Few; T.L. Henderson; A.J. Huebner; S.E. Jarrott; M. Keeling; K.J. Kim; M. Dolbin-MacNab; C. Smith; M.L. Stevenson
Instructors: A. Galway; M.E. Verdu
Adjunct Faculty: C. Davis; J.E. Garrison, Jr.; R.F. Verthelyi
Research Scientist: I. Bradburn

E-mail: HDD@vt.edu
Web: http://www.humandevelopment.vt.edu

Graduate Programs in the Department of Human Development, College of Human Sciences and Education, provide thorough preparation in the research and theory of human development. The Human Development Master's Program is offered at the Blacksburg campus. The program aims to prepare graduates to assume positions of leadership in a variety of human development organizations addressing the needs of children, adults, and families. The emphasis of the program is on the application of theory and research to authentic issues and programs in human development organizations. The applied orientation is evident throughout the core classes. In each course, students develop components that contribute to the Professional Portfolio. Besides the portfolio projects, students have opportunites for developing specialized expertise through the concentrations. There are over 20 concentrations in the program including adoption, foster care, domestic violence, families and sexuality, social support and aging, aging and health, arts and human development, transitional living, and many more. For each concentration, there is a Faculty Sponsor with expertise in the concentration area. Students meet periodically with faculty sponsors to learn more about the common area of interest. The internship provides another opportunity for individualizing with approximately a 3–4 month placement in an organization or agency. Through efficient scheduling and integrated curriculum design, students are able to complete the 30–credit program in one academic year, followed by an internship which includes a presentation at the *HD Master's Symposium and Poster Presentation* in the fall. For more information, visit the HD Master's Program website at: http://www.chre.vt.edu/HD/appliedmastersmain.htm.

Both the M.S. and Ph.D. programs in marriage and family therapy are fully accredited by the Commission on Accreditation for Marriage and Family Therapy Education of the American Association for Marriage and Family Therapy. The intent of the M.S. and Ph.D. programs is to train competent marital and family therapists who are well grounded theoretically and clinically. It is also the intent of the Ph.D. program to train marital and family therapists who are competent to teach and conduct research. A diversity of clinical practicum placements is available with each program. The department operates its own marriage and family therapy centers, staffed by graduate students and supervised by the clinical faculty. These centers provide opportunities for research and clinical training. Additional practicum experience is provided through relationships with medical centers and community service agencies. The M.S. in marriage and family therapy is available only at the Northern Virginia Graduate Center in Falls Church, Virginia, and the Ph.D. in marriage and family therapy is available only on the Blacksburg campus. A postmaster's certificate in marriage and family therapy is available at both Blacksburg and Falls Church.

The adult learning and human resource development program option offers the M.S. and Ph.D. for persons working with adult learners in such settings as business and industry, government, military, health care, education, nonprofit organizations, and professional associations. Concentrations are offered in human resource development and training, organizational development, international adult education, and continuing higher and professional education. The program faculty are based at the Virginia Tech Northern Virginia Center in Falls Church. With the exception of intact programs offered at other locations, all courses are offered at the Northern Virginia Center and doctoral residency requirements must be met at that site.

The Ph.D. program in adult development and aging prepares professionals for participation in academic, research, governmental, and private organizations. Students complete coursework that includes developmental theories, developmental research methods, public policy, social and psychological development, health, and advanced statistical analysis. Students have opportunities to participate in faculty research projects involving a variety of gerontological issues, such as family and friend relationships, spirituality, therapeutic interventions, health care and service delivery, intergenerational programming, community capacity, informal and formal support, employee retention in long-term care, and adaption to chronic illness. The department sponsors an Adult Day Services program that provides educational and research opportunities. The university's Center for Gerontology coordinates a Graduate Certificate in Gerontology that may be included as part of any graduate program at Virginia Tech.

The M.S. and Ph.D. programs in child development are designed to foster acquisition of knowledge and research skills essential to scientific exploration of both the content and processes of development. Multiple theoretical viewpoints are represented in the study of child development from the prenatal through the adolescent phases. Graduate programs of study are individually designed to permit students to concentrate in any preferred area of specialization, including early childhood education. Teaching and research experiences are facilitated by the laboratory school operated by the department, including infant, toddler, and three- and four-year-old groups. Students are encouraged to participate in the on-going research of faculty, especially in the areas of infancy, creativity, cognition, middle childhood, and adolescence.

The Ph.D. program in family studies provides a systematic approach to observing, understanding, and analyzing close relationships and families within diverse sociohistorical, political, and economic contexts. This program leads to a research and teaching degree designed to prepare students for college teaching or agency administration. Programs of study are individualized, permitting inclusion of

significant course work in child development, gerontology, or other subjects within the human life span. Students may participate in wide–ranging faculty research efforts dealing with intimate relationships, sex–roles, parenthood, family disorganization, families and technologies, and the middle and later years.

The department provides research and practicum opportunities through Adult Day Services, Family Therapy Center, and the Child Development Laboratory. These opportunities are also available through the Virginia Tech Center for Gerontology, the College Center for Information Technology Impacts on Children, Youth, and Families, and the Virginia Tech Office of Family Support. The university offers several types of assistance with research costs, for which students may apply on a competitive basis. Deadline for applications is January 2; Human Development Master's students may also apply for late admission by April 15. Students are accepted only once a year for Fall enrollment.

Students applying for assistantships/fee waivers must have applications completed by January 2.

All programs require Graduate Record Examination (GRE) scores prior to entrance. These scores, as well as letters of recommendation and grades, are considered in the admission process. A supplementary application form, which provides information on the applicant's experience and goals, is also required and may be obtained on–line. At the time of application, students must indicate the program for which admission is sought. For more information, see our department website at http://www.chse.vt.edu/HD/hd.html.

GRADUATE COURSES (ALHR)

5504: FOUNDATIONS OF ADULT LIFELONG LEARNING
Systematic review of organization and structure of adult learning systems in the United States, with particular attention to emerging paradigms for the education of adults, program coordination, participation patterns of adults, historical antecedents, and philosophical issues. (3H,3C).

5514: ADULT LEARNING
Study of the unique nature of adult learners, including motivation in adult learning processes and learning how to learn. Emphasis on understanding adulthood, adult development, and the maturation process and the relevance to learning of physiological/neurological, sociological, anthropological, and psychological factors. (3H,3C).

5524: THE PROGRAMMING PROCESS IN ADULT LEARNING
Models and procedures for developing, administering, and evaluating adult learning programs. Emphasis is on application of needs assessment models, implementation procedures, and evaluation approaches to various adult learning settings and clients. Conceptual programming models are examined as the basis for critical inquiry and improved professional practice. (3H,3C).

5534: DESIGNING & CONDUCTING ADULT LEARNING EXPERIENCES
Models and principles for designing, developing, conducting, and assessing adult learning experiences, with application to the various organizational and community contexts in which adult learning is promoted. Pre: 5514. (3H,3C).

5544: SMALL GROUPS IN ADULT LEARNING
An overview of the theory and practice of small groups in adult learning settings; growth and development of small learning and task groups; group processes, leadership styles, and educational conditions that enhance learning in groups. (3H,3C).

5554: THE PRACTICE & PROFESSION OF HUMAN RESOURCE DEVELOPMENT
Human resource development (HRD) is concerned with adult learning and change in work organizations. The types of organizations, programs, and issues that relate to HRD will be covered, as well as the roles and competencies of the HRD professional. Pre: 5504. (3H,3C).

5564: EDUCATIONAL GERONTOLOGY
Education of the aged as a special population and education of adults for and about aging, including development of educational programs. Examination of the myths and current research on learning capacity and ability in the gerontological years. Societal changes toward, in support for, educational gerontology studied in an historical context. Financing, federal policy, media interest, and trends in education for and about older adults. Pre: 5514. (3H,3C).

6804: THE HISTORY OF AMERICAN ADULT EDUCATION
Study of the development of adult education in the United States. Emphasis on institutional forms, social function, changing conceptions, and foreign influences. Pre: 5504. (3H,3C).

6814: CONSULTING WITH HUMAN SYSTEMS
Examinations and application of theory and procedures of consultation; roles of the consultant and consultee; consultant's role in the social change process. Pre: 5544. (3H,3C).

GRADUATE COURSES (HD)

5104: ADULT DEVELOPMENT & AGING I: INDIVIDUAL DEVELOPMENT
Introduction to theories and methods used to study adult development and aging. Provides students with a thorough grounding in the scholarly literature in regard to the demographic, biological, functional, psychological, and social aspects of aging with a specific focus on individual development. (3H,3C).

5114: ADULT DEVELOPMENT & AGING II: INTERPERSONAL ISSUES
Interpersonal and social development across the adult phases of the life cycle. Integration of theory and research as it pertains to family and friend networks, living arrangements, diverse family forms, and critical life events such as widowhood. Pre: 5104. (3H,3C).

5124: SOCIAL POLICY & AGING
This course reviews major issues and trends in social policies related to aging. The course emphasizes health, economic, and welfare policies for older individuals and their families, and considers their implications on federal, state, and local levels. Special consideration is given to dynamics that shape past, current, and future policy in the area of aging. Pre: 5104. (3H,3C).

5134: CONTEMPORARY ISSUES IN AGING
Seminar that examines literature and research on selected issues in gerontology, such as long–term care, work and retirement, older women, demographic variations of the aging experience, grant writing, intergenerational programs, administration of community–based services, and adult education programs. (3H,3C).

5144: SEMINAR IN GERONTOLOGY
Introduction to a wide variety of research, policy, and professional issues in gerontology, and programs and services for the aged. Pass/Fail only. (1H,1C).

5214: THEORETICAL FOUNDATIONS OF CHILD DEVELOPMENT
Selected theories related to child development. (3H,3C).

5224: SOCIAL & EMOTIONAL DEVELOPMENT IN CHILDREN
Review of research related to social and emotional development of the child from birth through middle childhood. Pre: 5214. (3H,3C).

5234: COGNITIVE DEVELOPMENT: INFANCY THROUGH ADOLESCENCE
In–depth study of developmental research and theoretical approaches to cognitive development. Pre: 5214. (3H,3C).

5244: DEVELOPMENTAL TRANSITIONS AND ADAPTATION
A developmental perspective will be used in examining adaptive and maladaptive patterns of person–experience transactions during major periods of developmental organization and transition. Strategies for the promotion of successful adaptation, and for the prevention of and intervention in maladaptation will be explored. (3H,3C).

5314: DEVELOPMENT OF MARRIAGE & FAMILY RESEARCH & THEORY
Development of research and theory in representative areas of study of marriage and the family. (3H,3C).

5324: MARRIAGE & FAMILY RELATIONSHIPS
An introduction to the literature in family studies with emphasis on integration of concepts and current developments in the field. (3H,3C).

5334: THEORIES IN MARRIAGE & THE FAMILY
Overview of theory construction; in–depth study of various theories of family development and interaction; application of theoretical frameworks to research and analysis of the family; and consideration of the explanatory value of theory when examining the relationship of the family to the larger society. Pre: 5314 or 5324. (3H,3C).

5344: PERSPECTIVES ON HUMAN SEXUALITY
Interdisciplinary historical consideration of writings, research, theory, and application of knowledge related to human sexuality. (3H,3C).

5404: SYSTEMS THEORY AND FAMILY THERAPY
Theory development and basic underlying assumptions of a systems framework to marriage and family therapy. Emphasis is on conceptualizing human problems as they are related to the functioning of systems. (3H,3C).

5414: FAMILY STRESS & CRISIS INTERVENTION
Review of strategies for intervening in crisis situations along with examination of the operation of stress and stress–producing experiences in individuals and families. (3H,3C).

5424: LIFE SPAN DEVELOPMENT
Stages of individual development as they occur in the context of the family life course. Overview of current developmental theories. Impact of race, gender, and class on cultural views of developmental norms. (3H,3C).

5434: CLINICAL MARRIAGE AND FAMILY THERAPY I
Underlying philosophy, theory, and practice of the Structural and Strategic approaches to marital and family therapy. Pre: HD 5404. (3H,3C).

5444: CLINICAL MARRIAGE AND FAMILY THERAPY II
This course comprises of three distinct parts. The first part examines the approaches to family therapy that have been labeled "Constructivist Approaches". The second part examines Emotionally Focused Therapy. The final part involves an in–dept look at the Metaframeworks Model developed at the Institute for Juvenile Research in Chicago, which integrates various schools of marriage and family therapy. Pre: 5404. (3H,3C).

5454: CLINICAL MARRIAGE AND FAMILY THERAPY III
Emphasis is on interrelationships between mind, body, environment, and social aspects of behavior in the context of the family system. The focus will be on the process of disgnosis and treatment in the family context. Pre: 5404, 5434, 5444. (3H,3C).

5464 (EDCI 5464): ADOLESCENT DEVELOPMENT
Advanced study of the physical, cognitive, social and emotional development of the adolescent, with emphasis on theoretical issues, research findings, and application of theory and research. Implications for education are highlighted. (3H,3C).

5474: PROFESSIONAL SEMINAR IN MARRIAGE AND FAMILY THERAPY
Focuses on the major ethical, legal, and professional issues faced by those in the new field of marriage and family therapy. Offered at National Capital Region campus only. (3H,3C).

5484: CLINICAL MARRIAGE & FAMILY THERAPY IV
Issues of treatment related to specialized content areas of family therapy. Focus on topics such as: sexual dysfunction, divorce counseling and mediation, the abusive/violent family, addicted family members, suicidal problems, ethical and professional issues in treating marriages and families. Offered at National Capital Region campus only. Pre: 5434, 5444. (3H,3C).

5514: RESEARCH METHODS
Introductory course in research methodology for the social sciences: formulation of a research problem, design, sampling, data collection, measurement, data analysis, interpretation, and writing the research report. (3H,3C).

5614: HUMAN DEVELOPMENT THEORY: LITERATURE AND APPLICATIONS
Introduction to major theories of human development and application of these theories to understanding and improving the well being of children, adults, couples, and families within complex social systems. Portfolio project: Preparation of a theoretically driven literature review. (3H,3C).

5624: PROFESSIONAL PRACTICES IN HUMAN DEVELOPMENT
Interdisciplinary approaches to professional practices in the delivery of human services. Emphasis on human service delivery to families and communities, management practices and professional development. Portfolio project: Professional management and leadership assessment. (3H,3C).

5634: LEGISLATION AND POLICY IN HUMAN DEVELOPMENT
This course provides a context for students to consider in–depth connections between government, policy, and individuals and families throughout the life course. Emphasis is placed on learning through individual study, analysis, and reflection. Students will engage in an advanced exploration of substantive and theoretical issues that relate to the development and implementation of human development policies affecting children, adults, couples, and systems. Portfolio project: Policy analysis paper based on a specific topic, position papers on policy topics. Pre: 5614, 5624, EDRE 5404. (3H,3C).

5644: PROGRAM DEVELOPMENT AND EVALUATION IN HUMAN DEVELOPMENT
Principles of development, implementation, and sustainability of programs for children, youth, adults, and families, and methodologies used to evaluate program effectiveness. Portfolio project: Program development and program evaluation. Pre: 5614, 5624, EDRE 5404. (3H,3C).

5654: GRANT DEVELOPMENT AND ADMINISTRATION IN HUMAN DEVELOPMENT
Overview of the methods and procedures for developing competitive grant proposals. Students learn basic grant writing skills that include identifying and seeking funding sources, preparing a fundable grant proposal, building a budget, and managing a funded project. Portfolio project: Development of actual grant proposal for an organization or special project. Pre: 5614, 5624, EDRE 5404. (3H,3C).

5664: INTERNSHIP IN HUMAN DEVELOPMENT
Provides consultation and seminar dialogue for advanced master's student in Human Development as they undertake experiences in a supervised field setting. Possible settings span an array of human development agencies focused on children, adults, and families. Experiences include activities of a regularly employed professional in the setting accompanied by periodic seminar meetings. Variable credit course. Pre: 5634, 5644, 5654, EDRE 5404.

5724: COUPLES THERAPY
Overview of the conceptual, clinical, and empirical advances in couples therapy. Focus of course will be on using current research on couple interaction and evidence–based marital therapy to assess and treat couples. Pre: 5404. (3H,3C).

5734: MFT TECHNIQUES
This course introduces the student ot the requisite skills for beginning practicum. Students will examine the role of theory in practice, the differences between process and content, the use of process in clinical work, and the impact of gender, ethnicity, and therapist's self perception on the therapy process. The course will also review "nuts and bolts" of therapy (i.e., writing appropriate clinical notes, identifying risk issues, etc.). Admission to the MFT Clinical Program is required. Pre: 5404, 5434. (3H,3C).

5744: SPECIAL TOPICS IN MFT
In–depth study of selected topics in marriage and family therapy (e.g., medical family therapy, play therapy, spirituality and family therapy). Focus of course will be on reviewing current research on the specific issue and developing treatment strategies for individuals, couples, and families. May be repeated for credit with different content for a maximum of 9 credit hours. For Northern Virginia Students only. Variable credit course. Pre: 5404.

5754: INTERNSHIP
Variable credit course. May be repeated.

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5964: PRACTICUM
Practicum experiences in departmental options under supervision. (Maximum 15 percent of student's graduate program). Variable credit course. X–grade allowed.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X–grade allowed.

5994: RESEARCH & THESIS
Variable credit course.

6004: PROFESSIONAL DEVELOPMENT SEMINAR
Review and critique of professional issues in the field of human development related to research and scholarship, pedagogy, outreach, and service. May be repeated. Pass/Fail only. (1H,1C).

6014: THEORY DEVELOPMENT
Principles of inquiry and idea generation in human development sciences. Examination of world views and their contexts, scientific revolutions and human development theories, principles of life span and life course models, principles of human systems, theory construction models, and characteristics and critiques of theory development approaches. Graduate standing required. (1H,1C).

6114: THEORY AND RESEARCH IN AGING
Advanced course in gerontology. Review and critique of theoretical constructs and their research applications. Principles of theory construction. Appropriate research designs and procedures for studying development in adulthood and old age. Pre: 5104, 5114. (3H,3C).

6124: THERAPEUTIC STRATEGIES FOR OLDER ADULTS
Review of the theoretical basis for clinical strategies and application of strategies to older adults and their families. For both therapy and non–therapy students. Pre: 5114, 6404. (3H,3C).

6214: PARENT–CHILD INTERACTION
Review of theories and research in parent–child interaction from birth through adolescence and exploration of practical application in various settings. (3H,3C).

6234: DEVELOPMENTAL PERSPECTIVES ON CHILD THERAPY
Examination of crucial issues related to the diagnosis and treatment of children with various developmental and adaptation problems. (3H,3C).

6314: SEMINAR IN FAMILY STUDIES
Introduction to literature and research in selected areas of family studies. (1H,1C).

6324: PROCESS IN RELATIONSHIPS
Advanced course on process in adult relationships with focus on properties, types, diversity, development, and maintenance of close relationships between adults. Pre: 5324. (3H,3C).

6404: ADVANCED SYSTEMS THEORY & FAMILY THERAPY
Advanced investigation of the development and conceptual basis of systems theory with application to marriage and family therapy. (3H,3C).

6414: ADVANCED TRADITIONAL MODELS IN MARRIAGE & FAMILY THERAPY
Advanced study and application of Systemic, Bowenian, and Narrative family therapy models within the profession of marriage and family therapy. Prior training in general systems theory, family therapy theories, and therapeutic experiences in family therapy required. (3H,3C).

6424: ADVANCED EXPERIENTIAL MODELS IN MARRIAGE & FAMILY THERAPY
Underlying theory and practice of couple and family therapy from experiential therapy models. Pre: 6404, 6414. (3H,3C).

6434: ADVANCED DIAGNOSIS AND ASSESSMENT
Comprehensive and advanced study of psychopathology and its assessment and diagnosis from a relational context. The traditional diagnosis of mental disorders are stated in the context of interactional systems, gender, race, and cultures. (3H,3C).

6444: ADVANCED CONTEMPORARY MARRIAGE & FAMILY THERAPY
Advanced study of the profession of marriage and family therapy. This course will rotate topics and cover two advanced practice areas such as feminist therapy, sex therapy, or therapy with families with substance abuse or violence. Pre: 6404, 6414, 6424. (3H,3C).

6454: ASSESSMENT TECHNIQUES IN MARRIAGE & FAMILY THERAPY
Investigation of the various types of assessment techniques and devices useful in marital and family therapy and related research. Six graduate credits of FCD required. (3H,3C).

6464: CLINICAL SUPERVISION OF MARRIAGE & FAMILY THERAPY
Underlying philosophy, theory, and principles of the process of supervising the practice of marriage and family therapy. Pre: 6404, 6414, 6424. (3H,3C).

6474: ADVANCED PROFESSIONAL SEMINAR IN MARRIAGE & FAMILY THERAPY
Advanced understanding of the major ethical, legal, and professional issues faced by those in the field of marriage and family therapy. (3H,3C).

6484: MARRIAGE & FAMILY THERAPY RESEARCH
Comprehensive overview of the major empirical research of marriage and family therapy. Prior training in family therapy theories and therapeutic processes required. A basic knowledge of quantitative and qualitative research methods required. (3H,3C).

6514: ADVANCED RESEARCH METHODS
Advanced level research methodology; examination of current procedures for studying individual development and family relationships. Pre: 5514. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (HD)

The following 4000–level courses have been approved for graduate credit:

4114: COMMUNITY BASED SERVICES FOR OLDER ADULTS
Introduces students to the health and human services programs that comprise the community–based long term care system. Topics include an overview of the continuum of community programs and services for older adults, methods to determine service eligibility, and procedures for maintaining quality assurance. Prerequisite or graduate standing is required. Pre: 3004. (3H,3C).

4214: CURRICULUM AND PROGRAM PLANNING IN CHILD DEVELOPMENT
Supervised experience in planning and implementing a learning environment conducive to meeting the developmental needs and interests of young children. Emphasis on exploration of means and materials suitable for creative expression. X–grade allowed. Pre: 1004, 3204. (3H,6L,5C).

4324: FAMILIES AND CHILDREN UNDER STRESS
An investigation of the crises and stresses experienced by families and their members, and their attempts to cope with them. (3H,3C).

4344: COMMUNITY PROGRAMS IN FAMILY LIFE
Issues related to formulation, delivery, and evaluation of family life education programs are included. Gain skills in conducting needs assessments and evaluating programs. Pre: 2335. (3H,3C).

4354: FAMILY, LAW, AND PUBLIC POLICY
Theoretical and substantive issues that relate to the development and implementation of family policies. Implications of political culture and family legislation for the well–being of children and their families. Pre: 2335, 3324. (3H,3C).

HUMAN NUTRITION, FOODS, & EXERCISE

Michael E. Houston, Head

Professors: R.H. Cox; W.G. Herbert; M.E. Houston; J.W. Rankin; E. Scheinker; J. H. Williams
Associate Professors: W.E. Barbeau; F.D. Conforti; K. P. Davy; K. Hosig; S.M. Nickols–Richardson; F.W. Thye
Assistant Professors: J. Bassagangi–Riera; B. Davy; R.W. Grange; Y. Ju; D. Liu; L. Niba; E. Serrano
Instructors: C.M. McIntyre; C.B. Papillon
Adjunct Professors: F. Anderson; H. Cox; L. Davis; J. Gregg; J. Neely; D. Zedalis
Post-Doctoral Fellow: R. Hontecillas–Magarzo

E-mail: houstonm@vt.edu
Web: http://www.hnfe.vt.edu

The department offers graduate programs leading to the M.S. and Ph.D. Students may specialize in one of the following areas: foods, nutrition, international foods and nutrition, or exercise physiology. Academic course work and research experiences are designed to meet the needs and career objectives of each student. Programs of study are built around a nucleus of courses taken within the department supported by work in the biological, physical, or social sciences, education or business. The department's research program is varied in scope and includes laboratory, community, clinical, and international experiences.

Within the department are laboratories and instrumentation for food analysis, biochemical evaluation of nutritional status, study of nutrient function utilizing molecular technology, analysis of muscle function and exercise testing. Facilities are available for sensory evaluation of foods, human metabolic studies, and animal and cell culture work. The college offers access to a computer laboratory for word processing, dietary analysis, and statistical evaluation.

CLINICAL EXERCISE PHYSIOLOGY: This option provides training in fitness testing, activity program leadership, health promotion, as well as "hands on" experience with the Therapeutic Exercise and Community Health Center. Individuals with undergraduate training in biology, nutrition, psychology, physical education or health education are well prepared to undertake study in this field. Prior clinical experiences in nursing, respiratory therapy, or physical therapy are also advantageous. Professional positions are available in adult fitness and wellness programs, corporate wellness, and rehabilitative programs for cardiopulmonary patients.

FOODS: Coursework and research in this area focus on various aspects of the chemical, sensory, nutritional, and functional quality of food and food ingredients. Specific research areas include lipids, proteins, complex carbohydrates and functional foods. Graduates in this option assume upper level positions in food product research and development in the food industry and food and commodity trade organizations, food consumer education in extension, government agencies, the food industry and food organizations, as well as academic and institutional positions in teaching and research.

HUMAN INTEGRATIVE PHYSIOLOGY: This option prepares students for careers in biomedical science with a primary emphasis in human integrative physiology. Students will receive training in conducting interdisciplinary research which focuses on understanding the mechanisms and consequences of the physiological and metabolic alterations that occur with aging, obesity and/or related cardiovascular and metabolic diseases. The role of physical activity and nutrition in the prevention and treatment of these adverse changes is emphasized. Coursework is designed to build a strong foundation in physiology, metabolism and nutrition but there are also opportunities in biomedical engineering, molecular biology, and genetics.

MUSCLE PHYSIOLOGY AND BIOCHEMISTRY: In this option, students are trained for teaching and research careers in the area of exercise science, specifically muscle physiology, molecular biology, and biochemistry. Emphasis is placed on understanding the short–term and long–term effects of exercise, inactivity, and disease on the functional aspects of the neuromuscular system and skeletal, cardiac and smooth muscle. In addition to course work, research experiences are available in veterinary medicine, animal science, and biochemistry Graduates qualify for positions in universities, industry, and the military.

NUTRITION: This option focuses on nutrition assessment and metabolic or molecular–biochemical research in a laboratory or clinical setting. Students also choose electives in toxicology, endocrinology, exercise physiology, biochemistry, and metabolism. Nutrition graduates assume positions in the food industry or in companies manufacturing drugs, nutritional supplements, or other medical or health products; research or monitoring activities in government agencies, long term health care facilities, and outpatient clinics; or teaching and research in colleges and universities.

NUTRITION EDUCATION & BEHAVIOR: Students in this option acquire proficiency in applied nutrition and social and behavioral sciences, which will prepare them to work effectively with communities, food assistance and nutrition education programs, and diverse audiences in the United States. Students learn and apply methods to assess nutrition status and the nutrition education and health needs of communities and special population groups. Graduates work on a wide range of issues such as hunger, food security, and health promotion and disease prevention. They work with a variety of audiences, such as women, children and teens, the elderly, limited resource families, and minority groups.

NUTRITIONAL IMMUNOLOGY & MOLECULAR NUTRITION: This option prepares graduates for a successful career in nutrition research and discovery. Participants will receive advanced training in cellular and molecular biology assays. Integrative and interdisciplinary approaches are utilized to investigate gene–nutrient interactions, to assess the safety and efficacy of foods and nutrients, and to elucidate the cellular and molecular mechanisms by which nutrients and nutraceuticals may reduce the risk of chronic diseases such as inflammatory bowel disease, cancer and cardiovascular disease. There is an emphasis on the immunoregulatory mechanisms and molecular targets of naturally occurring fatty acids and isoflavones. Ongoing research collaborations with the Virginia Bioinformatics Institute facilitate access to state–of–the–art genomics and proteomics facilities. Graduates of this option are prepared to assume leadership roles in academia or in the biotechnology industry.

NUTRITION IN SPORTS AND CHRONIC DISEASE: This option is designed for individuals who have previous training and experience in either exercise science or nutrition. It provides training in sports nutrition as well as additional courses in the disciplines of nutrition and exercise science to complement individual backgrounds. There is an emphasis on acquiring knowledge and experience with athletes and individuals attempting to prevent chronic diseases such as obesity and cardiovascular disease. Students completing this program find positions in fitness, weight management, athletic clinics/programs, university teaching or research.

SPECIAL DEGREE REQUIREMENTS

All students are required to complete a thesis or dissertation as part of their degree program. Generally, students can complete an M.S. program in two years and a Ph.D. program in three years past the M.S. degree. Entering graduate students in foods and nutrition are expected to have successfully completed undergraduate courses in nutrition, foods, chemistry, the biological sciences, statistics, and mathematics. Exercise physiology applicants must have successfully completed undergraduate work in chemistry, physics, the biological sciences, statistics, mathematics, and exercise science. For acceptance into the doctoral program a student must have completed a master's degree with thesis and demonstrate strong potential for further research and scholarly achievement. No foreign language is required for the M.S. or Ph.D.

GRADUATE COURSES (HNFE)

5014 (FST 5014): SENSORY EVALUATION OF FOOD
Principles of sensory evaluation including experimental methods, applications, and statistical analyses. Pre: FST 4524 or STAT 2004. (2H,3L,3C).

5044: SEMINAR IN HUMAN NUTRITION & FOODS
Critical review and oral reporting of pertinent literature and research in the various areas of foods and nutrition. (1H,1C).

5054 (ALS 5054): METHODOLOGY IN NUTRITION RESEARCH
Use of laboratory techniques, instrumentation, and experimental design in the solution of fundamental problems in human and animal nutrition. (2H,2C).

5104 (ALS 5104): NUTRITIONAL ASPECTS OF DIGESTIVE SYSTEMS
Principles of gastrointestinal tract structure, motility, and digestive functions with emphasis on neuroendocrine and metabolic regulation of absorption and transport of carbohydrates, lipids, amino acids, minerals, and vitamins during the life cycles of food animals and humans. Pre: 3026, ALS 3204. (2H,2C).

5114 (ALS 5114): VITAMINS & MINERALS
Study of metabolic regulation and physiologic functions of micronutrients; micronutrient functions as related to maintenance of health and prevention of disease; analytical methods, determination of micronutrient requirements and assessment of status. Pre: ALS 5104 or HNFE 5104, BCHM 5124. (3H,3C).

5124 (ALS 5124): PROTEIN & AMINO ACID METABOLISM
Protein and amino acid metabolism in liver, muscle, kidney, and brain; effects of dietary protein on gene expression; protein turnover in tissues; protein quality evaluations; analytical problems in amino acid metabolism. Pre: BCHM 5124, (ALS 5104 or HNFE 5104). (2H,2C).

5134 (ALS 5134): CARBOHYDRATES, LIPIDS & ENERGY METABOLISM
Concepts in the utilization, metabolism and regulation of carbohydrates and lipids as related to energy metabolism in the various organs and energy balance and its control; metabolism of carbohydrates, lipids and amino acids during activity, fasting, and different disease states in the liver, brain, adipose tissue, kidney and heart; methods of assessment of carbohydrate and lipid metabolism. Pre: BCHM 5124, (ALS 5104 or HNFE 5104). (2H,2C).

5144 (ALS 5144) (VMS 5544): MOLECULAR ASPECTS OF NUTRITION & DISEASE
The role of specific nutrients in human and animal health at a physiologic and molecular level. Emphasis is placed on the influence of nutrients on gene expression especially with regard to pathophysiology of diseases. Physiological and molecular aspects of nutrition and immune function will also be discussed. Pre: BCHM 5124, (ALS 5104 or HNFE 5104). (3H,3C).

5214: LIPIDS & COLLOIDS IN FOODS
Physiochemical properties and reactions of lipids and dispersions in foods. Pre: 3234. Co: BCHM 5124. (2H,3L,3C).

5224: PROTEINS & ENZYMES IN FOODS
Physical and chemical properties and reactions of proteins and enzymes in foods. Pre: 3234. Co: BCHM 5124. (2H,3L,3C).

5234: CARBOHYDRATES & PLANT PIGMENTS IN FOODS
The physical and chemical properties and reactions of carbohydrates and plant pigments in foods. Pre: 3234. Co: BCHM 5124. (2H,3L,3C).

5244: QUALITY CHANGES IN FOODS
Evaluation of nutritional, chemical, microbiological, and functional quality changes in foods during processing, preparation, and storage. Consideration of problems encountered by consumers in the food market including
legislation and regulations pertaining to the quality of food. Pre: 3234. (3H,3C).

5604: PRINCIPLES OF PUBLIC HEALTH NUTRITION
This course provides knowledge of community assessment, planning, implementation, and evaluation as related to nutrition services in health programs. It presents a conceptual background for viewing dietary as well as social, economic, and environmental factors influencing health and nutritional status of populations. Pre: 4624, 5654. (3H,3C).

5614: MATERNAL & CHILD NUTRITION
Nutritional needs and problems of pregnant and lactating women, infants, and children in relation to their nutritional physiology; physiological and pathological basis for current research and public health programs in this area are discussed. Pre: 2014, 4624. (2H,2C).

5624: NUTRITION & AGING
Concepts and principles relevant to nutrition of the aging individual are discussed. Consideration of physiological changes, major nutritional needs, and the application of nutrition principles are included. Human physiology and upper division nutrition course required. (2H,2C).

5634: FAMILY FOOD BEHAVIOR
Review of methods measuring family food use, cultural meanings, and family situations in relation to food and nutrition; identification of factors in the family milieu that influence food behavior and impact nutrition program successes. Pre: 2014. (2H,2C).

5644: STRATEGIES FOR DIETARY COUNSELING
Counseling skills and selected counseling theories are examined for their applicability to and use in dietary counseling. (2H,2C).

5654: DIETARY ASSESSMENT
The principles and techniques of assessment of the food and nutritional needs of individuals and populations will be presented. Current quantitative and qualitative dietary assessment methods will be reviewed in relation to design and methods of data collection. Practical skills training in dietary assessment, interpretation of data, and reporting of results will be incorporated in relation to field methods and use of technology. Interpretation of data in context to meeting food and nutritional needs of individuals and populations nationally and internationally will be discussed. Pre: 4624 or 4644. (3H,3C).

5664: PHYSIOLOGICAL ASPECTS OF AGING
Changes occurring in cells, tissues, and organs of human and mammalian species as they age. Physiology of aging in relation to the older person's total existence and quality of life in later years. Upper division undergraduate course required in any of the following; Biology, Physiology, Nutrition. (3H,3C).

5674 (EDHL 5304): PRINCIPLES OF COMMUNITY HEALTH EDUCATION
Public health issues and concepts are analyzed and evaluated in relationship to existing principles of health education. (3H,3C).

5684 (EDHL 5604): PROGRAM DEVELOPMENT IN HEALTH EDUCATION
Theory, trends, and design of community health education programs implemented in communities, health agencies, hospitals, and industry. Pre: EDHL 5304 or HNFE 5674. (3H,3C).

5694 (EDHL 5314): PUBLIC HEALTH ADMINISTRATION
This course will focus on relevant and timely public health administration concepts. The major topics covered include: health policy, health care planning, health care economics, health law, and managerial functions as they relate to health care and public health settings. (3H,3C).

5724: EPIDEMIOLOGY
Epidemiology is the study of the distribution and determinants of the varying rates of diseases, injuries, or other health states in human and animal populations. This course consists of an introduction to epidemiological terminology, concepts and research methodology. (3H,3C).

5754: INTERNSHIP IN HUMAN NUTRITION & FOODS
Student participation in a planned clinical experience under supervision of a university staff member in an appropriate work center. (Maximum 12C). Consent required. Pass/Fail only. Variable credit course. X-grade allowed.

5764: EXTERNSHIP IN HUMAN NUTRITION & FOODS
Special interdisciplinary problem-solving clinics for experienced health practitioners who are engaged part-time in graduate study while continuing in positions of leadership in health organization. (Maximum 12C). Consent required. Pass/Fail only. Variable credit course.

5774: PROBLEMS IN HUMAN NUTRITION AND FOODS/EDUCATION
Study of problems of professional educators in such areas as administration, curriculum development, and learning theory. (Maximum 6C). Variable credit course.

5784: GRADUATE SEMINAR IN COMMUNITY HEALTH EDUCATION
Selected topics in community health including current issues in community health, health administration, health research, and evaluation of health programs. (Maximum 3C). Variable credit course.

5804: RESEARCH DESIGN IN EXERCISE SCIENCE
Systematic procedures for observing, recording, and reporting information relating to exercise science. (3H,3C).

5814: SKELETAL–MUSCULAR FUNCTION IN EXERCISE
The skeleto–muscular system as the basis of human movement, muscular function in exercise and training, and assessment of muscle function. Pre: 3824, 3804. (2H,3L,3C).

5824: CARDIO–RESPIRATORY FOUNDATIONS OF EXERCISE
A study of the acute circulatory, myocardial, and respiratory responses in various forms of muscular exercise and the adaptations in these functions which occur through bed rest and physical training. Development of laboratory skills in human cardio–respiratory fitness testing. Pre: 3804. (2H,3L,3C).

5834: METABOLIC ASPECTS OF EXERCISE
A study of basic energy and muscle metabolism during exercise and the adaptations which develop through physical training. Pre: 3804, 3025 or BCHM 2024. (2H,3L,3C).

5844: EXERCISE TESTING & PRESCRIPTION
A study of theory and practice of clinical exercise testing for determination of functional capacity in apparently healthy adults and those with selected chronic diseases, primarily ischemic heart disease. The scientific and clinical basis of prescribing developmental and rehabilitative exercise for these two types of individuals. Pre: 5824. (2H,3L,3C).

5854: WORKSHOP IN PREVENTIVE & THERAPEUTIC EXERCISE
Theory and practice of exercise training for adult fitness and certain chronic disease clients, especially those with ischemic heart disease. Topics include physiology of training, implementation, and monitoring of medically prescribed exercise, leadership techniques, primary and secondary prevention of ischemic heart disease, and program administration. Pre: 5844. (3L,1C).

5864: ORTHOPEDIC TESTING & REHABILITATION
A study of the measurement and rehabilitation of musculoskeletal function. Pre: 5814. (3H,3C).

5874: ADVANCED SPORTS NUTRITION
Investigation of the role of nutrition in optimizing physical performance and health of active individuals. Emphasis will be on evaluation of the latest scientific information regarding sports nutrition and translation of this information for athletes and the general public. Pre: 3804, BION 5124. (3H,3C).

5964: FIELD STUDY
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6104: ADVANCED TOPICS IN NUTRITION
Selected topics having current importance in nutrition. 6 credits in 5000 level HNFE courses required. required. (1H,1C).

6204: ADVANCED TOPICS IN FOODS
Selected topics having current importance in foods. 6 credits in 5000 level HNFE courses required. required. (1H,1C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (HNFE)

The following 4000–level courses have been approved for graduate credit:

4124: THERAPEUTIC NUTRITION
Emphasis on the relationship between principles of nutritional care and the medical treatment of individuals with selected diseases or clinical problems. Pre: 3026, 3034, 3214, 3234, BIOL 2406. (4H,4C).

4224: ALTERNATIVE AND COMPLEMENTARY NUTRITION THERAPIES
Critical evaluation of health claims, mechanisms of action, and research literature for a wide variety of unconventional nutrition therapies used for disease prevention and treatment. Practical application of knowledge through completion of problem–based learning projects.Pre: 3025. (2H,2C).

4254: EXPERIMENTAL FOODS
Experimental study of the functions of ingredients and factors affecting food quality with emphasis on an independent project. Pre: 3234. (1H,3L,2C).

4634: SOCIO–CULTURAL FOOD SYSTEMS
Study of social, cultural, and economic aspects of food systems, using quantitative and qualitative methods to assess nutritional status. Pre: 1004, SOC 3004. (2H,2L,3C).

4844: EXERCISE AND NEUROMUSCULAR PERFORMANCE
Functional properties of the neuromuscular system. Emphas is placed on the acute and chronic responses of muscle in exercise, rehabilitation and the factors which determine human performance. Special emphasis on the molecular biological factors responsible for skeletal muscle development and differentiation, as well as adaptation to training and disease states, including activation of signal cascades responsible for the changes in muscle performance. Pre: 3804. (3H,3C).

HUMANITIES

Peter Schmitthenner, Director, Humanities Programs

Several courses are offered to serve the needs of graduate students majoring in other disciplines. This department does not offer a degree program. The courses listed below are available to graduate students and may complement their work in their particular fields.

ADVANCED UNDERGRADUATE COURSES (HUM)
The following 4000–level courses may be taken for graduate credit:

4404: APPALACHIAN FOLK CULTURE
Examination of informal learning systems and traditional aesthetic expressions in Appalachia. Investigation of worldview and cultural premises as expressed in traditional artifact. Pre: 1704. (3H,3C).

4414: CRITICAL ISSUES IN APPALACHIAN STUDIES
Examination of dominant value conflicts in contemporary Appalachia, focusing on questions of exploitation of human and natural resources. Comparative study of Appalachia, other mountain cultures worldwide, and the Third World. Pre: 1704. (3H,3C). Alternate years.

INDUSTRIAL & SYSTEMS ENGINEERING

UNIVERSITY EXEMPLARY DEPARTMENT *

G. Don Taylor, Charles O. Gordon Professor and Department Head

John W. Hancock, Jr. Chair: P.E. Torgersen
John Grado Professor: J.G. Casali
John L. Lawrence Professor: F.F. Chen
Paul T. Norton Professor: S.C. Sarin
W. Thomas Rice Professor: H.D. Sherali
Professors: M.P. Deisenroth; R. Sturges; K.P. Triantis
Associate Professors: K.P. Ellis; L.K. Harmon; B.M. Kleiner; C.P. Koelling; R.D. Meller; J.A. Nachlas; M.A. Nussbaum; J. P. Shewchuk; M.R. Taaffe; E.M. Van Aken
Assistant Professors: K.L. Babski–Reeves; E. Bish; L.M.A. Chan; T.E. Lockhart; T. Smith–Jackson

E-mail: ise.grad.prog@vt.edu (applications and general information)
Web: ise.vt.edu

The Grado Department of Industrial and Systems Engineering offers programs of study leading to the M.S., and Ph.D., with the major in Industrial and Systems Engineering. The M.S. is available with concentrations in Human Factors and Ergonomics (thesis optional); Management Systems (thesis optional); Manufacturing Systems (thesis optional); and Operations Research (thesis optional). The Ph.D. is available in all four concentrations and requires a dissertation.

The Master of Engineering Administration (MEA) provides practicing engineers, scientists, and technical professionals with a graduate–level academic experience that further prepares them for career advancement in the role of managing and providing administrative support for the technology–based operations of a progressive enterprise. Also, the ISE department is the administrative home for the interdisciplinary master's degree program in Systems Engineering. This program is offered primarily off–campus and leads to the M.E. or M.S. See the separate section entitled "Systems Engineering" for a description of academic requirements.

Areas of specialized study and research available within the ISE department include automation, collaborative work systems, concurrent engineering, decision theory, display design and evaluation, engineering economy, enterprise systems, ergonomics, facility design and location, flexible manufacturing, human audition, human computer interaction, life–cycle engineering, maintenance planning, management, manufacturing engineering, mathematical programming optimization, occupational biomechanics, organizational assessment and analysis, procurement and inventory systems, production planning, performance management,

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

quality control, queueing theory, queueing networks, reliability, robotics, safety engineering, scheduling and sequencing, strategic planning, supply chain management, systems simulation methodology, and work physiology. A graduate advisory committee is established for each student to help develop a suitable plan of study and to guide the project, thesis, or dissertation research.

GRADUATE COURSES (ISE)

5004: INFORMATION SYSTEMS ANALYSIS
Structured and scientific approaches to management, management system model, pursuits and uncertainty, levels of endeavors, stages of maturity, decision types, contingency theory, situational management, management information systems, decision support systems, and shared information processing. Pre: 4015. (3H,3C).

5015–5016: MANAGEMENT OF CHANGE, INNOVATION, & PERFORMANCE IN ORGANIZATIONAL SYSTEMS
The management (planning, measurement and evaluation, control, and improvement) of organizational systems (work groups, departments, functions, plants, and companies). 5015: Managing performance, change, and innovation in organizational systems. 5016: Measurement and evaluation of performance or organizational systems. (3H,3C).

5024: ISE SEMINAR
Discussion of research projects and results of sponsored and other research in the ISE Department and elsewhere, including descriptions of specialized equipment and facilities. In addition orientation to the department, its organization and operation is provided. Pass/Fail only. (1H,1C).

5104: OPERATIONS RESEARCH
Basic techniques and methods of Operations Research are presented. The course will cover the phases of problem identification, model building and analytical methods of decision making. Students will be introduced to the implementation of these algorithms and models. Not for credit for students pursuing the M.S. or Ph.D. in the O.R. option. (3H,3C).

5114: CASE STUDIES IN INDUSTRIAL ENGINEERING
Applications of the methodologies in Industrial Engineering and Operations Research to actual problems in Business, Industry and Government operations. The study will cover all the phases of analysis, problem description, system structure, model development and validation and solution techniques. Student involvement in the case studies will be accomplished through project assignments. Not for credit for M.S., M.E., or Ph.D. degrees in ISE. Pre: 5104, 5434, STAT 5004. (3H,3C).

5124: MANAGEMENT OF QUALITY & RELIABILITY
This course presents the managerial and mathematical principles and techniques of planning, organizing, controlling, and improving the quality and reliability functions of an organization. The approach taken is to study the management of quality and reliability through the product life cycle, i.e., from research and development, through testing and analysis. The implementation of the managerial and mathematical techniques will be achieved through the study of selected case studies. Pre: STAT 5004. (3H,3C).

5134: MANAGEMENT INFORMATION SYSTEMS
Systems approach to management, domains of responsibility, structured and synergistic management tools, management system model, contextual frameworks, information portrayal, automation objectives model, evaluation, shared information processing, information modeling. Not for credit for M.S., M.E., or Ph.D. degrees in ISE. X–grade allowed. (3H,3C).

5144: PERFORMANCE & PRODUCTIVITY MEASUREMENT & EVALUATION
This course presents the principles and techniques of performance management at the organizational level. Emphasis is placed on the measurement of performance with a focus on productivity measurement, as well as on performance evaluation and how these areas facilitate performance planning, control and improvement. Each student will be required to complete a project which will emphasize the application of these techniques to an organizational setting. (3H,3C).

5154: APPLIED HUMAN FACTORS ENGINEERING
An examination of present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into system, subsystem, equipment, and facility design in order to achieve effectiveness, simplicity, efficiency, reliability and safety of system operation, training and maintenance. Not for credit for students pursuing the M.S. or Ph.D. in the Human Factors option. (3H,3C).

5174: ENGINEERING PROGRAM & PROJECT MANAGEMENT
The project approach as applied in the accomplishment and management of complex technical work typically performed by engineers, scientists, and other technology professionals. Practical application and ongoing enhancement of program and project management systems with emphasis on process, techniques, standards, empirical guidelines, computer software, teamwork and economic considerations. (3H,3C).

5204: MANUFACTURING SYSTEMS ENGINEERING
Conceptual models of manufacturing, process, and service organizations for various operational levels are presented. Functional activities and interrelationships are defined for each type of manufacturing model. Typical objectives and operating constraints are identified for functional activities, particularly production planning/control, materials management, facilities design/material handling, manufacturing engineering, quality control, and personnel administration. (3H,3C).

5234: MANUFACTURING COSTS & PRODUCTION ECONOMICS
Concepts and techniques of analysis for evaluating the life–cycle costs and benefits of manufacturing assets and production systems. International economic competition, design and production economics, strategic implications of capital investment, investment decision analysis, economic appraisal and control, and the economic retirement of manufacturing assets. Pre: 2014, 5204. (3H,3C).

5244: FACILITIES PLANNING & MATERIAL HANDLING
Application of decision theory andoperations research techniques in development ofmathematical models to specific study areas of facilities planning and material handling. Pre: 2404, 3414. (3H,3C).

5304: DIGITAL COMPUTERS IN MANUFACTURING SYSTEMS CONTROL
An introduction to computer software and hardware concepts as applied to manufacturing systems interfacing control. Includes microprocessor architecture, related hardware devices, software systems concepts in data acquisition and control, manufacturing applications of computers, and computer integration for manufacturing systems control. (3H,3L,4C).

5314: INDUSTRIAL APPLICATIONS OF ROBOTICS DEVICES
Technical aspects of robotics devices and automation islands employed by the industry are discussed in detail. On–line job teaching and off–line job planning for the industrial robot are compared. Various industrial applications including spray painting, welding, machine loading, and assembly are studied. Pre: 4264. (3H,3L,4C).

5324: FLEXIBLE MANUFACTURING SYSTEMS
Technical aspects of FMS components, including automated material handling devices, robots, CNC machines, job selection/design, and their aggregations are discussed. Hierarchical structure of the FMS system is explored and mathematical models of FMS are discussed. Pre: 5204, 5405. (3H,3C).

5405,5406: OPTIMIZATION
5405: Linear programming, modeling, assumptions, and structural properties; primal, dual, and primal–dual simplex algorithms; convergence and implementation issues; duality theory; sensitivity and parametric analysis; linear multiobjective and goal programming, introduction to integer, dynamic, and nonlinear programming. 5406: Nonlinear programming theory and algorithms: convex sets and functions, generalized convexity; and theorems of the alternative, constraint qualifications, necessary, and/or sufficient optimality conditions. (3H,3C).

5414: RANDOM PROCESS
Stochastic processes of use in many areas of study, specifically industrial engineering and operations research. Emphasis on Markov processes. Applications will be given. Pre: STAT 4105. (3H,3C).

5424: SIMULATION I
Introduction to discrete event digital simulation, including development of simulation models, random number and random variable generation, model validation and testing, analysis of model output, and an overview of simulation languages. Emphasizes the use of simulation modeling in decision–making through a series of projects involving decision problems. Knowledge of programming required. Pre: STAT 4105. (3H,3L,3C).

5434: ECONOMIC EVALUATION OF INDUSTRIAL PROJECTS
Application of engineering economy to the economic evaluation of industrial projects. In general, these projects will include investment in the new facilities as well as replacement of old facilities. Concepts of wealth maximization, utility, and risk will be discussed. Financing will be treated as an integral part of the investment problem. (3H,3C).

5444: QUALITY AND RELIABILITY ENGINEERING
Quality performance of production processes; evaluation of statistical techniques used for quality control; foundations of reliability; acceptance procedures based on the reliability of products; reliability of systems; and optimization of system reliability. Pre: 5405, 5414. (3H,3C).

5454: PRODUCTION PLANNING & CONTROL
Introduction to the mathematical analysis of various aspects of production planning and control. Among others, this includes topics in inventory control, forecasting, aggregate production planning, production and project scheduling, and line balancing. Pre: 5405. (3H,3C).

5464: QUEUEING THEORY
Classic models of queues including M/M/1, M/GI/1, and GI/M/s. Topics in queue length processes, waiting time processes, busy period processes, and traffic processes. Pre: 5414. (3H,3C).

5474: STATISTICAL THEORY OF QUALITY CONTROL
Development of statistical concepts and theory underlying procedures used in quality control applications. Sampling inspection procedures, the sequential probability ratio test, continuous sampling procedures, process control procedures, and experimental design. Pre: STAT 5104, STAT 5114. (3H,3C).

5484: MODELING PROCESS IN OPERATIONS RESEARCH
Introduction to and demonstrations of the phases and activities involved in the development, validation, and use of models in the solution of management decision problems. Student involvement in the process of modeling will be accomplished through project assignments. Pre: 5405, 5406, 5414, 5424. (3H,1L,3C).

5605,5606: HUMAN FACTORS SYSTEM DESIGN
Human factors input into operator–system design, development, testing, and evaluation. Emphasis on the systems approach to human–machine interfacing, with discussion and application of specific methodologies and analytical techniques. Display and control design and selection fundamentals with engineering modeling of manual control systems. In 5606, each student performs a design project relying on application of systems analysis and design techniques. Pre: 3614 for 5605; 3614, 5605 for 5606. Co: 5614. 5605: (3H,3C) 5606: (4H,4C).

5604: HUMAN INFORMATION PROCESSING
An examination of human information reception, information processing, and skilled performance capabilities and limitations in human–machine systems with an emphasis on models and techniques, including psychophysics, signal detection theory, information theory, supervisory control, and decision theory. (3H,3C).

5605,5606: HUMAN FACTORS SYSTEM DESIGN
Human factors input into operator–system design, development, testing, and evaluation. Emphasis on the systems approach to human–machine interfacing, with discussion and application of specific methodologies and analytical techniques. Display and control design and selection fundamentals with engineering modeling of manual control systems. In 5606, each student performs a design project relying on application of systems analysis and design techniques. Pre: 3614 for 5605; 3614, 5605 for 5606. Co: 5614. 5605: (3H,3C) 5606: (4H,4C).

5614: HUMAN PHYSICAL CAPABILITIES
An examination of human physical attributes in human–technology systems, with emphasis on models of anthropometry and biomechanics, on intero– and exteroceptors, and on the work environment: force fields (transitory and sustained), sound, light, and climate. Pre: 3614. (3H,3C).

5615–5616: HUMAN FACTORS RESEARCH DESIGN
Procedures for conducting human factors experiments, including research methodology, multifactor design alternatives, field research, designs for reducing data collection, empirical model building, and sequential research procedures. 5615: (4H,4C) 5616: (2H,2C).

5634: TRAINING SYSTEM DESIGN
A systems approach to the design and development of training, with emphasis on techniques to conduct training–needs analysis; a survey of training technology with an emphasis on computer–assisted techniques and training simulators; and procedures to evaluate training effectiveness. Pre: 5605, 5616. (3H,3C).

5644: HUMAN AUDITION & AUDITORY DISPLAY DESIGN
An examination of the human sensory and perceptual experience of sound, with emphasis on relating the capabilities and limitations of audition to the design of auditory display systems and to noise abatement in hearing conservation efforts. In addition to discussion of human sound reception and sensitivity, human psychological and physiological responses to sound will be covered. Pre: 5604. (3H,3C).

5654: HUMAN FACTORS ENGINEERING FOR THE DISABLED AND AGING
An examination of human attributes which may be reduced in disabled persons and which change with the aging process, and of the associated needs regarding work procedures and equipment with respect to the design of the domicile and of care facilities. Human factors requirements for aids in transportation (individual and mass), personal hygiene, and environment are also topics of this course. Pre: 5606. (3H,3C).

5664: ASSESSMENT STRATEGIES IN REHABILITATION
A survey of human mental and physical disabilities as they affect the work environment, with emphasis on the various forms of assessment used in measuring residual manipulative abilities. In addition to the measurement of abilities, alternative approaches adaptive devices will be covered. Pre: 3614. (3H,3C).

5674: SYSTEM SAFETY ANALYSIS
The analytical techniques and documentation requirements to provide proper design of equipment and systems and to protect against products liability. Safety concepts, legal concepts, qualitative and quantitative hazard evaluation, hazard classification, system life cycle safety, statistical distributions, software safety analysis, inductive and deductive analysis, Mort, Fault Tree, hands–on projects emphasizing hazard identification and control. Pre: 4644, STAT 3604 or STAT 4105. (4H,4C).

5684: INDUSTRIAL HEALTH & SAFETY ENGINEERING
Identification, analysis and control of biological, chemical, electrical, radiation, and fire hazards in industrial settings. Hands–on analysis of several "case–study" projects associated with these hazards in a variety of settings. Recognizing and measurement of hazards, prioritize hazards for control, select effective control methodologies and evaluate the effectiveness of implemented controls. Pre: 4644, STAT 3604 or STAT 4105. (4H,4C).

5694: MACROERGONOMICS
The optimization of work system design through consideration of relevant personnel, technological, and environmental variables and their interactions. Emphasis is on the theoretical background, research methods, analyses, design, development and applications of work systems and the relationship between macro– and micro–ergonomics. (3H,3C).

5714 (CS 5714): USABILITY ENGINEERING
Design and evaluation of effective user interfaces, beginning with principles for designing the product. Development process for user interaction separate from interactive software development. Development process includes iterative life cycle management, systems analysis, design, usability specifications, design representation techniques, prototyping, formative user–based evaluation. Integrative and cross–disciplinary approach with main emphasis on usability methods and the user interaction development process. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6324: COMPUTER INTEGRATED MANUFACTURING
The concept of an integrated manufacturing system is introduced as a centralized control alternative with its request for a master mind and a common language. Computerized planning facilities for production related decisions and automated manufacturing machines are discussed in technical detail. The structure of a hierarchically accessed control system is explored. Pre: 5324. (3H,3C).

6404: GRAPH THEORY & NETWORK FLOWS
Graph theoretic concepts and definitions, optimization problems over graphs, and basic results; minimum cost network flow problems (including assignment, transportation, max flow, and shortest–path problems) and associated algorithms with implementation strategies; PERT and CPM; and network design and synthesis problems. Pre: 5405. (3H,3C).

6414: INTEGER PROGRAMMING
Modeling with integer variables; enumeration and cutting plane methods; partitioning and relaxation techniques; computational complexity issues; and some special combinatorial optimization problems. Pre: 5405. (3H,3C).

6424: DYNAMIC PROGRAMMING
Introduction to the theory, applications, and computational aspects of dynamic programming. Markovian decision processes. Pre: 5405, 5414. (3H,3C).

6434: SCHEDULING & SEQUENCE THEORY
Theory of deterministic scheduling; sequencing of jobs on a single processor; multi–processor problems including flow shop and job shop scheduling; and introduction to the complexity of computations. Pre: 5405. (3H,3C).

6464: QUEUEING NETWORKS
Applications of queueing theory results to queueing networks. Topics include reversibility, insensitivity, product forms for queue length processes, and traffic processes including traffic flow within the network. Pre: 5464. (3H,3C).

6474: RELIABILITY THEORY
An introductory graduate–level examination of mathematical models of failure processes and complex system reliability. Included are existing probability models of component and system failure processes, statistical and experimental methods for estimating failure behavior, and optimization models for supporting design, replacement, and maintenance decisions. Pre: 5414, 5405, STAT 5004. (3H,3C).

6484: SEMINAR IN APPLIED PROBABILITY
Working seminar open to anyone doing research in applied probability. The purpose is to review student research progress through a series of seminars offered by them and to present new research results offered by faculty attending. May be taken more than once. Enrollment in Ph.D. program required. (1H,1C).

6494: ADVANCED SIMULATION
Introduction to advanced methods of analysis of simulation model output. Particular emphasis is placed upon the relationship between the decision process and model output. Topics include impact of non–normality, dependence, and transient behavior on model output; methods for identifying near steady–state behavior, batch means, sequential systematic sampling, regeneration method, and determination of simulation run length. Pre: 5614, STAT 4105. (3H,3L,3C).

6504: MARKOV RENEWAL & RELATED PROCESSES
Renewal theory, Markov renewal theory, and applications. Pre: 5414. (3H,3C).

6514: ADVANCED TOPICS IN MATHEMATICAL PROGRAMMING
Decomposition algorithms for largescale linear and nonlinear programs having special structures; algorithmic maps and convergence analysis; optimality conditions and duality in nonlinear programming; polynomial algorithms for linear programming problems; optimization theory and algorithms for nonsmooth and nonconvex nonlinear programs; calculus of variations and optimal control. Pre: 5406. (3H,3C).

6524: ADVANCED TOPICS IN ENGINEERING ECONOMY
In–depth study of factors that affect the economic decisions for investments in manufacturing and other industries. Such factors would include, but not be limited to: joint evaluation of return and risk, utility concepts and foundations, inflation, and growth of a corporation. Pre: 4224. (3H,3C).

6604: HUMAN FACTORS IN VISUAL DISPLAY SYSTEMS
Quantitative analysis of human visual system capabilities and limitations, and their relationship to the design of visual display components and systems. Emphasis is placed on the measurement and physics of light, visual science data, hardware design, and the use of linear systems theory in display design and evaluation. Pre: 5604, 5605. (3H,3C).

6614: HUMAN COMPUTER SYSTEMS
A survey of human factors procedures used in the design of computer–based systems. Consideration is given to the iterative interface design process, hardware interface design, software interface design, and workplace design. Pre: 5616. (3H,3C).

6624: ADVANCED TOPICS IN HUMAN FACTORS
A research–oriented course reviewing the scientific literature in Human Factors Engineering of selected complex systems. Industrial, civil, transportation, military and computer–based systems will be considered. State–of–the–art topics will be examined to an extent not covered in other courses. May be repeated, with different content. Pre: 5616. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ISE)

The following 4000–level courses have been approved for graduate credit:

4004: THEORY OF ORGANIZATION
A theory of cooperative behavior in formal organizations, including the structure and elements of formal organizations. The executive process and the nature of executive responsibility also are examined. (3H,3C).

4015,4016: MANAGEMENT SYSTEMS THEORY, APPLICATIONS, AND DESIGN
Systems approach to management, domains of responsibility, structured and synergistic management tools, management system model, contextual frameworks, information portrayal, automation objectives model, evaluation, shared information processing, information modelling. A management process for definition, measurement, evaluation and control, the organization as an information processor, corporate culture, scoping agreements, schemas and management elements, structured design. (3H,3C).

4234: MODELING AND SIMULATION LANGUAGES
Modeling of industrial situations and introduction to the use of simulation languages. Several simulation languages commonly used for industrial engineering applications such as GPSS, SLAM, and SIMAN will be covered. A grade of C– or better required in prerequisite ISE 3424. Pre: 3424.

4244: FUNDAMENTALS OF COMPUTER INTEGRATED MANUFACTURING
Concepts and techniques for modeling, designing, and implementing Computer Integrated Manufacturing (CIM) systems. Emphasis on relational databases and communications networks and their use in modern manufacturing enterprises. Fundamentals and role of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), and Computer Aided Process Planning (CAPP) in CIM systems. Pre: (2204 or 2214), (4204). (3H,3C).

4264: INDUSTRIAL AUTOMATION
A survey of the various technologies employed in industrial automation. This includes an emphasis on industrial applications of robotics, machine vision, and programmable controllers, as well as an investigation into problems in the area of CAD/CAM integration. Examination of the components commonly employed in automation systems, their aggregation and related production process design. Laboratory work is required. A grade of C– or better required in prerequisites ISE 2204 or 2214. Pre: 2204 or 2214. (2H,3L,3C).

4404: STATISTICAL QUALITY CONTROL
Application of statistical methods and probability models to the monitoring and control of product quality. Techniques for acceptance sampling by variables and attributes are presented. Shewhart control charts for both classes of quality characteristics are examined in depth. The motivation for each method, its theoretical development, and its application are presented. The focus is upon developing an ability to design effective quality control procedures. Pre: STAT 4706. (3H,3C)

4414: INDUSTRIAL QUALITY CONTROL
Implementation of statistical quality control techniques in an industrial setting. Development and analysis of cost models for use in the design of optimal quality control plans. Also included are new techniques, advanced quality control models, and an examination of the role of industrial statistics in the overall product quality assurance function. A grade of C– or better required in prerequisite Pre: 4404. (3H,3C).

4424: LOGISTICS ENGINEERING
Introduction to the key issues in the integrated support of a product of process. Synthesis of topics from earlier studies to provide a cohesive approach to their applications. Logistics engineering provides a survey of product support issues and methods of resolving them within the context of the overall production activity. A grade of C– or better required in prerequisite ISE 3414. Pre: 3414. (3H,3C).

4624: WORK PHYSIOLOGY
Anthropometry, skeletal system, biomechanics, sensorimotor control, muscles, respiration, circulation, metabolism, climate.Ergonomic design of task, equipment, and environment. A grade of C– or better required in prerequisite ISE 3614. Pre: 3614. (3H,3C).

4654: PRINCIPLES OF INDUSTRIAL HYGIENE
Introduction to the foundations of the field of Industrial Hygiene, that discipline devoted to the anticipation, recognition, measurement, evaluation, and control of occupational health hazards. Includes biological (e.g. microbial agents, allergens), chemical (e.g. solvents, carcinogens, dusts), and physical (e.g. radiation, temperature) hazards. Overview of control of health hazards, such as personal protective equipment, administrative controls, and engineering controls. Will involve lecture and participatory "case–study" activities. Will provide ample opportunity for hands–on use of monitoring equipment, protective equipment and controls testing devices. (3H,3C).

INFORMATION TECHNOLOGY

Thomas T. Sheehan, Program Director

E-mail: Thsheeha@vt.edu
Telephone: 703–538–8361

The Online Graduate Program in Information Technology offers skill upgrading to working professionals desiring to participate in the rapidly expanding area of information technology. The program is built on a number of course work modules (currently six). Each module consists of two courses (6 credit hours total) and focuses on one of the areas important to the Information Technology discipline. As described in the following sections, students may pursue the master of information technology degree or may enroll in the program as Commonwealth students with the purpose of obtaining a graduate certificate in one of the areas covered by the IT modules.

Program Overview

The program consists of two basic components; a four–course sequence of foundation material and six IT modules, each of which contains at least two courses. All courses are three–credit–hour semester–length courses. The IT modules span the broad range of activities of interest in the IT discipline. The modules in the program cover 1)communications, 2)networking, 3)computer engineering, 4)software development, as well as the business aspects of information technology including 5)business information systems and 6)decision support systems. In order to cover such a broad range of technical disciplines, the program brings together faculty from three colleges: Engineering (the Department of Electrical and Computer Engineering), Arts and Sciences (the Department of Computer Science) and the Pamplin College of Business (the Departments of Accounting and Information systems and Business Information Technology). Another unique aspect of the program is that students can enroll as graduate students seeking the master of information technology degree or students may enroll as Commonwealth students seeking to increase their expertise in one specific area of course work.

Degree and Certificate Requirements

The Master of Information Technology Degree

Thirty (30) credit hours of course work are required for the master of information technology degree. Each student must complete three modules for a total of 18 credit hours (three modules with 6 credit hours per module), as well as the 12 credit–hour block of foundation courses listed below. The student selects the three modules which best fit his or her needs. The foundation courses are tailored to provide the background material required for success in the set of modules selected by the student.

Certificate Requirements

Students in the Information Technology program receive a graduate certificate (awarded by the appropriate college) upon successful completion of any module together with the foundation course appropriate to that module. Successful completion of a certificate requires between 9 and 12 credit hours (3–6 credit hours for the foundation course[s] plus 6 credit hours that constitute the module.)

Foundation Courses

1. Object–Oriented Programming & Java
2. Software Engineering
3. Fundamentals of Computer Systems
4. Strategic Leadership in Technology–Based Organizations

Information Technology Modules

1. Communication Systems (COMM)
   - Digital Communications
   - Introduction to Wireless Communication
2. Networking (NET)
   - Network Architecture and Protocols I
   - Network Architecture and Protocols II
3. Computer Engineering (CPE)
   - Design of Systems on a Chip
   - Computer Architecture
4. Software Development (SD)
   - Software Design & Quality
   - Internet Software
5. Business Information Systems (BIS)
   - Information Systems Design & Database Concepts
   - Advanced Database Management Systems
6. Decision Support Systems (DSS)
   - Computer–Based Decision Support Systems
   - DSS Design & Implementation
   - Web Applications & Electronic Commerce

INTERNATIONAL RESEARCH
(Graduate Certificate Program)

S.K. De Datta, Director

Advisory Committee: S.K. De Datta (Associate Provost for International Affairs, Director, Office of International Research, Education, & Development, and Chairperson); J. Browder (College of Architecture and Urban Studies); K. DePauw (Graduate School); A. Fernandez (Foreign Languages, College of Liberal Arts & Human Sciences); L. Grossman (Geography, College of Liberal Arts & Human Sciences); T. Hammett (Wood Science & Forest Products, College of Natural Resources); B. Kleiner (Industrial & Systems Engineering, College of Engineering); G. Norton (Agricultural & Applied Economics, College of Agriculture & Life Sciences); N. Sriranganathan (Biomedical Sciences and Pathobiology, College of Veterinary Medicine); D. Sutphin (Academic Programs, College of Agriculture and Life Sciences); R. Thompson (Finance, Insurance & Business Law, College of Business); J. Tlou (Dept. of Teaching and Learning, College of Liberal Arts & Human Sciences); D. Yang (College of Science).

E-mail: dedatta@vt.edu
Web: http://www.oired.vt.edu/resanddev/overview/grad_cert.htm

Areas of Specialization

International Development is a process of improving the lives of people in developing countries. It has three components: education and training, collaborative research, and technical assistance. Development work is multidisciplinary in nature, often involving members of several disciplines working together to define a common goal. No single discipline can provide a thorough understanding of the development process.

Special Admission Requirements

Any student enrolled in either a master's or doctoral program in an established academic department at Virginia Tech can be accepted into the program.

Special Certificate Requirements

There must be at least one faculty member on the student's graduate committee with experience in international development. The student must choose at least three electives from the approved list, one course outside the student's college and one course outside the student's department to ensure broader training. Other courses not on the approved list or independent study courses may be accepted, subject to the approval of the Specialization Advisory Committee. A total of 9 credit hours are needed to complete the course work requirements. The student's thesis, dissertation, or major paper must be on a topic related to international development. The student must produce evidence of completion of his or her degree program before the certificate can be issued.

The advisory committee has determined that the MIP/Peace Corps experience can satisfy the certificate requirements for 6 credits outside the student's department (one course outside the college and both courses outside the department). The certificate program will accept a thesis directed to an international development topic. However, a major paper option must not only have an international focus, but also be subject to the student's graduate committee review. In both thesis and major paper options, one of the student's graduate committee members must come from outside the student's college and must have international development experience. The MIP practicum will not be accepted toward the certificate requirement. All other requirements are consistent with the current guidelines.

Those wishing to pursue the specialization must register with the Office of International Research, Education, and Development (OIRED) and meet the director. Upon successful completion of the program, a certificate is issued by the Graduate School.

Approved Courses:

College of Agriculture & Life Sciences
BSE 4394: Water Supply & Sanitation in Developing Countries
AAEC 4304: Environment & Sustainable Development Economics
AAEC 5154: International Agricultural Development & Trade
AAEC 5244: Rural Development
*AAEC 5974: Independent Study
CSES 4124: Soil Survey/Taxonomy
CSES 4544: Forage Crop Ecology
ENT (PPWS) 4264: Pesticide Usage
ALS/NR/UAP 4404: Approaches to International Development
*ALS 5974: Independent Study

College of Architecture & Urban Studies
BC 5044: International Construction Practices
UAP 4184: Community Involvement
ALS/NR/UAP 4404: Approaches to International Development
UAP 4624: Comparative Urban Policy
UAP/SOC/GEOG 4764: International Development Policy & Planning
UAP 5404: Alternative Development Strategies for Urban & Regional Systems in the Third World
UAP 5364: NGOs in International Development
UAP 5394: Nature, Society, & the Global Economy: Interdisciplinary Perspectives
UAP/SOC 5524: Critical Theories and Controversies about Globalism
UAP 5764: International Development Project Studio
UAP 5974: Independent Study
UAP 4214/5984: Women, Environment and Development in a Global Perspective
NECT 6614: International Production & Trade of Textiles & Apparel

College of Science
ECON 4124: Growth & Development
ECON 6054: Economic Development
GEOG 4204: Geography of Resources
GEOG 5204: Geography of Third World Development

College of Liberal Arts & Human Sciences
EDCI 6034: Education & Anthropology
EDCI 6534: Ethnographic Methods in Educational Research
EDAE 5604: Seminar - Comparative Education: International School Reform
EDAE 6914: Problems in Education Seminar: International Adult Education
*EDVT 5984: Special Study
EDVT 5414: Contemporary Problems & Issues in Technology Education
EDVT 6694: Vocational & Technical Education for Developing Countries
HIST 5534: Imperialism, Nationalism, & Decolonization
HIST 5924: World Systems Theory & History
HIST/FLL 5984: Methods of Area Studies
HNFE 5634: Family Food Behavior
NERM 5304: Family Economics
SOC 4514: Rural Sociology
SOC 5504: Population Processes and Policies

SOC/GEOG 5654: The Global Division of Labor
PSCI 5434: Politics of Developing Areas
*FR 5974: Independent Study
*FR 5984: Special Study
*SPAN 5974: Independent Study
*SPAN 5984: Special Study
SPAN 5234: Spanish-American Institutions & Concepts
*SPAN 4334: Special Topics in Hispanic Life, Literature, & Language

COLLEGE OF BUSINESS
FIN 5184: International Finance
MGT 5784: International Management
MKTG 5704: International Marketing Strategies
MSCI 5494: Global Operations & Information Technology
FIN 5984: Study Abroad
MKT 5954: Study Abroad
MGT 5954: Study Abroad
MSCI 5954: Study Abroad

COLLEGE OF ENGINEERING
EE 4364: Alternative Energy Systems
ISE 4304: Global Issues in Industrial Management

COLLEGE OF NATURAL RESOURCES
CSES/NR 4964 and NR 5964: Global Seminar
FOR/CSES 4334: Principles & Practices of Agroforestry Systems
FOR/WOOD 5974: Independent Study (World Forestry)
NR/ALS/UAP 4404: Approaches to International Development
NR 5114: Global Issues in Natural Resources

*Topic must be relevant to international development and is subject to approval by the Certificate Advisory Committee.

INTERNATIONAL STUDIES

Scott G. Nelson, Director

E-mail: scnelson@vt.edu

Several courses are offered to serve the needs of graduate students majoring in other disciplines. This department does not offer a graduate-level degree. The courses listed below are available to graduate students and may complement their work in their particular fields.

ADVANCED UNDERGRADUATE COURSES (IS)

4014: SEMINAR IN GRASSROOTS DEVELOPMENT
Utilizes development, gender, and social theory to examine the impact of aid programs on communities in the Third World. Analyzes such issues as the impact of development projects in agriculture, natural resources, and employment on the local people, the impact of aid on women; and the policies and administrative structures that direct the world of international development. (3H,3C). II.

4044 (COMM 4044): INTERNATIONAL COMMUNICATION
Comparative perspectives on global communication systems; problems with the flow of information; roles of international organizations; mass communication and national development; implications for conflict resolution; selected case studies. Pre: Senior standing or consent. (3H,3C). Alternate years.

LANDSCAPE ARCHITECTURE

Dean R. Bork, Head

Professors: B.C. Johnson: P.A. Miller
Associate Professors: D.R. Bork; T.L. Clements; W. Jacobson; R. Kagawa; B. Katen
Assistant Professors: M. Bryant
Assistant Research Professor: L.R. Skabelund; R. S. Kennedy
Adjunct Professors: G. Buhyoff; A. Buikema; D. Hill; B. Hull

E-mail: tphipps@vt.edu
Web: www.lar.arch.vt.edu/

Landscape architecture involves the design, planning, and management of sustainable human environments on many scales - from garden, to plaza, to park, to entire communities and regional landscapes. Landscape architects contribute to a greater societal understanding of the relationships between people and the physical environment through the thoughtful integration of natural processes, individual needs, and societal vision.

The Master of Landscape Architecture encompasses the breadth of the profession. There are two M.L.A entry levels: one for students who do not have an undergraduate degree in landscape architecture (Qualifying Studies); and the second for students who already have a professional degree in landscape architecture (M.L.A. Studies). Students who enter the first professional degree program through Qualifying Studies are expected to acquire professional skills at, or above, the entry level and to pursue in-depth studies in a specific focus area of the profession. Advanced M.L.A students work directly with faculty to conduct scholarly inquiry in the areas of: Sustainable Urban Design and Community Planning, and Cultural Landscape Studies. Students may pursue M.L.A studies on the Blacksburg campus or through the College of Architecture and Urban Studies - Washington Alexandria Architecture Center located in Alexandria, Virginia. In addition, students who have already earned a master's degree may study for a Ph.D. under the direction of landscape architecture faculty to earn their degree through the Environmental Design and Planning program.

Qualifying Studies

Qualifying studies precede the M.L.A. studies and are taken by students whose undergraduate degree is not in landscape architecture. Normally a year that includes 30 credits of course work, qualifying studies prepare the student to enter the profession of landscape architecture by providing an introductory foundation in landscape architecture history and theories; introducing basic design, technical knowledge and skills; and providing a basic understanding of natural and human systems as they relate to landscape planning and design. Students in the NOVA/DC area complete their Qualifying Studies, under dual enrollment status, through the graduate Landscape Design Program at The George Washington University. The first professional degree program is accredited by the Landscape Architecture Accreditation Board and leads to licensure as a professional landscape architect. For students with an undergraduate degree in a related field, the qualifying studies may be shortened.

M.L.A. Studies

M.L.A. studies, normally two years in duration, allow each student to acheive mastery in a focused aspect of landscape architecture. M.L.A. studies prepare graduates to assume leadership positions in the profession in the future by:

1. developing advanced proficiency in the theory and technology associated with the practice of landscape architecture; and/or
2. acquiring research skills for the ultimate purpose of deepening and broadening the foundation of the profession.

Students work with a major professor and graduate committee in developing a program of study. The program of study is based on the student's professional and/or research interests and prepares the student to undertake a master's thesis. The capstone experiences in the M.L.A. program, either the thesis or thesis studio, are vehicles for demonstration of the student's scholarly ability within the chosen area of concentration. Generally, students in the first professional degree program are encouraged to undertake the thesis studio option. Students holding previous degrees in landscape architecture are encouraged to do a traditional thesis.

It is possible for students who have extensive professional experience to pursue an abbreviated program of study which includes one year of full-time study plus a thesis (2 semesters x 13 credits of course work approved for graduate credit = 26 credits plus 10 credits of thesis for a total of 36 credits).

Graduate Courses (LAR)

5005-5006: GRADUATE LANDSCAPE ARCHITECTURE DESIGN LABORATORY
Graduate landscape architecture laboratory addressing complex issues of landscape design and planning. The scope of planning and design includes the relationship of specific sites to their larger urban and/or regional contexts. Pre: undergraduate degree in landscape architecture or related field, or permission of instructor. Pre: 4705, 4706. (1H,8L,5C).

5044: LAND ANALYSIS
Introduction to the concepts and methods of ecological resource survey and analysis at regional and site scales. Approaches to environmental problem solving with an emphasis on data collection, evaluation, and synthesis using applicable technologies such as geographic information systems. Interpretation of landscape resource data for the purpose of physical planning and design. Pre: 3004. (2H,2L,3C).

5444: SEMINAR
Special topics, critical reviews, and discussions of pertinent literature in landscape architecture. (1H,1C).

5604: ADVANCED LANDSCAPE PLANNING AND MANAGEMENT
Review of major systems of land resource survey and land evaluation. Intensive study of problems of integrating urban and natural land uses through design and planning strategies. Emphasis on development of land use planning policies which implement management strategies for use, conservation, and protection of land resources. (1H,6L,4C).

5704: ADVANCED LANDSCAPE DESIGN & PLANNING LAB
Studio addressing advanced problems in landscape design and planning. Pre: 5006. (1H,10L,5C).

5724: SCHOLARSHIP IN LANDSCAPE ARCHITECTURE
An overview of scholarship in landscape architecture with emphasis on research approaches and methods pertaining to the advancement of knowledge in the profession. Application of ideas through the completion of a preliminary research project. Pre: Familiarity with landscape architecture or a closely allied environmental planning/ design discipline. Non-majors by consent of instructor. (2H,2L,3C).

5754: THESIS STUDIO
Thesis studio is an alternative to the conventional academic thesis for students pursuing a master's degree in landscape architecture. Thesis studio involves literature review, composition of a position paper grounded in design or planning theory and completion of studio projects(s) that test or demonstrate the theoretical position. Variable credit course.

5964: LANDSCAPE ARCHITECTURE FIELD STUDIES
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6734: DESIGN THEORY AND DECISION MODELS
A comprehensive examination of decision models used by designers in generating physical form (design). A series of decision-models, from a rational choice model to models based on an alternate cosmology, are explored through lecture discussion, reading, and research. The course provides a theoretical basis for design decision-making. (3H,3C)

ADVANCED UNDERGRADUATE COURSES (LAR)

The following 4000-level courses have been approved for graduate credit:

4004: HISTORY AND THEORY OF LANDSCAPE ARCHITECTURE II
This course studies theoretical and practical developments in landscape architecture and related arts through investigation and analysis of design theory and philosophy, and built form. Pre: 2004 or permission of instructor. Pre: 2004. (3H,3C).

4034: EVOLUTION OF THE AMERICAN LANDSCAPE
An examination of physical change in the rural and urban landscape of America as reflected by changes in needs during the country's history. Some of the factors influencing the character, form, and use of American space that will be studied are economic growth, changing philosophies on conservation and exploitation of natural resources and the resulting legislation, technological advancement, and social reform. (3H,3C).

4084: LANDSCAPE DESIGN AND PLANNING STUDIO This course is an advanced studio that enables students to address landscape architectural design and planning issues in various contexts and at a range of scales. Pre: 3016 or permission of instructor. Landscape Architecture majors must take minimum of 6 credits. May be repeated to a maximum of 12 credit hours. Pre: 3016. (1H,11L,6C).

4124 (ARCH 4044): PROFESSIONAL PRACTICE
Introduction to scope and diversity of the building enterprise, addressing private and public macroeconomic, industrial, technical, professional, and regulatory institutions. Analysis of historic evaluation of professional roles and practices; emergence of new modes of practice, including innovative facilities procurement methods. (3H,3C).

4234: THEORY AND PRACTICE OF URBAN DESIGN
This course examines historic and contemporary trends in urban design theory and practice; methods of analyzing urban form; social, cultural, and environmental dimensions of urban design. (3H,3C).

4244: LANDSCAPE ARCHITECTURE TECHNOLOGY II: HYDROLOGY
Landscape architecture hydrology examines water resource issues as they relate to landscape planning, site planning and site design. Key topics include estimation of stormwater runoff, stormwater management, watershed planning/flood routing and impact mitigation, design of open channel conveyances, and erosion and sedimentation control. Pre: LAR 2035 and 2036 or consent of instructor. Pre: LAR 2035, LAR 2036. (2H,4L,4C).

4304: TOPICS IN LANDSCAPE ARCHITECTURE
Topics in landscape architecture history, theory and design methods is an advanced course focusing upon issues facing the professional practice of landscape architecture today. Special emphasis on methods of analysis and interpretation including application of creative techniques, analogous thinking, computer-aided procedures and information handling in landscape architecture design and practice. Pre: 3015 and 3016 or permission of instructor. (3H,3C).

4324: LANDSCAPE ARCHITECTURE TECHNOLOGY III: CONSTRUCTION DOCUMENTS
This course provides the link between landscape architectural design and construction documentation. Landscape technology covered in preceding technology courses is combined with information on construction principles and practices in the preparation of landscape architectural construction drawings and technical specifications. Pre: 4244. (2H,4L,4C).

4705-4706: LANDSCAPE DESIGN AND PLANNING
Theories, methods, techniques, and tools relating to the planning and design of sites, communities, and regional landscapes. 4705: Emphasis on the development of design ability through the study of: two- and three-dimensional design, principles and elements of spatial composition, and theories and techniques for planning and design of small sites. 4706: Emphasis on the evaluation of land resources and the allocation of land uses within large complex sites and regional landscapes. Theories and techniques of site planning and community design are explored. (1H,8L,5C).

MACROMOLECULAR SCIENCE & ENGINEERING (MACR)

J. S. Riffle, Director

Participating Faculty

Chemistry: J. Dillard; W. Ducker; A. Esker; F. Etzkorn; R. Gandour; H. W. Gibson; T. Long; J. McGrath; J. Merola; J. Morris; J. Riffle; L. Taylor; D. Troya; R. Turner; T. Ward
Chemical Engineering: D. Baird; R. Davis; A. Goldstein; E. Kiran; E. Marand; G. Wilkes (Emeritus); K. Forsten-Williams
Civil and Environmental Engineering: T. Cousins; R. Weyers; C. Roberts-Wollmann
Electrical and Computer Engineering: R. Claus
Engineering Science & Mechanics: S. Case; D. Dillard; J. Lesko
Materials Science Engineering: B. Love
Mechanical Engineering: M. Ellis; D. Leo
Physics: J. Heflin
Wood Science & Forest Products: C. Frazier; W. Glasser (Emeritus); A. Zink-Sharp

E-mail: anflynn@vt.edu

Web: www.macro.vt.edu

The Macromolecular Science and Engineering (MACR) program is an interdisciplinary M.S. and Ph.D. program comprised of participating faculty from 9 departments and 3 colleges. The program focuses on a variety of topics in polymer science and engineering. Students choose an area of concentration from the following concentrations: Composites & Structures, Civil Infrastructure, Life Sciences, Adhesion and Surface Science, Opto and Micro Electronics, Mechanics, Synthesis, Processing, and Structure. Students pursuing a M.S. degree must take the 4 MACR core courses (8 hours total), at least 6 credit hours of coursework from their technical concentration module, at least 8 credit hours of electives, and at least 10 credit hours of Research and Thesis (32 total required hours). Students pursing a doctoral degree are required to take the 4 MACR core courses (8 hours total), at least 9 credit hours from their technical concentration, at least 6 credit hours from courses in other MACR modules (other than their module of concentration), at least 9 credit hours of electives, and Research & Dissertation hours sufficient to accumulate 90 total credit hours (~58 hours).

Required Core Courses

MACR

5015: FUNDAMENTALS OF MACROMOLECULAR SCIENCE AND ENGINEERING I: Fundamentals of Macromolecular Science and Engineering with Laboratory. Two weeks will be devoted to each of seven subjects (Chain Growth Polymerization, Molecular Weight Determination, Morphology and Structure, Infrared Analysis Methods in Polymer Science and Engineering, Thermal Analysis of Polymers, Constitutive Mechanical Properties of Polymers, and Rheology). Two hours of lecture per week provides both the fundamentals and a discussion of the experimental methods for the topic and one three-hour laboratory session per week enables the students to learn via a "hands-on" approach. These courses are team-taught by multiple faculty to achieve the breadth and depth intended. One faculty member coordinates and provides administration for the courses and a laboratory instructor teaches the experimental components. (5H, 3C)

5016: FUNDAMENTALS OF MACROMOLECULAR SCIENCE AND ENGINEERING II: Fundamentals of Macromolecular Science and Engineering with Laboratory. Two weeks are devoted to each of seven subjects (Step Growth Polymerization, Wettability of Polymers, Surface and Adhesive Analysis of Polymers, Rubber Elasticity of Polymers, Optical Properties of Polymers, Fracture Behavior of Polymers, and Molding and Extrusion of Polymers). Two hours of lecture per week provide both the fundamentals and a discussion of the experimental methods, and one three-hour laboratory session per week enables students to learn via a "hands-on" approach. (5H, 3C)

CHEM/CHE/ASE

5014: COMMUNICATION SKILLS & METHODS OF PRESENTATION: Methods and style to make effective technical and non-technical presentations, including blackboard presentations, overhead presentations, computer projection presentations, and research poster presentations. Presentations are videotaped and peer reviewed. (2H, 1C)

MACR

5024: WRITING AND LITERATURE FOR MACROMOLECULAR SCIENCE AND ENGINEERING: This course emphasizes methods for preparing a manuscript for submission to a refereed technical journal. This technical literature and writing course incorporates formal peer review and in-class critiques. 5014: (2H,1C)

COURSE SELECTION FOR TECHNICAL CONCENTRATION MODULES IN MACROMOLECLAR SCIENCE AND ENGINEERING:

SYNTHESIS
CHEM 4534 Organic Chem. of Polymers
CHEM 5704 Synthesis of Macromolecules
CHEM 6564 Current Topics in Polym. Chem.
Choice of
CHEM 5505 or 5506 Adv. Org. Chem.
CHEM 5535 or 5536 Syn. Org. Chem.
CHEM 5045 Molecular Struct. Deter.
CHE 5984 Interfacial Chemistry & Engr.

MECHANICS
Choice of:
ESM 4044 Mech. of Composite Materials
ESM 4054 Solid and Structural Mechanics
ESM 5014 Intro. to Continuum Mechanics
ESM 5734 Intro. to Finite Element Analysis
CHEM/ESM 5174 Polymer Viscoelasticity
ESM/ChE 5564 Non-Newtonian Fluid Mechanics
ESM 5514 Viscous Flow
ESM 6104 Mech. of Comp. Strength and Life

PROCESSING
ESM 4054 Solid and Structural Mechanics
ChE 4224/MSE 4524 Intro. to Polym. Proc.
ChE 5224 Adv. Polymer Processing
MSE 5504 Polymer Deform. & Fracture
ESM 5514 Viscous Flow
ESM/ChE 5564 Non-Newtonian Fluid Mech.
CHE 5984 Interfacial Chemistry & Engr.

LIFE SCIENCES
BCHM 5984 Molecular Modeling of Proteins & Nucleic Acids
BCHM 5304 Enzyme Kinetics & Reaction Mechanisms
BCHM 5224 Protein Structure & Function
BCHM 4104 Bioinformatics
WOOD 6424 Structural Biopolymers & Biocomposites
CHEM 4534 Organic Chem. of Polymers

STRUCTURE
CHEM 6674 Physical Chem. of Polymers
CHEM/ESM 5174 Polymer Viscoelasticity
CHE 5984 Interfacial Chemistry & Engr.
CHEM 4534 4534 Org. Chem. of Polymers

ADHESION AND SURFACE SCIENCE
CHEM/ESM/MSE 5654 Adhesion Science
CHEM/ESM 5174 Polymer Viscoelasticity
CHEM 5644 Colloid and Surface Chemistry
CHEM 6674 Physical Chem. of Polymers
ESM 5264 Mechanics of Adhesive Bonding
MSE 5504 Polymer Deform. & Fracture

OPTO- AND MICRO-ELECTRONICS
Phys. 5984 Opto-electronic Prop. of Polymers & Macromolecules
Choice of
  CHEM 4534 Organic Chem. of Polymers
  ChE 4224/MSE 4524 Intro. to Polym. Proc.
  MSE 4554 Polymer Engineering
Choice of
  EE 5144 Intro. to Electro-Optics
  MSE 5214 Opto-electronics/Mag. Appl.
  Phys. 5614 Intro. to Quantum Electronics

CIVIL INFRASTRUCTURE
CEE 5984 Degradation of Structural Materials
ESM 4044 Mech. of Composite Materials
ESM 5204 Composites Mfg.
CHEM/ESM 5174 Polymer Viscoelasticity
MSE 5504 Polymer Deform. & Fracture
CEE 5684 Rehabilitation of Bridges
CEE 5484 Adv. Bridge Design

COMPOSITES & STRUCTURES
Choice of:
ESM 4054 Solid and Structural Mechanics
  ESM 4044 Mech. of Composite Materials
  MSE 4604 Adv. Composite Materials
ESM 5204 Composites Mfg.
ESM 5074 Mech. of Laminated Comp. Str.
ESM 6104 Mechanics of Comp. Str. & Life
CHEM/ESM 5174 Polymer Viscoelasticity
MSE 5504 Polymer Deform. & Fracture

MANAGEMENT

Richard E. Wokutch, Head

Digges Professor of Entrepreneurship: S.E. Markham
Strickler Professor of Entrepreneurial Studies: J.R. Lang
Pamplin Professor of Management: R.E. Wokutch
Professors: M.K. Badawy; T.W. Bonham
Associate Professors: L.D. Alexander; K.D. Carlson; A.T. Cobb; M.L. Connerley; J.L. French; D.E. Hatfield; D.R Gynawali; K.F. Murrmann; C.P. Neck; L..H. Poppo; W.J. Smith; L..F. Tegarden
Assistant Professors: J.B. Arthur
Emeritus Faculty: R.M. Madigan; M.C. Schnitzer; J.F. Robinson; J.M. Shepard; C.U. Stephens
Career Advisor: C.P. Neck (231-4559)

E-mail: wokutch@vt.edu
Web: www.cob.vt.edu/mgmt/

Faculty in the Department of Management provide a multi-disciplinary approach to the traditional areas of management study: organization behavior, organization theory, strategic management, social issues, business ethics, human resources management, and labor & employee relations. Across these areas the Department of Management offers graduate studies leading to the MBA with a concentration in management and to the Ph.D. in business with a major in management.

The MBA is a non-thesis degree program that provides students seeking careers in either the private or public sector with a broad background in the functional areas of business. All students complete the MBA core curriculum and may then select a management concentration in Leadership through the selection of appropriate electives.

The MBA Leadership Concentration is a twelve-hour integrated set of courses that equips students for leadership positions through study of behavioral, economic, technical and ethical dimensions of leadership.

The Ph.D. program in business with a major in management prepares students for an academic career in university research and teaching. The doctorate is designed as a four-year program that offers a series of foundation seminars that integrate theory and research in strategic management, organization theory, and organization behavior. After completion of the basic seminars, students may specialize in any of several management subdisciplines, including organization behavior, strategic management, social issues and labor and employee relations. Each doctoral student is required to complete a minimum of one semester as a teaching assistant and two semesters as a research assistant.

General requirements for the MBA and Ph.D. are provided in the sections of this catalog entitled "Requirements for Master's Degrees" and "Requirements for the Doctor of Philosophy (Ph.D.)."

GRADUATE COURSES (MGT)

5304: SOCIAL, LEGAL & ETHICAL ENVIRONMENT OF BUSINESS
Analysis of the social, legal, and ethical environment of the corporation that impacts upon its operations. Social, legal, and ethical implications of such topics as business-government relations, pollution issues, monopolies and antitrust regulation, discrimination and affirmative action, multinational operations, product and workplace safety, and corporate social responsibility will be considered. X-grade allowed. (3H,3C).

5314: DYNAMICS OF ORGANIZATION BEHAVIOR
This course examines the determinants and consequences of human behavior in formal organizations. The specific graduate focus is on understanding the individual, interpersonal, and group processes which underlie all human dynamics. X-grade allowed. (3H,3C).

5324: ORGANIZATION THEORY & DESIGN
This course is based upon behavioral science concepts and research findings directed toward the understanding of organizations as systems. Specific focus will be on the design of the structure and procedures of complex organizations to meet both internal and environmental demands. Pre: 5314. (3H,3C).

5334: MANAGING CHANGE THROUGH LEADERSHIP: INDIVIDUAL & TEAM DEVELOPMENT
This course examines techniques for successfully managing change in formal organizations through a variety of individual and team based methods. Both practical techniques and theoretical perspectives for leadership development will be emphasized within the context of improving organizational effectiveness. Consent required. X-grade allowed. Pre: 5314. (3H,3C).

5344: LEGAL ENVIRONMENT OF EMPLOYEE RELATIONS
Legal environment in which labor-management relations occur, with emphasis on federal labor laws and socioeconomic causes for their passage. (3H,3C).

5364: EMPLOYEE RELATIONS IN THE PUBLIC SECTOR
Employee relations in the public sector. Study of the evolution of public sector employee-management relations with emphasis on private-public sector differences, growth of employee organizations, and bargaining relations and procedures at the federal, state, and local levels. (3H,3C).

5384: ETHICAL DIMENSIONS OF LEADERSHIP
This course examines conduct in business within the context of moral philosophy. Emphasis is placed on the relevance of philosophical theories of morality to leadership and decision making in organizations. (3H,3C).

5394: CURRENT POLICY ISSUES IN PERSONNEL & LABOR RELATIONS
Consideration and analysis of relevant current policy issues in the fields of personnel management and labor relations. Emphasis both on macro policy issues and their implementation at organization level. (3H,3C).

5404: MBA CAREER PLANNING
This course is designed to improve career success and satisfaction of MBA students. Students use the Success-Related Observable Behaviors Model (SROB) to identify behaviors that are critical to their chosen career roles. Students assess their mastery of those behaviors with which to improve the effectiveness of their career search through changed behaviors or changed objectives. Strategies for developing networks of individuals and organizations are covered. Assignments emphasize a progressive process for creating a features profile that differentiates the student's self-promotion from that of competitors. MBA students only. Must be enrolled in first semester MBA core courses. (1H,1C).

5414: MBA JOB SEARCH STRATEGY
The Success-Related Observable Behaviors (SROB) model will be used to understand role-specific interviews. Also introduced are alternate interview concepts, such as the case interview, industry/field targeted interviews, and panel interview strategy. Legal vs. illegal interview questions and how to respond to them without impairing one's candidacy are covered. Students learn how specific salary offers are determined given a company's job evaluation approach and hiring philosophy. The concept of "basis" for salary negotiation is introduced, as well as appropriate responses to low offers allowing for further negotiation. The ethics of recruitment is addressed, including ethical behavior expectations for candidates, recruiters and career services professionals. MBA students only. Must have completed the first year of MBA core courses. Pre: 5404. (1H,1C).

5604: TEAM DEVELOPMENT
An introduction to teams in management for executive MBA students. This course considers the justification for team formation. Practical consideration for developing teams to improve personal and organizational effectiveness are covered. The course considers effective team building in organizations where significant diversity is present. A practical exercise is a key part of this course. Executve MBA students only. (1H,1C).

5614: GLOBAL ORGANIZATIONAL BEHAVIOR
This course focuses on the implications of globalization and the resulting cross-cultural relationships for leaders and managers of business organizations. The ways in which culture affects characteristics of individuals, interpersonal relationships, negotiation styles, and leadership practices are examined. Cases and exercises develop skills in applying theories and concepts to concrete situations. Executive MBA students only. (2H,2C).

5624: TECHNOLOGICAL INNOVATION FOR COMPETITIVENESS
This course provides EMBA students with an understanding of the managerial issues, processes, tools, and skills necessary for the effective organization and management of technology (MOT). It will help practicing managers develop awareness and appreciation of managing technology as a central tool for achieving technological innovation and competitive advantage. An in-depth examination of the nature of MOT as both a discipline and a practice will be emphasized. The focus will be on a detailed analysis of the issues involved in managing the four components or subsystems of MOT: Research and Development (R&D) Management, Product Technology Management, Process Technology Management, and Information Technology Management. The course's domain will be both the service and manufacturing industrial sectors. Executive MBA students only. (2H,2C)

5634: STRATEGIC BUSINESS ENVIRONMENT
Course focuses on tools and techniques for industry and competitive analysis and describes methods used by organizations to develop and sustain a competitive advantage. Examples and cases from current business, single- and multi-business corporations in a variety of industries will be studied. Executive MBA students only. (2H,2C).

5644: LEADERSHIP IN A TECHNOLOGY ENVIRONMENT
This course focuses on the role of the manager as leader in the crafting of corporate and business strategies where technology provides the basis for the firm's competitive advantage. Students learn to understand the complex nature of integrating the work of people in multiple functions, and the challenges of managing innovations and the impacts of innovation upon organizations. Executive MBA students only. (2H,2C).

5654: INTERNATIONAL STRATEGY AND CULTURE
Students complete this course during an international trip. The class requires interaction with business professionals and government officials as well as participation in lectures. The course will illustrate strategies that have led to business success (or failure) outside the U.S. Students will experience some aspects of international culture and consider how the local environment affects commerce. Executive MBA students only. (2H,2C).

5664: BUSINESS ETHICS AND CULTURE
This course examines significant issues in business ethics and the forms they take in different cultures. A stakeholder approach is adopted and attention is focused on firms' relationships with four important stakeholders: employees, consumers, governments, and communities. Skills at stakeholder analyses are developed through the application of various ethical theories to case studies of problems

encountered in different cultures. Creativity in resolving conflicts among stakeholders with different values and interests is fostered through participation in experiential negotiation exercises. Executive MBA students only. (1H,1C).

5674: LEADERSHIP FOR CHANGE MANAGEMENT
Study methods for changing organizations and individuals within organizations using organizational transformation techniques, information technologies, and different leadership/personality styles. Executive MBA students only. (2H,2C).

5684: GLOBAL STRATEGIC MANAGEMENT
This course focuses on management challenges associated with global competition and the ways in which firms can create and sustain superior returns by formulating and implementing effective strategies. It will integrate knowledge and skills students have gained in other MBA classes. The course will help students to develop an integrated, multi-functional, "general management" perspective of the organization. Comprehensive case studies of large firms will be used to develop students' skills in strategic thinking, analysis, and execution. Strong emphasis will be placed on the global environment. Executive MBA students only. (2H,2C).

5694: SEMINAR IN CURRENT BUSINESS ISSUES
This course will address current issues in business with content changing each time it is offered. Topics may include theoretical, conceptual, and practical concerns in business-related functions such as accounting, information systems and technology, finance, management, or marketing. Executive MBA students only. (1H,1C).

5704: HUMAN RESOURCE MANAGEMENT
A study of the scope of personnel administration practices in both the private and public sectors of American industry. Emphasis is placed on the procedures and techniques currently used in manpower planning, recruitment, selection, evaluation, compensation, and training and development of employees in an organization. (3H,3C).

5714: HUMAN RESOURCE STAFFING & DEVELOPMENT
This course is designed to integrate theoretical, legal, and pragmatic considerations pertaining to the acquisition, deployment, and development of human resources within organizations (public and private sector). The course adopts a management perspective in which emphasis is placed on the design and implementation of staffing and development processes to achieve organizational objectives within social and economic constraints. (3H,3C).

5724: COMPENSATION & REWARDS SYSTEMS
Study of employee compensation theory and practice in private and public sector organizations. Special emphasis is placed on wage and incentive program design techniques and administrative considerations, and their theoretical justifications. (3H,3C).

5744: EMPLOYEE RELATIONS
This course examines employee relations policies and practices in modern business organizations. A comparative assessment of U.S., European, Japanese and other systems of employee relations in union and nonunion settings will be included. (3H,3C).

5754: DISPUTE RESOLUTION TECHNIQUES/SIMULATIONS
Examination of the various techniques which leaders increasingly utilize in the resolution of disputes in a global society, including negotiation, mediation, fact finding, med-arb, and different varieties of arbitration. Different work settings are utilized whereby teams become involved in simulated disputes. The practical applications in different global settings illustrate the theoretical bases of the techniques. Both private and public as well as different cultural settings are included. Senior standing. (3H,3C).

5764: APPLIED HUMAN RESOURCE INFORMATION SYSTEMS
Applied human resource information systems is the study of how human resource information systems (HRIS) can and should be applied in organizations to support organization strategy, improve efficiency and flexibility, increase productivity, and improve the quality of work life for all employees. Pre: Graduate standing. (3H,3C).

5784: INTERNATIONAL MANAGEMENT
This course focuses on the management challenges associated with the development of strategies and the management of organizations in business enterprises whose operations stretch across national boundaries. It will provide students with the knowledge, skills, and sensitivities that will help them manage more effectively in an international environment. Pre: 5314. (3H,3C).

5794: STRATEGIC MANAGEMENT
Examines business policy through a study of general management's task of strategy formulation and implementation. Comprehensive case studies concerning a variety of organizations serve as a basis for analysis. Pre: Final term MBA standing. (3H,3C).

5804: STRATEGIC LEADERSHIP IN TECHNOLOGY-BASED ORGANIZATIONS
This course focuses on the role of the leader in crafting corporate and business strategies where technology provides the basis for the firm's competitive advantage. (3H,3C).

5814: ENTREPRENEURIAL LEADERSHIP
Concepts and techniques for providing leadership in the entrepreneurial venture. Provides the theoretical understanding of the entrepreneurial process in the economy as well as the practical leadership, marketing, financial and production considerations for entrepreneurial initiatives for new ventures and established firms. (3H,3C).

5824: ADVANCED LEADERSHIP: SKILLS & CONCEPTS
This cornerstone course provides innovative experiences, skills, and knowledge in leadership for MBA students. Within an historical context that balances military, political and business perspectives, four types of leadership will be examined: self-leadership, dyadic leadership, team leadership, and enterprise leadership. Special emphasis will be placed on the specific skills, such as computer literacy and project management, required for leaders to succeed in modern, technologically oriented organizations. Pre: Graduate standing. Pre: 5314. (3H,3C).

5834: ESSENTIALS OF MANAGEMENT OF TECHNOLOGY
This course focuses on providing MBA students with a thorough understanding of the managerial issues, processes, tools, and skills necessary for the effective organization and management of technology (MOT). The goal is to help students develop an awareness and appreciation of the complex task of managing technology at the micro-level of the organization. An in-depth examination of the nature of MOT as both a discipline and a practice will be emphasized. The course will focus on analyzing the central issues involved in managing the four subsystems of MOT: (1) Research and Development (R&D) Management; (2) Product Technology Management; (3) Process Technology Management; and (4) Intellectual Capital Management. The course's domain will be both the service and manufacturing industrial sectors. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C)

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

6104: ADVANCED RESEARCH STUDIES
Students will carry out a theoretical or empirical research project, produce a research paper, present the research findings to the departmental faculty and students, and submit the manuscript for presentation at a professional meeting or for publication in an academic journal. Pre: Six hours of graduate statistics, completion of the first year of the management doctoral program. (3H,3C).

6305-6306: SEMINAR IN STRATEGIC MANAGEMENT
An analysis of activities that fall within the purview of general management and which typically relate to the firm as a whole. Special emphasis is placed on that research dealing with the tasks and responsiblities of general management and currently evolving subjects. Pre: 5794. (3H,3C).

6315-6316: SEMINAR IN ORGANIZATION BEHAVIOR
A study of the nature of organization behavior and the processes pertinent to organizational effectiveness. The first course deals with the classical theory while the second concerns itself with current research. Pre: 5314. (3H,3C).

6325-6326: SEMINAR IN ORGANIZATION THEORY
A thorough chronological and analytical study of the development of organization theory which concentrates on macro-level organizational issues from its genesis to the present day. Pre: 5324. (3H,3C).

6344: SEMINAR IN SOCIAL ISSUES IN MANAGEMENT
Examination of the role of business in society as defined by its relationships with consumers, employees, stockholders, government, and other corporate stakeholders. Emphasis is on examination of and learning to do research on the relationships between business and these stakeholders. Pre: 5304. (3H,3C).

6354: SEMINAR IN LEADERSHIP RESEARCH IN FORMAL ORGANIZATIONS
This course is designed to develop a doctoral-level research framework for analyzing the role of the leader or manager in formal work settings. The major theoretical position, empirical models, and methodological techniques for analyzing leadership will be examined. Pre: 5314. (3H,3C).

6364: ADVANCED SEMINAR IN LABOR RELATIONS
Examination of various aspects of labor relations from both a macro and micro perspective with emphasis on contemporary labor theories and their application in the labor-management interactions. May be repeated once. (3H,3C).

6374: SEMINAR IN ADVANCED TOPICS IN HUMAN RESOURCES MANAGEMENT
A course designed for doctoral students with a special emphasis on existing research and writings which contribute to understanding the constraints and opportunities for effective management of the human resource. (3H,3C).

6384: TOPICS IN BUSINESS ETHICS
This course, through coverage of varying topics, is designed to develop knowledge of the moral dimensions of business. Coverage includes major philosophical theories of morality and the place of ethics in business. (3H,3C)

7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (MGT)

The following 4000-level courses have been approved for graduate credit:

4104 (FL 4104): GLOBAL CULTURE
This course will examine problems of cultural differences using an interdisciplinary approach combining business studies with cultural studies in the humanities and social sciences. It will address issues related to living and working with people from other countries or cultures, whether domestically or abroad. It will also explore the impact of globalization on various aspects of culture. Junior standing required. (3H,3C).

MARKETING

Kent Nakamoto, Head

PMAC-V Professor of Purchasing: J.R. Brown
Robert O. Goodykoontz Professor of Marketing: D. Brinberg
R. B. Pamplin Professor of Marketing: K. Nakamoto
Professors: E.F. Fern; J.E. Littlefield; M.J. Sirgy
Associate Professors: E. Coupey; J.E. Keith; N.M. Klein; J.L. Ozanne
Assistant Professors: C.J. Lambe; A.M. Parker
Career Advisor: D. Rieley (231-5759)

E-mail: nakamoto@vt.edu
Web: www.cob.vt.edu/

Marketing consists of the spectrum of activities that join production of goods and services with the consumer or industrial user. Marketing management consists of planning, implementing, and controlling marketing activity. Included among these activities are such things as helping to design products or services to satisfy customers' needs, designing pricing strategies to achieve profitable utilization of resources, implementing distribution procedures to obtain a smooth flow from production to use, and evaluating the personal selling and advertising operations to assure that users have sound bases for their buying choices. Marketing management is closely affiliated with such social and behavioral sciences as economics, sociology, and psychology, as well as such quantitative disciplines as accounting, statistics, management science, and computer science.

The marketing faculty offers a master's and a doctoral degree. At the master's level, students may pursue an M.B.A. with a concentration in marketing or an M.S. in business administration degree with a major in marketing. A course program may be selected that enables a student to pursue specific career objectives in marketing management or marketing research.

The primary objective of the doctoral program is to prepare students for careers in college or university teaching and research. Each plan of study is tailored to the individual's academic interests in marketing. However, all students are expected to take courses in marketing theory and research methodology. All doctoral students are required to complete two semesters as a teaching assistant and two additional semesters as a research assistant.

GRADUATE COURSES (MKTG)

5004: FUNDAMENTALS OF MARKETING
Intensive study of the principles and process of marketing management. Pre: ACIS 5104, STAT 5624. (3H,3C).

5104: MARKETING POLICY & STRATEGY
Principles and processes of strategic marketing planning. Emphasis on development and implementation of marketing plans and programs. Comprehensive case studies are used as the basis for analysis. Pre: ACIS 5104, STAT 5624. (3H,3C).

5154: RESEARCH FOR MARKETING DECISIONS
The course encompasses: problem formulation, research design, data gathering instruments, scaling, sampling, data analysis for making marketing-related decisions, and solving marketing-oriented problems. Pre: 5004 or 5104. (3H,3C).

5204: BUYER BEHAVIOR
Marketing management's use of explanatory and predictive models concerning buyer/market behavior in establishing marketing policy and strategy. Pre: 5004 or 5104. (3H,3C).

5254: PRODUCT STRATEGY
Strategic product planning and new product development within the context of marketing. Topics include the role of the product manager, strategic marketing planning, product/market identification, new product development, and diffusion of innovations. Pre: 5104. (3H,3C).

5264: PRICING STRATEGY
Emphasis on pricing strategy. Economic, financial, legal, and marketing principles are integrated to analyze pricing decisions. Behavioral implications of pricing are also considered. Pre: 5104. (3H,3C).

5304: PROMOTION STRATEGY
Emphasis on understanding and applying the principles of marketing communication from a managerial perspective. Course examines the marketing communication activities of an organization focusing on the economic, sociological, and psychological aspects of behavior. Pre: 5104. (3H,3C).

5354: MARKETING CHANNELS AND DISTRIBUTION
Design, evaluation, and management of marketing distribution channels. Topics include channel member roles and behavior; transportation, inventory, materials handling, and information management; channel performance evaluation; and distribution channel modeling. Pre: 5104. (3H,3C).

5504: MARKETING & THE INTERNET
This course extends students' knowledge of marketing skills by building on basic principles of marketing management to understand and develop theoretical and practical approaches to marketing strategy that leverage the information technologies of the Internet. Topics include the characteristics of the Internet as a marketing environment; perspectives of agents (e.g., consumers, marketers, technologists) within the Internet environment, and implications of the Internet for strategic marketing and marketing management. Pre: 5104. (3H,3C).

5554: BUSINESS MARKETING MANAGEMENT
Business marketing is a course designed to familiarize the student with the environmental framework and major managerial problems in businesses marketing to other businesses, nonprofit organizations, governments, and those in other countries. It is also the purpose of this course to acquaint the student with the professional and operational literature of business marketing. Pre: 5104. (3H,3C).

5564: MARKETING OF HIGH TECHNOLOGY
This course covers the unique nature of demand for high tech products and applies the basic elements of marketing strategy–market segmentation and targeting, marketing mix elements–to the context of high technology. It also addresses the development of effective strategic, marketing plans for high technology goods and services. Pre: permission of instructor and 5104. (3H,3C).

5604: MARKETING PRINCIPLES
An introduction to marketing management for executive MBA students. Considers the principles and processes of marketing planning in business and non-profit organizations. Executive MBA students only. (2H,2C).

5614: MARKETING ANALYSIS AND STRAGTEGY
Study of methods for analyzing customers (particularly market segmentation), diagnosing competitive market structure, and forecasting demand and the use of this information to develop marketing strategy. Executive MBA students only. (2H,2C).

5624: BUSINESS NEGOTIATIONS
The course addresses the practice of successful negotiations in business, including the business activities of marketing, operations, finance, and information management. This course utilizes behavioral principles of negotiation to develop and refine students' understanding and practice of effective negotiating skills. Executive MBA students only. (2H,2C).

5704: INTERNATIONAL MARKETING STRATEGY
This course provides the background to make managerial marketing decisions at the international level. It is composed of four sections: macro dimensions of international marketing, e.g., culture, politics, and economics; international comparative marketing systems; international marketing management decisions; and international strategic planning and control. Pre: 5004 or 5104. (3H,3C).

5754: DEVELOPMENT OF INTERNATIONAL MARKETING PLANS
This course is concerned with the development of international marketing strategies for firms in Virginia. Group projects are used to expose students to the details of business firms and to give “hands on” experience in developing international strategies. Pre: 5104. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT AND REPORT
Variable course credit

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6105-6106: ADVANCED TOPICS IN MARKETING
6105: Seminar in marketing theory, marketing research, buyer behavior, and marketing strategy. Emphasis on conceptual and methodological developments in marketing. 6106: Seminar in marketing management. Emphasis is placed on conceptual and methodological developments and quantitative decision models in promotion management, product and price management, channel of distribution management, and sales force management. May be repeated for credit up to 9 hours each. (3H,3C).

6214: MARKETING THEORY
Issues related to research quality such as validity and reliability of measures, marketing theory construction and evaluation, philosophical foundations of research, and research values. Alternative methodological approaches for marketing research are also explored at a conceptual level. X-grade allowed. Pre: 6105, 6106. (3H,3C).

6224: ADVANCED MARKETING RESEARCH
Issues related to research design, measurement and scaling, and data collection procedures. Methods for doing integrative research reviews are also covered. Six hours of graduate statistics required. Pre: 5154, 6214. (3H,3C).

6304: SEMINAR IN BUYER BEHAVIOR RESEARCH
This course applies current psychological, social psychological, sociological, communication, and economic theories and research to the study of buyer behavior phenomena. Emphasis is placed on recent research findings and methodologies in buyer behavior. Pre: 5154. (3H,3C).

6404: ADVANCED QUANTITATIVE MARKETING METHODS
Theory, method, and application of selected quantitative methods for marketing: linear structural relations, path analysis, canonical and discriminant analysis, and exploratory and confirmatory factor analysis. Special purpose methods such as conjoint analysis, multidimensional scaling, cluster analysis, and recent methodological developments also will be covered. Pre: 5154. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

M001: PRINCIPLES OF MARKETING
Mini course. Provides a foundation in basic principles of marketing. Off Campus/Distance Learning course.

S002: MARKETING STRATEGY
Short course. Provies an introduction to the topic of marketing strategies. Off Campus/Distance Learning course.

MATERIALS SCIENCE & ENGINEERING

UNIVERSITY EXEMPLARY DEPARTMENT *

D.E. Clark, Head

Langley Professor: K.C. Logan
Willis Worcester Professor: R.O. Claus[1]
Professors: D.E. Clark; N.E. Dowling[2]; D. Farkas; B.J. Love; G-Q. Lu[1]; W.T. Reynolds, Jr.; D.D. Viehland
Associate Professors: L.V. Asryan; S.G. Corcoran; L.J. Guido[1]; S.L. Kampe
Assistant Professors: P.K. Lu; M.C. Paretti; G.R. Pickrell; Y. Wang
Research Associate Professors: J-F. Li; C.T.A. Suchicital
Research Assistant Professor: Jie-Fang Li; C.T.A. Suchicital
Instructor: C.B. Burgoyne
Adjunct Professors: A. Amith; R.G. Kander, V.I. Levit, H.F. Wu
Adjunct Assistant Professors: M.M. Julian
Affiliated Faculty[3]: A.O. Aning[a]; J.R. Heflin[b]; R.W. Hendricks[c]; R.H. Yoon[d]

[1] Joint appointment with Electrical and Computer Engineering
[2] Joint appointment with Engineering Science and Mechanics
[3] Faculty with regular appointments in other departments: (a) EF, (b) PHYS, (c) ECE, and (d) MINE.

E-mail: msegrad@vt.edu
Web: http://www.mse.vt.edu

The Department of Materials Science and Engineering awards the M.S. (thesis required), the M.E. (non-thesis), and the Ph.D. in materials science and engineering. Candidates for these degrees must hold, or be pursuing, a degree in any branch of engineering, physics, chemistry, geological science, or mathematics.

Specialization is available in: 1) structure and properties of crystalline and non-crystalline materials, 2) materials synthesis, processing, and fabrication, 3) theoretical understanding and computer modeling of materials structures, properties and processes, 4) phase transformations, 5) thermodynamics and phase equilibria, 6) diffusion and kinetics of solid state reactions, and 7) mechanical, thermal, electrical, optical, magnetic property characterization of all material types.

SPECIAL FACILITIES

Specialized laboratories permit research in the following areas: thermodynamics and phase equilibria; materials corrosion and stability; x-ray diffraction and crystal structure determination; phase transformations, precipitation hardening and diffusion in materials systems; electron (STEM, SEM, ESEM) and optical microscopy; mathematical modeling and computer simulation of structure, defects and processes; surface characterization of materials by ESCA; materials synthesis, processing and fabrication; characterization of residual stresses in materials, fabrication of thin film electronic and optical materials, mechanical alloying of metals; composite material fabrication and characterization; and electrical, optical, thermal, and mechanical property characterization of ceramics, metals, polymers and glasses including composites, thin films, dielectrics and semiconductors.

Major research facilities include optical and transmission electron microscopy; an environmental scanning electron microscope; x-ray diffraction equipment including facilities for the measurement of residual stresses in materials; surface analysis instruments; mechanical testing frames; instruments for measuring the thermal response of materials including thermal expansion, thermal diffusivity, and differential thermal analysis; sputtering, thin film and vacuum deposition equipment; heat treatment and sintering furnaces; a metal melt spinner; mechanical alloying ball mills; dry and hot isostatic presses; electrical and dielectric characterization instruments; polymer processing and characterization equipment; and computer modeling and simulation facilities including access to multimedia and computer visualization facilities.

Financial aid in the form of graduate assistantships and tuition scholarships/waivers are available to all qualified graduate students. Recipients of assistantships may be assigned either teaching and/or research activities depending upon available funding, student interest, and departmental requirements.

GRADUATE COURSES (MSE)

5014 (CHE 5014) (CHEM 5014): PRESENTATION SKILLS
Methods and style to make effective technical and nontechnical presentations including blackboard presentations, overhead presentations, slide presentations and research posters. Video presentations with critiques. (1H,1C).

5015,5016: MSE SEMINAR
Materials Science and Engineering students are required to register for and participate in Materials Science and Engineering Seminar during every semester of residency. Masters of Science or Engineering students must present one seminar during the course of their studies; Ph.D. students must present two seminars during their tenure. Provides training in the organization, preparation, and presentation of technical information. Pre: Graduate standing in MSE. Pass/Fail only. (1H,1C).

5024: MATHEMATICAL METHODS IN MATERIALS RESEARCH
Analytical and numerical techniques applied to problems in materials science. Translating physical information into a mathematical model, obtaining a solution by selecting and applying suitable mathematical methods, applying modern computing tools, and interpreting the meaning and implication of the mathematical solution in terms of the appropirate theories of materials science. An undergraduate science or engineering degree and mathematics through differential equations required. (3H,3C).

5025,5026 (MESC 5025, 5026): ELEMENTS OF MATERIALS SCIENCE AND ENGINEERING
5025: The structure and thermodynamics of materials are introduced. Topics include bonding, crystal structure and symmetry, defects, and thermodynamic stability. Elementary aspects of transport processes such as heat, mass, and fluid flow are presented. 5026: How physical and mechanical properties of a material are represented and measured. (4H,4C).

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

5034: STRUCTURE & PROPERTIES OF MATERIALS
An introduction to descriptions of the structure of matter and materials properties. Bravais lattices, Miller indices, reciprocal space, stereographic projections, symmetry and crystal defects. Matrix methods for calculating crystal directions, lengths and angles. Tensor descriptions of properties. Diffraction and scattering from crystals. Undergraduate physical sciences or engineering degree required. (3H,3C).

5044: POWDER PROCESSING
Theoretical consideration of variables in treatment of metal and ceramic powders and solution of compacting and sintering problems. Pre: 5165. (3H,3C).

5054: ADVANCED MATERIALS THERMODYNAMICS
Material systems with particular emphasis on alloys. Thermodynamic relationships. Experimental and computational methods for the determination of the thermodynamic properties of alloys. Applications in alloying, heterogeneous reactions, and the thermodynamics of surfaces. Pre: 4034. (3H,3C).

5064: DIFFUSION & KINETICS
Theories of diffusion mechanisms in solids. Solutions of governing differential diffusion equations. Classic nucleation theory, spinodal decomposition, diffusion-controlled growth kinetics, overall transformation kinetics. Pre: 5054, 5024. (3H,3C).

5104: COMPOSITE MATERIALS
The application of the fundamental concepts of mechanics, elasticity, and plasticity to multiphase and composite materials. Constitutive equations for the mechanical and physical properties of metal, ceramic, and polymeric matrix composites. The role of processing and microstructure on properties. Undergraduate degree in engineering or science required. (3H,3C).

5114: INTRODUCTION TO MATERIALS CHARACTERIZATION
Introduction to techniques used to characterize material structure and chemistry. Physical principles behind surface and microanalysis techniques and the information various techniques provide. X-ray, electron, ion, vibrational, and absorption spectroscopy and optical, electron, and acoustic microscopy. Undergraduate degree in physical sciences or engineering required. (3H,3C).

5124: MATERIALS OPTIMIZATION THROUGH DESIGNED EXPERIMENTS
Methods of analysis of variation in materials systems, in manufacturing or R&D, through the use of statistical methods including experimental design techniques (DOE) with instructional examples related to Materials Science and Engineering. Undergraduate physical sciences or engineering degree required. (3H,3C).

5134: HIGH TEMPERATURE BEHAVIOR OF MATERIALS
Recovery and creep behavior of metals and ceramics at elevated temperatures. Microstructural modifications during creep, effect of microstructural variables on creep, and fracture at elevated temperatures. Stress and temperature dependence of creep rates. Time-temperature correlations for temperature-variant conditions. (3H,3C).

5144 (ESM 5144): DEFORMATION & FRACTURE OF MATERIALS
Deformation and fracture of engineering materials is considered in the context of solid mechanics and engineering methods for predicting strength and life. Topics include plasticity, failure criteria, fracture mechanics, crack growth, strain-dased fatigue, and creep. Microstructure-property relationships are discussed. Laboratory demonstrations of behavior in mechanical tests are included. Partially duplicates material in ESM 4024 and both should not be taken. (3H,3C).

5164: PRINCIPLES OF CORROSION & ELECTROCHEMICAL PROCESSES
Introduction to the principles of materials corrosion and corrosion protection. Topics include: thermodynamics of materials corrosion, including potential-pH (Pourbaix) diagrams; kinetics of corrosion reactions and mixed potential theory, types of corrosion (uniform, galvanic, crevice, pitting, fatigue, stress corrosion cracking, intergranular, and hydrogen embrittlement), material/environmental factors that promote or prevent the various types of corrosion, and methods and techniques of corrosion testing. Undergraduate physical sciences or engineering degree required. (3H,3C).

5174: ADVANCED PHYSICAL CERAMICS
Characteristics of vitreous and crystalline inorganic nonmetallic materials. Application and discussion of effects of composition and microstructure on thermal, mechanical, optical, electrical, and magnetic properties of ceramic products. (3H,3C).

5200 (ECE 5200): SOLID-STATE MATERIALS & DEVICES
Introduction to the structural, thermal, optical, electrical, and magnetic properties of solid-state materials. Atomic scale models of physical phenomena at the macroscopic scale. Connection is made between basic materials properties and the operational characteristics of selected solid-state devices. Pre: 3255 or ECE 4214, PHYS 3455 and graduate standing in the College of Engineering. (3H,3C).

5214: OPTOELECTRONIC & MAGNETIC APPLICATIONS
This course will introduce the field of man-made modifications in the properties of materials obtained by controlled growth of structures of nearly atomic dimensions. Devices which utilize these properties will be studied. The course will emphasize the relationships between advanced materials growth technologies, new materials properties, physics concepts and new devices. Pre: 4206 or 4216. (3H,3C).

5224: PHOTONIC MATERIALS
An introduction to materials used in the generation, propagation and harnessing of light for useful applications. An emphasis on understanding the structure of materials including glasses, single crystals, and polycrystalline materials and their effects on the propagation of elecromagnetic energy. Luminescence (including phosphorescence and fluorescence), refractive index, transmission, absorption, reflection, origin of color in materials, fiber optics, dispersion, nonlinear effects, lasers, LEDs, detectors, numerical aperture, attenuation coefficients, Rayleigh scattering, infrared absorption spectra, holey fibers, and photonic crystals. Undergraduate degree in engineering or science is required. (3H,3C).

5234: INTRODUCTION TO THE MATERIALS SCIENCE OF SURFACES & INTERFACES
Fundamental and applied aspects of surfaces. Solid/solid, solid/liquid, and solid/vapor interfaces. Their structure and defects, thermodynamics, reactivity, electronic and mechanical properties. Applications depend upon class interests, but can include microelectronics, soils, catalysis, colloids, composites, environment-sensitive mechanical behavior, UHV single cystal studies, materials durability, and surface bioactivity. Pre: 5054, 5034. (3H,3C).

5254: SCIENCE & TECHNOLOGY OF THIN FILMS
Fundamental properties and microstructure of materials in thin film (thin coating) form, their interaction with a substrate, thin film processing/characterization techniques, and instrumentation. Areas of application have been selected to exemplify the interdisciplinary nature of the field and include the electronics, biomedical, military, aerospace and construction industries. Undergraduate degree in engineering or physical sciences required. (3H,3C).

5504: POLYMER DEFORMATION & FRACTURE
Continuum, statistical and molecular response of polymers under mechanical loading conditions. Molecular determinations of modulus, molecular and mechanical mechanisms of crazing and crack propagation, analytical methods relating molecular, micromechanical and mechanical response in polymers. Pre: 4554, 4564, ESM 4024. (3H,3C).

5654 (CHEM 5654): ADHESION SCIENCE
Introduction to basic principles of adhesion science from the areas of mechanics, materials, and chemistry. Consent required. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH & THESIS
Variable credit course.

6304: ADVANCED TOPICS IN MATERIALS SCIENCE
Advanced topics selected from the technical literature that stress the development of fundamental concepts and/or technologies of contemporary interest to materials science and egineering. Topics will vary; may be repeated for credit. Pre: 5024, 5034. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (MSE)

The following 4000-level courses have been approved for graduate credit:

4034: THERMODYNAMICS OF MATERIALS SYSTEMS
Topics in thermodynamics on the solution of materials selection and design related problems such as materials stability at high temperatures and in corrosive chemical environments. Thermodynamic principles important in controlling equilibrium in single component systems and multicomponent solid solutions and in establishing the thermodynamic driving force in kinetic processes which are important in materials processing unit operations. Estimation of thermodynamic properties and equilibrium calculations in multicomponent and multiphase systems. Pre: 2054, 2054. (3H,3C).

4064 (ME 4704): TRIBOLOGY
Basic principles of tribology–the study of friction, wear, and lubrication–including the importance of materials, surfaces, design, operating conditions, environment, and lubrication on friction, wear, and surface damage in any system. Application of tribological theories, concepts, techniques, and approaches to design, research, development, evaluation, and problem-solving. Pre: 2034 or 2044, 3034 or ME 3404. (3H,3C).

4154 (ESM 4154): NONDESTRUCTIVE EVALUATION OF MATERIALS
Concepts and methods of nondestructive evaluation of materials. Discussion of techniques and mathematical bases for methods involving mechanical, optical, thermal, and electromagnetic phenomena; design for inspectability; technique selection criteria; information processing and handling; materials response; laboratory. Pre: 3054, 3064, PHYS 2306. (2H,3L,3C).

4164 (MINE 4164): PRINCIPLES OF MATERIALS CORROSION
Introduction to the scientific principles of materials corrosion and corrosion protection. Topics include: thermodynamics of materials corrosion, including potential-PH (Pourbaix) diagrams, kinetics of corrosion reactions and mixed potential theory, types of corrosion (uniform, galvanic, crevice, pitting, fatigue, stress corrosion cracking, intergranular, and hydrogen embrittlement), material/environmental factors that promote or prevent the various types of corrosion, and methods and techniques of corrosion testing. Co: 4034 or ME 3114 or ME 3124 or ME 3134. Pre: CHEM 1074. (3H,3C).

4254: SCIENCE AND TECHNOLOGY OF THIN FILMS
Study of the fundamental properties and microstructure of materials in thin film (thin coating) form, their interaction with the substrate, and their processing techniques. Areas of application to exemplify the interdisciplinary nature of the field, including the electronics, biomedical, military, aerospace, and construction industries. Pre: 4206 or 4215 or 4124. Co: 3255. (3H,3C).

4274 (ECE 4274): ELECTRONIC PACKAGING LABORATORY
A laboratory course on electronic package design, fabrication and processing, and testing. Technologies addressed in the course are thick-film hybrid, thin-film processing, surface mount, wire bonding, and multichip module technologies. Pre: 4235 or ECE 4235. (3L,1C).

4304: METALS AND ALLOYS
This course covers the production, properties and uses of commercially important metals and alloys. The influence of structure, chemistry, and processing upon the properties of metals is emphasized. Alloy selection is discussed. Mechanical, electrical, thermal and chemical characteristics of ferrous and nonferrous alloys are studied. Pre: 2034 or 2044 or AOE 3094. (3H,3C).

4354: STRENGTH & FRACTURE
Microstructural origins of strengthening, deformation, and fracture in engineering materials. Pre: 3304. Co: 3054, 3064. (1H,1C).

4414: PHYSICAL CERAMICS
Study of the relationships between the physical properties (thermal, optical, mechanical, electrical and magnetic) and the structure and composition of ceramics at the atomic and microscopic level as affected by processing and service environment. Emphasis will be placed on application and design using structural ceramics. Pre: 3314. Co: 4424. (3H,3C).

4434: GLASS AND REFRACTORIES
Manufacturing processes and applications of glassy and refractory materials. Current theories of the structure of glassy and refractory materials are studied and related to their properties and behavior at high temperature and other demanding applications. Environmental effects of these energy intensive processes are taken into consideration. Pre: 3024, 3134. Co: 3424. (3H,3C).

4534 (CHEM 4634): POLYMER AND SURFACE CHEMISTRY
Physical chemical fundamentals of polymers and surfaces including adhesives and sealants. Pre: CHEM 3615 or CHEM 4615. (3H,3C).

4544 (CHEM 4074): LABORATORY IN POLYMER SCIENCE
Experimental techniques used in the synthesis of various linear polymers, copolymers, and crosslinked networks. Determination of polymer molecular weights and molecular weight distribution. Methods used in the thermal, mechanical, and morphological characterization of polymeric systems. Pre: CHEM 3616, CHEM 4534. (1H,3L,2C).

4554: POLYMER ENGINEERING
This course is designed to introduce the student to polymers from the MSE perspective. The basics of polymer snythesis and polymerization will be outlined. The relationship between processing, structure, and properties will be presented with respect to the performance and design requirements of typical polymer applications. Pre: CHEM 1074, PHYS 2306, MATH 2224, MSE 2054. (3H,3C).

4564: POLYMER ENGINEERING LABORATORY
Laboratory experiments exploring the processing-structure-property relationships in polymers and polymer based composites will be performed. Experiments will be conducted in synthesis, melt rheology, crystal structure and mechanical properties of polymers. Effects of reinforcement on the properties of engineering polymers will also be investigated. Co: 4554. (3L,1C).

4574 (ESM 4574): BIOMATERIALS
Lectures and problems dealing with materials used to mimic/replace body functions. Topics include basic material types and possible functions, tissue response mechanisms, and considerations for long term usage. Integrated design issues of multicomponent materials design in prosthetic devices for hard and soft tissues are discussed. Must meet prerequisite or have graduate standing in the College of Veterinary Medicine. Pre: 3054. (3H,3C).

4604: COMPOSITE MATERIALS
The application of the fundamental concepts of mechanics, elasticity, and plasticity to multiphase and composite materials. Constitutive equations for the mechanical and physical properties of metal, ceramic, and polymeric matrix composites. The role of processing and microstructure on properties. Pre: (2034 or 2044 or 3094), (ESM 2204). (3H,3C).

MATHEMATICAL PHYSICS

George A. Hagedorn, Director

Professors: L. N. Chang (Physics); W. Greenberg (Mathematics); G. A. Hagedorn (Mathematics); M. Klaus (Mathematics); B. Schmittmann (Physics); R.K.P. Zia (Physics)
University Distinguished Professor Emeritus: P.F. Zweifel (Physics)

E-mail: hagedorn@math.vt.edu
Web: www.mathphys.vt.edu

The mathematical physics program, a joint program of the mathematics and physics departments, is available to students with undergraduate degrees in either mathematics or physics. Students are enrolled for the Ph.D. in one of the participating departments, and follow a course of study overlapping the two departments. Research is carried out under the direction of one of the participating faculty members under the auspices of the Center for Statistical Mechanics and Mathematical Physics, the research arm of the program. Students must pass the written preliminary examinations of their home departments, as well as an oral examination, before being admitted to candidacy for the Ph.D. A typical course of study includes:

GRADUATE COURSES (MATH)
MATH 5225-5226: Real Analysis
MATH 6255-6256: Functional Analysis

GRADUATE COURSES (PHYS)
PHYS 5354: Classical Mechanics
PHYS 5405: Classical Electromagnetism
PHYS 5455-5456: Quantum Mechanics
PHYS 5705-5706: Statistical Mechanics

GRADUATE COURSES (MATH-PHYS)
PHYS 6755-6756 (MATH 6755-6756): Mathematical Foundations of Quantum Mechanics

Many other relevant courses are available in both departments, for example MATH 5435, 5436: Principles and Techniques of Applied Mathematics; PHYS 6674: Theory of Relativity; etc.

MATHEMATICS

John Rossi, Head
George A. Hagedorn, Graduate Program Chair

Hatcher Professor of Mathematics: J.A. Burns
Professors: J.T. Arnold; J.A. Ball; C.A. Beattie; E.A. Brown; M.V. Day; D.R. Farkas; W.J. Floyd; E.L. Green; W. Greenberg; G.A. Hagedorn; P.E. Haskell; T.L. Herdman; J.R. Holub; J.U. Kim; M. Klaus; W.E. Kohler; R. Laubenbacher; T. Lin; P.A. Linnell; C.J. Parry; C.W. Patty; C.L. Prather; F.S. Quinn; M. Renardy; Y. Renardy; R.D. Riess; R.C. Rogers; J. F. Rossi; D.L. Russell; E. Sachs; J.K. Shaw; R.L. Snider; B. Sun; R.L. Wheeler
Associate Professors: S. Adjerid; J. Borggaard; D. Gao; G. Letzter; G. Lloyd; M. Shimozono; J.E. Shockley; J.K. Washenberger; M. Williams
Assistant Professors: S. Gugercin; T. Iliescu; P. Wapperom
Instructors: D. Agud; S. Anderson; E. Bonawitz; T.A. Bourdon; M. Cothren; S. Hagen; L.L. Hanks; H. Hart; C. Hodges; J. Hoggard; L.M. Holub; A. Kohler; M.P. McQuain; L.A. Peters; L. Powers; B.B. Shealor; E.T. Shugart; D.B. Smith; C. Stephens; D. Wells
Graduate Program Coordinator: H.S. Swiger (231-6537)
GTA Coordinator: E.T. Shugart (231-8044)
Career Advisors: G.A. Hagedorn (231-6575); R.D. Riess (231-6536)

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This department offers courses of study leading to the degrees of M.S. and Ph.D. The M.S. program (thesis or non-thesis) is designed to increase the candidate's understanding of the content and methodology of basic mathematical disciplines. Various options are available, giving the student and advisor the flexibility to design an individualized program emphasizing mathematics relevant to the student's personal interests and objectives. An interdisciplinary M.S. option is offered for students interested in related disciplines and those intending to seek employment immediately after earning the master's degree. The candidate for the Ph.D. will, in accordance with Graduate School requirements, pass a preliminary examination, which is designed to test the student's competence in basic areas of mathematics closely allied with his program of study – whether pure, applied, or mathematical physics. Under ordinary circumstances, the preliminary exams should be taken before the start of the third year after entering the Ph.D. program. A reading knowledge of one foreign language, to be determined by the student's advisory committee, is required. The student must also prepare a dissertation which makes a substantial contribution to the area concerned. The university library has extensive paper and electronic holdings in mathematics. Several hundred journals devoted to mathematics are currently being received.

Special Facilities

The Mathematics Department offers a high performance network consisting of UNIX servers, workstations, a Linux cluster, and personal computers. The department's network is interconnected with the university network providing 622 Mbps OC12 access to the Internet and the Internet2 Abilene network. All graduate students have a networked office computer running their choice of Windows, Mac OS, or Linux. Mathematics software such as Mathematica, Maple, MATLAB, and TeX is available for graduate student office computers.

The **Interdisciplinary Center for Applied Mathematics (ICAM)** promotes and facilitates interdisciplinary research and education in applied mathematics at Virginia Tech. ICAM provides a wide range of research and educational programs emphasizing interaction between engineers, mathematicians, and scientists.

Special Admissions Requirements

Along with the general Graduate School admissions requirements, the mathematics department requests prospective students to submit their Graduate Record Examination scores. More specific information is available from the department upon request.

Graduate Courses (MATH)

5114: SPECIALIZED TOPICS IN ALGEBRA
Various graduate level topics in algebra such as field theory, non-commutative ring theory, group representation theory, Lie algebras. May be taken for credit more than once with departmental permission. Pre: 4124. (3H,3C).

5125-5126: ABSTRACT ALGEBRA
Groups, rings and ideals, modules, brief introduction to homological algebra. Pre: 4124. (3H,3C).

5135-5136: TOPICS IN NUMBER THEORY
Advanced topics in number theory such as algebraic number theory, analytic number theory, or theory of quadratic forms. Pre: 4124, 4234. (3H,3C).

5144 (GEOL 5144): INVERSE THEORY & GEOSCIENCE APPLICATIONS
Overview of inverse theory, utilizing geophysical examples to illustrate the concepts of model construction, parameter estimation, resolution, and non-uniqueness. Emphasis is on the linear problem, concluding with an overview of nonlinear inversion. Pre: 2214, 2224. (3H,3C).

5214: SPECIALIZED TOPICS IN ANALYSIS
Various graduate level topics in analysis for graduate students in mathematics and qualified students in other areas. Consent required. (3H,3C).

5225-5226: REAL ANALYSIS
Basic set theoretic and topological notions, fundamental theorems of measure and integration, differentiation, applications to linear analysis. Pre: 4226. (3H,3C).

5235-5236: COMPLEX ANALYSIS
Holomorphic functions, complex integration and residues, series expansions, normal families and the Riemann mapping theorem, entire functions, power series in the unit disk. Pre: 3224 or 4225. (3H,3C).

5244: SYSTEMS & STABILITY OF DIFFERENTIAL EQUATIONS
Systems: First and second order equations, phase plane, general theory of linear systems, autonomous and periodic systems, matrix exponentials, Floquet theory, survey of existence and uniqueness, variation of parameters, elementary models. Stability: Poincare and Liapunov stability, linearization, sufficient conditions for stability, stability of linear systems, Liapunov functions, LaSalle's theorem, invariance. Pre: 4525 or 4425 or 4225. (3H,3C).

5245-5246: ORDINARY DIFFERENTIAL EQUATIONS
Existence theorems, linear theory, stability theory, periodic solutions, Poincare-Bendixon theory, boundary-value problems, functional differential equations. Pre: 4225. (3H,3C).

5344: SPECIALIZED TOPICS IN TOPOLOGY & GEOMETRY
Various graduate level topics in topology and geometry. May be taken for credit more than once with department consent. Pre: 4324. (3H,3C).

5415,5416: SPECIALIZED TOPICS IN APPLIED MATH
Various graduate level topics in applied mathematics for graduate students in mathematics and qualified students in other areas. May be taken for credit more than once with department consent. Consent required. X-grade allowed. (3H,3C).

5425-5426: APPLIED PARTIAL DIFFERENTIAL EQUATIONS
Partial differential equations of first and second order, hyperbolic equations, elliptic equations and Green's functions, parabolic equations, canonic forms, application to physics and engineering. Pre: 4426 or 4564. (3H,3C).

5435-5436: PRINCIPLES & TECHNIQUES OF APPLIED MATHEMATICS
Methods and techniques for obtaining approximate solutions to differential and integral equations that are not solvable exactly. Asymptotic and perturbation analysis, complex integration. Consent required. (3H,3C).

5444: NUMERICAL METHODS FOR ORDINARY DIFFERENTIAL EQUATIONS
Computational procedures for ordinary differential equations including Runge-Kutta methods, variable-step Runge-Kutta methods, predictor-corrector methods, applications to two-point boundary-value problems and parameter estimation. Error control, relative and absolute stability, methods for stiff equations; with computer assignments. Senior standing in engineering, science, or mathematics, and some programming ability required. (3H,3C).

5454: GRAPH THEORY
Graphs, trees, connectivity, Euler tours, matching, independent sets and cliques, planar graphs, directed graphs. Consent required. (3H,3C).

5464: COMBINATORICS
Counting problems, generating functions, recurrence relations, principle of inclusion and exclusion, experimental designs. Consent required. (3H,3C).

5465-5466 (CS 5465-5466): NUMERICAL ANALYSIS
A survey of the construction, analysis, and implementation of numerical algorithms in linear algebra, nonlinear equations and optimization, approximation by polynomials, quadrature, and ordinary differential equations. High-level programming language required. Pre: 4525. (3H,3C).

5474 (CS 5474): FINITE DIFFERENCE METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Finite difference methods for initial and boundary value problems for partial differential equations. Consistency, stability, convergence, dispersion, and dissipation. Methods for linear and nonlinear elliptic and parabolic equations, first- and second-order hyperbolic equations, and nonlinear conservation laws. High-level programming language required. Pre: 3414, 4525. (3H,3C).

5484 (CS 5484): FINITE ELEMENT METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Weak formulations of boundary-value problems for elliptic partial differential equations. Finite element spaces. Approximation theory for finite element spaces. Error estimates. Effects of numerical integration and curved boundaries. Nonconforming methods. Concrete examples of the application of the finite element method. Efficient implementation strategies. Time dependent problems. High-level programming language required. Pre: 3414, 4525. (3H,3C).

5485,5486 (CS 5485, 5486): NUMERICAL ANALYSIS & SOFTWARE
Presentation and analysis of numerical methods for solving common mathematical and physical problems. Methods of solving large sparse linear systems of equations, algebraic eigenvalue problems, and linear least squares problems. Numerical algorithms for solving constrained and unconstrained optimization problems. Numerical solutions of nonlinear algebraic systems. Convergence, error analysis. Hardware and software influences. Efficiency, accuracy, and reliability of software. Robust computer codes. X-grade allowed. Pre: 4445, 4446. (3H,3C).

5495,5496 (ESM 5725, 5726): MATHEMATICAL METHODS IN ENGINEERING I,II
Linear algebra and matrix theory, vector calculus, complex variables and integral transforms, ordinary and partial differential equations, special functions, integral equations and calculus of variations. Facility with an existing math software package knowledge of senior level engineering mathematics required. (3H,3C).

5515,5516 (GBCB 5515, 5516): MATHEMATICAL METHODS FOR MODELING AND SIMULATION OF BIOLOGICAL SYSTEMS
Introduction to mathematical techniques for modeling and simulation, parameter identification and analysis of biological systems. Emphasis on both theoretical and practical issues and methods of computation, with concrete applications. Suitable for students from the mathematical and life sciences who have a basic foundation in multivariate calculus and ordinary differential equations. 5515: Continuous models and methods. 5516: Discrete models and methods. (3H,3C).

5524: MATRIX THEORY
Determinants, rank, linear systems, eigenvalues, diagonalization, Gram-Schmidt process, Hermitian and unitary matrices, Jordan canonical form, variational principles, perturbation theory, Courant minimax theorem, Weyl's inequality, numerical methods for solving linear systems and for determining eigenvalues. science or engineering. (3H,3C).

5545-5546: CALCULUS OF VARIATIONS & OPTIMAL CONTROL THEORY
Unified course in the calculus of variations and control theory including multiple integral problems and distributed parameter control systems. Necessary conditions, sufficient conditions, nonclassical problems, optimal control, distributed parameter control, computational methods. Pre: 4525, 4425. (3H,3C).

5554: APPROXIMATION THEORY
Approximation of functions by polynomials, splines, and rational functions. Derivation of computational methods; minimax and least-squares error estimates. Pre: 4446 or 3414. (3H,3C).

5614: TOPICS FOR IN-SERVICE TEACHERS
Various topics in mathematics and its applications to real-life problems, presented in light of contemporary instructional technologies and standards of learning. The course is designed for in-service mathematics teachers at the high and middle school levels

and is suitable for recertification credit. The specific topics covered will be tailored to the location and delivery mode of the course, as well as evolving standards and methodology. May be repeated for credit with different content. May not be applied toward graduate degrees in mathematics. In-service status required. (3H,3C).

5725,5726 MATHEMATICS FOR FINANCIAL MODELING
Introduction to stochastic models used in financial market analysis and associated computational methods. 5725: Brownian motion, stochastic integration, Ito calculus, martingales, no-arbitrage pricing, Black-Scholes formula, basic term-structure models. 5726: PDE characterizations for American, Asian, and other path-dependent options, development and application of numerical methods for computation. Pre: 5425, 5426 or consent, (3H, 3C).

5754 (ESM 5754): INTRODUCTION TO PERTURBATION METHODS
Asymptotic expansions and series, approximate solutions of algebraic equations, straightforward expansions and their regions of nonuniformities, the Lindstedt-Poincare technique, the method of renormalization, the method of averaging, the method of matched asymptotic expansions. Pre: 2214 or 2514 or 4544. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6105-6106 (STAT 6105-6106): MEASURE & PROBABILITY
Development of measure theoretic foundations of probability theory. 6105: sigma fields, probability, and general measures; random variables, measurability and distributions, integration, and expectation; product measures; Radon-Nikodym theorem and conditioning. 6106: Random variables and strong and weak laws of large numbers; characteristic functions, central limit theorem and martingales; stochastic processes and Brownian motion. 6105 partially duplicates Math 5225. Pre: 4525, STAT 5104. (3H,3C).

6125,6126: TOPICS IN ALGEBRA
Advanced topics in algebra for graduate students in mathematics. May be taken for credit more than once with department consent. Pre: 5126. (3H,3C).

6225,6226: TOPICS IN ANALYSIS
Advanced analysis for graduate students in mathematics. May be taken for credit more than once with department consent. Consent required. (3H,3C).

6255-6256: FUNCTIONAL ANALYSIS
Banach spaces, Hilbert spaces, linear operators on Banach and Hilbert spaces, Riesz Representation Theorems, spectral theory, topological vector spaces, other topics in functional analysis. Pre: 5226. (3H,3C).

6324: TOPICS IN TOPOLOGY AND GEOMETRY
Advanced topics in topology and geometry. May be taken for credit more than once with department consent. Pre: 5344. (3H,3C).

6425,6426: TOP IN APPLIED MATH
Advanced topics in applied mathematics for graduate students in mathematics, science, and engineering. May be taken for credit more than once with department consent. Consent required. (3H,3C).

6745-6746 (PHYS 6745-6746): MATHEMATICAL FOUNDATIONS OF STATISTICAL MECHANICS
Advanced course in mathematical physics which encompasses the frontiers of research in statistical mechanics. Content varies from year to year and includes rigorous equilibrium statistical mechanics as well as topics from non-equilibrium statistical mechanics and Boltzmann theory. This course frequently taken concurrent with thesis research. The course alternates with Math 6755-6756 and may be taken a second time with instructor's consent. Pre: 5226, PHYS 5706. (3H,3C).

6755-6756 (PHYS 6755-6756): MATHEMATICAL FOUNDATIONS OF QUANTUM MECHANICS
Advanced course in mathematical physics which encompasses the frontiers of research in quantum theory. Content varies from year to year and includes scattering theory, spectral and perturbation theory, and many-body quantum dynamics. This course frequently taken concurrent with thesis research. The course alternates with Math 6745-6746 and may be taken a second time with instructor's consent. Pre: 6256, PHYS 5456. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

MECHANICAL ENGINEERING

K.S. Ball, Head

George R. Goodson Professor: D.J. Inman
Roanoke Electric Steel Professor: C.R. Fuller
Chris Kraft Professor of Engineering: W.G. Ng
J. Bernard Jones Professor: W.F. O'Brien
Alumni Distinguished Professor: C.F. Reinholtz

Professors: M. Ahmadian; K.S. Ball; E.F. Brown; R.A. Burdisso; T.E. Diller; C.R. Fuller; D.J Inman; R.G. Kirk; D.J. Leo; D.J. Nelson; W. Ng; W.F. O'Brien; C.F. Reinholtz; H.H. Robertshaw; E.P. Scott; K.A. Thole; M.R. von Spakovsky;
Associate Professors: J.H. Bohn; C.L. Dancey; S.M. Duma; M.W. Ellis; D.R. Jaasma; M.E.F. Kasarda; A.A. Kornhauser; W.R. Saunders; D. Tafti; U. Vandsburger; B. Vick; R.L. West; A.L. Wicks
Assistant Professors: D.W. Hong; S. Huxtable; M.E. Johnson; M. Paul; C. Sandu; P. Vlachos
Instructor: M.P. Alley

E-mail: megrad@vt.edu
Web: www.me.vt.edu

The Department of Mechanical Engineering offers advanced study and research in a wide range of areas leading to the M.S., M.E., and Ph.D. Each student, in cooperation with his or her advisory committee, develops a plan of study that may include courses appropriate to the student's individual interests and needs. The plan will include courses selected from the many subjects available in other departments, both in the College of Engineering and other colleges. Courses within the department include tribology, acoustics, kinematics, computer-aided design, automatic controls, vibrations, combustion, fluid mechanics, heat transfer, thermodynamics, modal analysis, finite element analysis, turbomachinery, smart material systems, and propulsion. Students often take courses from outside the department in mathematics (required), statistics, and other fields.

Eight research centers are headquartered in the department: the Advanced Vehicle Dynamics Laboratory, the Center for Automotive Fuel Cell Systems, the Center for Turbomachinery and Propulsion Research, the Center for Intelligent Material Systems and Structures, the Energy Management Institute, the Rotor Dynamics Laboratory, the Vibration and Acoustics Laboratory, and the Virginia Active Combustion Control Group.

The Department of Mechanical Engineering is also a participating department in the Virginia Tech-Wake Forest University School of Biomedical Engineering & Sciences (VT-WFU SBES) and the Center for Biomedical Engineering. The School offers joint graduate degrees (M.S. and Ph.D.) and a graduate option in Biomedical Engineering to students in participating departments. For more details see *www.sbes.vt.edu*

In addition to the research centers, many of the mechanical engineering faculty members are actively involved in numerous other interdisciplinary centers including the Center for Adhesive and Sealant Science, the Polymer Materials and Interfaces Laboratory, the NSF Center for High Performance Polymeric Adhesives and Composites, the Center for Advanced Ceramic Materials, the Center for Adhesion and Surface Science, the Center for Transportation Research, the Manufacturing Systems Engineering Center, the Center for Energy and the Global Environment, and the Virginia Power Electronics Center. The activities of these centers, combined with the many different research activities within the department, offer an extremely diverse choice of research topics. The department has a number of specialized laboratories housing a substantial collection of sophisticated instrumentation. These laboratories include an anechoic chamber, a reverberation room, a gas turbine test cell, a rotor dynamics laboratory, a fluids laboratory, a fuel cell systems laboratory, a heat transfer laboratory, a mechatronics laboratory, a microwave processing laboratory, a modal analysis laboratory, a multi-phase flow laboratory, a rapid prototyping laboratory, a reacting flows laboratory, a robotics and mechanisms laboratory, a thermal radiation laboratory, a tribology laboratory, a computer-aided design laboratory, a combustion laboratory, a laser dynamic imaging laboratory, and the impact biomechanics laboratory.

In general, for admission to the graduate program, an applicant must be a graduate of an ABET-accredited engineering curriculum with a record indicating the ability to pursue advanced study. The GRE engineering subject test is recommended. The GRE General Test is required for all applicants. For applicants from engineering programs at non-English speaking institutions, the TOEFL is also required. Mathematics course work through ordinary differential equations is required; further mathematics, as well as advanced courses in some of the engineering sciences, are strongly recommended as preparation for study at the graduate level. Unless otherwise noted by prerequisites, it is assumed that students have completed the necessary undergraduate coursework to be prepared for ME graduate courses. Please see the ME web site, *www.me.vt.edu*, for the most current course information.

SPECIAL DEGREE REQUIREMENTS

The M.S. requires a minimum of 30 semester credits, including at least 6 semester credits of research and thesis and 3 semester credits of mathematics. The M.S. in Mechanical Engineering also requires at least 15 credits of 5000 or 6000 level courses.

The Ph.D. plan of study requires a minimum of 90 semester credits beyond the B.S., including at least 30 semester credits of research and dissertation and 9 semester credits of mathematics.

GRADUATE COURSES (ME)

5104: THERMODYNAMICS: FOUNDATIONS & APPLICATIONS
Exposition of the basic concepts and principles of thermodynamics. Principles and results developed for both macroscopic and microscopic systems as well as equilibrium and non-equilibrium states. Definition of entropy for any state. The definition of temperature; pressure, total potential; heat; work; the fundamental Gibbs, Euler, Gibbs-Duhem, and Maxwell relations; characteristic functions; and the state principle. Definition and use of thermophysical properties, charts, tables, and equations of state for pure as well as mixtures of ideal and real gases, liquids and solids. Second Law analysis, energy conversion, chemical reactions and chemical equilibrium, and introduction to the phenomenological laws of non-equilibrium thermodynamics. (3H,3C).

5135–5136 (AOE 5135–5136): VEHICLE PROPULSION
Aerothermodynamics of gas turbines and rockets: cycle analysis of turbojets, turbofans, prop fans, and turbo props. Analysis of ramjets and scramjets. Performance of inlets, combustors, and nozzles. Elementary theory of turbomachinery. Liquid and solid propellant chemical rockets. Electrostatic, electromagnetic, and electrothermal propulsion. Integrated rocket–ramjet. Fuels and propulsion systems for future transportation system. (3H,3C).

5214: COMBUSTION
Combustion of solid, liquid, and gaseous fuels, kinetics of hydrocarbon oxidation and pollutant formation/destruction, premixed flames, diffusion flames, ignition, quenching, combustion diagnostics. (3H,3C).

5254: FUEL CELL SYSTEMS
Fuel cell systems for transportation, buildings, utility and portable power energy conversion applications. Overview of fuel cell technology. Thermodynamics of direct energy conversion and fuel cell efficiency. Electrochemistry, equilibrium and reaction kinetics. Temperature and pressure effects on polarization curves. Proton exchange membrane fuel cell performance modeling. Fuel cell system components: heat exchangers, humidifiers, air compressors, electric power processing and management. Overall system integration, modeling, and control. Fuel cells for transportation, vehicle performance and efficiency characteristics. Fuel processing and reformers. Fuel cell system design, economics, and optimization. Graduate standing in Engineering required. (3H,3C).

5304: CONDUCTION & RADIATION HEAT TRANSFER
Principles of conduction. Analysis of one–dimensional and multidimensional steady and transient, phase change and moving heat source problems are examined. A comprehensive treatment of numerical and analytical methods for solving heat conduction problems is presented. (3H,3C).

5314: CONVECTIVE HEAT & MASS TRANSFER
Principles of convection. Analysis of transfer for internal and external flows; laminar and turbulent boundary layer theories; forced and natural convection; similarity solutions; Reynolds analogy. (3H,3C).

5324: RADIATION HEAT TRANSFER
Introduction to thermal radiation; the electromagnetic spectrum; the black body; wave phenomena versus geometric optics; polarization, diffraction, and refraction effects; emission, reflection, absorption, and transmission of thermal radiation by surfaces; radiant interchange among surfaces; radiation through a participating medium; the Conte Carlo ray trace method; uncertainty and confidence interval of results. Knowledge of thermodynamics at the undergraduate level is recommended. (3H,3C).

5404: FLUID DYNAMICS
Fundamental fluid mechanics: kinematics and dynamics. Continuum fluid dynamics including hydrostatics, flow kinematics, the concept of stress, constitutive relations, the equations of motion and energy for compressible and incompressible viscous and inviscid flows. Incompressible Newtonian viscous flows, similitude and physical modeling, inviscid potential flows, inviscid flows with vorticity, boundary layers, and an introduction to turbulent flow. (3H,3C).

5414: ADVANCED THERMODYNAMICS OF FLUID FLOW
Builds on introductory material covered in undergraduate thermodynamics, fluid mechanics, heat transfer, and gas dynamics courses. Topics in one– and two–dimensional, steady and unsteady, inviscid compressible flows including: generalized one–dimensional flows, unsteady one–dimensional flow, linearized methods, method of characteristics, and advanced numerical methods. Mainframe and micro–computer programs both supplied by the instructor and written by the student. (3H,3C).

5424: TURBOMACHINERY
Application of fluid mechanics and thermodynamics to turbomachinery, with emphasis on high speed machines. Review of basic concepts and ideal performance. Viscous effects – losses and stall. Three dimensional and secondary flow. Actual machine performance and design considerations. Selected topics including axial and centrifugal machines, transonic flow, transient behavior, and three–dimensional flow design. (3H,3C).

5504: INTRODUCTION TO ROTOR DYNAMICS ANALYSIS
Theory and application of dynamics, vibrations, fluid mechanics and tribology to the design of rotating machinery. Course content covers material from single–mass rotor analysis up to multi–mass rotor system analysis. System critical speeds, forced response, and dynamic stability are discussed. Hydrodynamic bearings, liquid seals, and gas labyrinth seals are presented as necessary elements for rotor design analysis. Field balancing by single plane, two plane and multi plane methods are presented. Experimental in–class work on single and two–plane methods. Industry standards are discussed. State of the art PC computer analysis tools are provided for the student to use in course for optimum rotor design analysis. One computer analysis program will be written by the student in a language or math package of their choice. A formal presentation of a course project will be given at the end of semester by each student enrolled for credit. Even years. (3H,3C).

5505–5506: ADVANCED CONTROL ENGINEERING
Unification of the analysis and design techniques of a broad range of dynamic systems through the use of the tools of modern control. Builds upon the background of classical control topics including Nyguist, Bode, and root locus. Emphasis upon developing the tools of state–space control theory and applying these tools to effect the design of controllers for linear dynamic systems. Transform analysis and design of systems with digital and continuous components. Classical and modern treatments along with discussion of quantization effects. Design problems with hands–on experience. (3H,3C).

5514: VIBRATION OF MECHANICAL SYSTEMS
Single degree–of–freedom systems, multiple–degree–of–freedom system and distributed parameter systems ending in dynamic finite element modeling. Numerical solutions, isolation, absorption, optimal design for vibration reduction, analytical modal methods, transfer function methods. Damping models and analysis. (3H,3C)

5534: EXPERIMENTAL MODAL ANALYSIS
The basics in experimental modal analysis will be investigated with emphasis on obtaining a quality database. Methods for the development of mathematical models from experimental data will be studied along with the methods of assembling substructures and of modifying the design of a prototype via modification and reanalysis of the experimentally derived mathematical model of that prototype. Selected topics in advanced experimental modal analysis will be treated. (3H,3C).

5604: GRAPHICS FOR COMPUTER–AIDED DESIGN
Participants will study topics fundamental to the creation of computer–aided design software, including current CAD hardware and computer graphics standards (Motif, OpenGL, PHIGS). They will also study topics relevant to the rendering of CAD models (e.g., shading, lighting, and color transformations). Application programs will be developed which use standard computer graphics support software. Pre: Graduate standing. (3H,3C).

5614: ADVANCED KINEMATICS
Advanced kinematic and dynamic analysis of planar and spatial linkages and robotic manipulators. Advanced methods for the design and analysis of cam mechanisms. Advanced gear design. Analysis of elastic mechanisms. Computer–aided analysis of planar and spatial mechanisms. Pre: 3604. (3H,3C).

5624: MACHINE DESIGN
Advanced analysis and design of machine components; problems in bearings, gears, contact stresses, plates, rotating disks, press fits, torsion, springs, and other topics. Pre: 3614. (3H,3C).

5634: FINITE ELEMENTS IN MACHINE DESIGN
Advanced analysis and design of machine components with emphasis on the finite element method of analysis using commerical software. Structural and continuum elements will be used for both the static and dynamic analysis and design of machine components. Practice oriented analysis techniques and design procedures employable through the finite element method will be developed. Design problems will constitute a significant part of the course. Pre: 3614. (3H,3C).

5644: RAPID PROTOTYPING
Participants will study topics fundamental to rapid prototyping and automated fabrication, including the generation of suitable CAD models, current rapid prototyping fabrication technologies, their underlying material science, the use of secondary processing, and the impact of these technologies on society. The rapid prototyping process will be illustrated by the actual design and fabrication of a part. Partially duplicates ME 4644; credit may only be received for one course. Co: ME 4634 or equivalent background; programming skills. (3H,3C).

5714: DIGITAL SIGNAL PROCESSING FOR MECHANICAL MEASUREMENTS
The fundamentals of digital signal processing of data experimentally obtained from mechanical systems will be covered. Attention will be given to the data acquisition, A/D conversion, aliasing, anti–aliasing filtering, sampling rates, valid frequency ranges, windowing functions, leakage, and various transform methods. Special attention will be given to random, transient, and harmonic function data processing. Various methods of estimation of the frequency response function (FRF) will be explored. The estimation methods will be assessed as to their impact on FRF estimation errors. (3H,3C).

5724: ADVANCED INSTRUMENTATION & SIGNAL PROCESSING
Advanced techniques in instrumentation using state–of–the–art transducers, techniques in data acquisition and signal processing. Techniques for estimating errors and optimizing data quality. (3H,3C).

5734: ADVANCED ENGINEERING ACOUSTICS
The fundamental principles underlying, the generation, transmission and reception of acoustic waves will be presented. Methods for analytically investigating various acoustic and structural acoustic situations encountered in practice will be developed. The application of these methods to typical engineering acoustical problems with physical interpretation of the results will be studied. (3H,3C).

5744: METHODS OF MECHANICAL ENGINEERING ANALYSIS
Introduction to selected mathematical techniques oriented toward solving advanced continuous and lumped parameter problems of the type often encountered in mechanical engineering. Elliptic, parabolic and hyperbolic ordinary and partial differential equations are discussed. Solution by separation of variables, integral transforms, Green's functions and numerical methods. The emphasis is on understanding how physical processes work. (3H,3C).

5754 (BMES 5164): ADVANCED IMPACT BIOMECHANICS
A review of impact biomechanics and critical investigation of the impact response of the human body. Participants will study the dynamic response of the head, neck, chest, abdomen, upper extremities and lower extremities. Real world examples from automobile safety, military applications, and sport biomechanics. Pre: 3504, 3614 or ESM 3054, ESM 3124. (3H,3C).

5804: ACTIVE MATERIALS I
The behavior of ceramic and polymeric active materials is studied and related to the dynamics of structural systems. Constitutive models of piezoelectric and electrostrictive ceramics and polymers are derived from thermodynamic relationships and applied to the modeling of structures that contain active materials. System–level models of active material systems are developed using variational mechanics. The fundamental physics of polymeric transducers (ionomers, conductive polymers, carbon nanotubes, and dielectric elastomers) areexamined and related to the performance of more conventional transducers. Applied topics in structural health monitoring, motion control, and sensing will be studied. Pre: 3514, 4504 or 3504. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6104: ADVANCED TOPICS IN THERMODYNAMICS
Exposition of the basic concepts and principles of statistical thermodynamics including statistical mechanics, probability theory, quantum mechanics, kinetic theory, and thermo–physical and transport properties. Presentation of the basic concepts and principles of gas dynamics for compressible flow within normal temperature ranges (i.e. excluding the very high temperatures at which plasmas form). A more in–depth look at chemical thermodynamics including chemical equilibrium and chemical kinetics. (3H,3C).

6304: ADVANCED HEAT TRANSFER – CONDUCTION
Selected topics on recent developments in theoretical, experimental, and analysis techniques for conduction heat transfer problems. Numerical, analytical, and approximate methods in conduction heat transfer research and problem solution. Pre: 5304. (3H,3C)

6314: ADVANCED HEAT TRANSFER – CONVECTION
Selected topics on recent developments in convection heat and mass transfer research by analytical and numerical methods. Forced and natural convection theory and applications. Computational procedures for momentum, heat, and mass transfer. Pre: 5314. (3H,3C)

6324: ADVANCED HEAT TRANSFER – RADIATION
Recent developments in theoretical methods for solving problems in radiation and combined mode heat transfer. Emphasis on radiation transport in participating media. Pre: 5324. (3H,3C)

6404: TURBULENCE & TURBULENT FLOW
Turbulence as a random process, equations governing turbulence, equations governing turbulent flows. Spectral content and analysis. Turbulence modeling in two– and three–dimensional flows. Turbulence property measurement techniques. Pre: 5404. (3H,3C).

6405: ADVANCED INTERNAL FLOW
Conservation equations and constitutive relations, exact Navier Stokes solutions; boundary layer approximation and special solutions; approximate methods; compressibility and heat and mass transfer effects; numerical methods, turbulence models. 6406: selected topics on recent activities in the fluid dynamics research community, including theory, analysis, and computational modeling. Specific topics will vary depending upon the instructor's areas of expertise. Pre: 5404. (3H,3C).

6504: TOPICS IN ADVANCED CONTROL APPLICATIONS
Timely subjects in applications of control theory. Topics to be chosen from include optimization, adaptive control, learning control, and non–linear analysis. (3H,3C).

6604: COMPUTER–AIDED GEOMETRIC DESIGN
Participants will study the mathematics of parametric sculptured curves and surfaces of computer–aided geometric design. Topics include a synthetic development of B–spline geometry based on Bezier geometry via the de Casteljau algorithm, definition of B–splines based on knot insertion, B–spline recurrence relations, solution of the B–spline inverse problem, formulation of various surfaces and rational parametric curves. The course project will relate to reading and critiquing the current literature. Pre: 5604. (3H,3C)

6614: KINEMATIC SYNTHESIS
Advanced analytical methods for the kinematic synthesis of planar and spatial cams and linkages. Pre: 5614. (3H,3C).

6624: ADVANCED FINITE ELEMENT APPLICATION IN MECHANICAL DESIGN
Advanced application of the finite element method to mechanical design problems. Nonlinear analysis techniques; geometric nonlinearity, material behavior elastic and inelastic response, moving boundary conditions, multi–component contact problems. Dynamic response analysis; direct integration, mode superposition. A semester finite element analysis/design project is a significant part of the course. Must have prerequisite or an equivalent linear finite element background. Taught alternate years. Pre: 5634. (3H,3C).

6704: ACOUSTIC–STRUCTURAL INTERACTION
The fundamental principles underlying the coupled vibration of structures and their radiated sound field will be outlined. Methods for analytically investigating the motion of elastic structures surrounded by acoustic mediums will be studied. Beam, plate, and cylindrical shell structures will be considered. Application of the methods developed to various situations encountered in practice and research will be studied. An introduction to the boundary element method will be presented. Pre: 5734. (3H, 3C).

6754 (BMES 6164): COMPUTATIONAL MODELING IN IMPACT BIOMECHANICS
Dynamic modeling of the human body subjected to transient impact loading. A combination of finite element analysis and multi–body simulation techniques. Utilizes software packages with dynamic solvers. Applications include computer–aided design for automobile safety, sports biomechanics, and military restraint systems. Pre: 5754 or BMES 5444. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (ME)

The following 4000–level courses have been approved for graduate credit:

4174 (AOE 4174): SPACECRAFT PROPULSION
Spacecraft propulsion systems and their applications inorbital, interplanetary, and interstellar flight. Rocket propulsion fundamentals; advanced mission analysis; physics and engineering of chemical rockets, electrical thrusters, and propellantless systems (tethers and sails); spacecraft integration issues. Pre: 4234 or AOE 4234. (3H,3C).

4204: INTERNAL COMBUSTION ENGINES
Analysis and design of gasoline and diesel engines. Fundamental processes and their application in current technology. Thermodynamics: air standard and air–fuel cycles. Combustion: stoichiometry, fuels, chemical equilibrium, chemical kinetics, flame propagation, knock, pollutant formation and control. Flow processes: volumetric efficiency, intake and ehaust tuning, two–stroke scavenging, carburetion, fuel injection, super– and turbo–charging. Pre: 3124, 3404. (3H,3C).

4214: POWER GENERATION
The design, control, and performance characteristics of electric power generating plants, with major emphasis upon the steam generating system, both fossil and nuclear. Pre: 3124, 3304. Co: 4414. (3H,3C).

4224: AIRCRAFT ENGINES AND GAS TURBINES
Performance and characteristics of aircraft engines and industrial gas turbines, as determined by thermodynamic, fluid mechanic, heat transfer, and solid mechanic behavior of components. Operational limitations and component matching. Stress and associated temperature limits and influence of blade cooling techniques on turbines. Pre: 4414 or 4234. (3H,3C).

4254: RAMJET AND ROCKET PROPULSION
Detailed study of analysis and design of ramjet and rocket propulsion systems. Vehicle performance requirements relating to choice of propulsion systems. Ramjet inlets, combustion chambers, and nozzles; analysis techniques for high–speed flow. Liquid and solid propellent rocket engine designs. Solid propellent burning rates, grain design. Special propulsion systems for high speed, trans–atmospheric, and space flight. Pre: 4234. (3H,3C).

4304: HEAT TRANSFER ANALYSIS
Methods for solving multidimensional and transient conduction problems. Convective heat and mass transfer with applications to industrial process heating, heat exchanger design, boiling and condensation, cooling tower design, and aerodynamic heating. Radiation properties of materials and heat transfer applications to real surfaces and absorbing–transmitting media including gases and windows. Transfer from wetted surfaces and through porous media with applications to drying, evaporative cooling, and heat pipe theory. Pre: 3304. (3H,3C).

4424: THERMODYNAMICS OF FLUID FLOW
One–dimensional compressible flow of perfect gases under specialized conditions: isentropic flow (with area change), normal and oblique shocks, constant area flow with friction, constant area flow with heat transfer, Prandtl–Meyer flow, and generalized one–dimensional flow. Introduction to propulsion systems and other selected topics. Pre: (3124 or 3114), 3404. (3H,3C).

4524: INTRODUCTION TO ROBOTICS AND AUTOMATION
Automation, robot technology, kinematics, dynamics, trajectory planning, and control of two–dimensional and spatial robots; robot programming; design and simulation of robotic devices. (3H,3C).

4534: LAND VEHICLE DYNAMICS
Analytical methods for land vehicle dynamics. Mechanics of pneumatic tires on pavement and steel wheels on rails. Vehicle stability, handling, response to random guideway and roadway irregularities, ride quality computation methods and standards, suspension design. Pre: 3514. (3H,3C).

4554: ADVANCED TECHNOLOGY FOR MOTOR VEHICLES
Energy use and environmental issues for motor vehicles: Emissions standards, fleet requirements, dynamometer testing, fuel economy, and vehicle performance. Alternative fuel vehicles: Characteristics and infrastructure of fuels, batteries, electric vehicles, and hybrid electric vehicles. Vehicle design: Modeling and simulation of vehicle energy use and performance, component sizing. Fuel cells for transportation. Heavy–duty vehicles and busses. Low mass vehicles and future vehicle technology. Pre: 3114 or 3124 or 3134. (3H,3C).

4614: MECHANICAL DESIGN II
Design of mechanical elements such as welded joints hydrodynamic bearings, spur gears, shafts, brakes. Alternative fatigue design methods, cumulative fatigue, mechanical design computer software. Pre: 3614. (3H,3C).

4624: FINITE ELEMENT PRACTICE IN MECHANICAL DESIGN
Application of the finite element method to stress analysis problems in mechanical design. Modeling techniques, proper use of existing computer programs, interpreting of results, application to design modification. Pre: 3614. (3H,3C).

4634: INTRODUCTION TO COMPUTER–AIDED DESIGN AND MANUFACTURING
Participants will study the computer–aided design and manufacturing of mechanical systems. A mechanical system will be designed including preliminary design, analysis, detail design, numerical control programming, and documentation. Applications programs will be written and interfaced to the CAD/CAM database. All assignments will be carried out on a CAD/CAM system. (2H,3L,3C).

4704 (MSE 4064): TRIBOLOGY
Basic principles of tribology–the study of friction, wear, and lubrication–including the importance of materials, surfaces, design, operating conditions, environment, and lubrication on friction, wear, and surface damage in any system. Application of tribological theories, concepts, techniques, and approaches to design, research, development, evaluation, and problem–solving. Pre: 4304 or MSE 2034 or MSE 2044, MSE 3034. (3H,3C).

4714: THEORY AND APPLICATION OF HYDRODYNAMIC LUBRICATION
Basic equation of lubrication as applied to design problems. Reynolds equation, plain journal bearing analysis, fixed arc geometry bearing analysis, tilting pad bearing analysis. Fluid film seal analysis and design. Thrust bearing design and application. Introduction to gas bearing theory. Finite element solution for fluid film bearing analysis. Pre: 3404. (3H,3C).

4724: ENGINEERING ACOUSTICS
Basic acoustical theory and practice, acoustic terminology, measurement, transmission, and perception of sound, muffler design, noise control techniques. Pre: 3404, 3124. (3H,3C).

4734 (ECE 4734): MECHATRONICS
Electromechanical system modeling, control and applications. Design of electronic interfaces and controllers for mechanical devices. Sensor technology, signal acquisition, filtering, and conditioning. Microcontroller–based closed–loop control and device communications. Sensor and actuator selection, installation, and application strategies. Pre: 3514 or ECE 2504, ECE 2704. (3H,3C).

MINING & MINERALS ENGINEERING

UNIVERSITY EXEMPLARY DEPARTMENT *

Tom Novak, Holland Professor and Department Head

Assistant Department Head and Professor: G.T. Adel
Stonie Barker Professor: M.E. Karmis
Massey Professor: G.H. Luttrell
Nicholas T. Camicia Professor: R.H. Yoon
Associate Professor: M.G. Karfakis
Assistant Professors: A. Nieto; E. Westman

E–mail: mineinfo@vt.edu
Web: www.mining.vt.edu

The department offers the M.S., M.E., and Ph.D. in mining and minerals engineering. The graduate program is designed to educate mining and minerals engineers for higher level and challenging efforts in research, development, design, industry, university teaching, and government.

The various areas offered are flexible to provide specialization in particular phases of mining and minerals engineering or to provide a broad general training. Graduate research may be pursued in the field of rock mechanics, ground control, equipment evaluation, systems analysis, health and safety, mineral processing, coal preparation, conservation, mining environment, mining ventilation, and mineral economics. Because of the close location of the university to the extensive number of operating mines and facilities of the central Appalachian coal fields, an opportunity is provided for qualified individuals to pursue a part–time graduate program. The part–time student may earn an M.S. or an M.E. over a three– to four–year period.

Graduate students are generally supported by assistantships, fellowships, federal traineeship grants, departmental grants, and the departmental hourly payroll. Graduate students play an important role in the sponsored research program active in the department. The student is provided the opportunity to participate in creative research projects and to produce results that have potential for dissemination by publication in the literature.

The facilities of the department include laboratories for rock mechanics, mineral processing, coal preparation, surface chemistry, electrochemistry, comminution, sizing analysis, image analysis, electrostatic separation, environmental control, mine ventilation, systems analysis, health and safety, chemical analysis, and necessary shop facilities. Rock mechanics facilities include a laboratory for preparation of rock specimens for strength testing, three megapound testing

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

machines (three MTS servo–controlled, stiff–test units with computerized data acquisition facilities, one of which is for dynamic testing at 2m/sec loading rate), triaxial and two shear testing units, a creep testing machine with digital data–acquisition system, equipment for seismic testing of rock in both field and laboratory, and subsidence monitoring equipment.

The facilities in health and safety and mining ventilation laboratories include capability for gas detection, dust analysis, and noise monitoring, a series of wind tunnels, fans, and airflow monitoring equipment and micro–computing facilities.

The facilities in mineral processing include various types of crushing and grinding equipment; complete pilot plant with a ball mill, flotation banks, flotation columns, a thickener, a filter and ore bins, conveyors, belts, and pumps. Equipment for particle characterization includes a Kontron SEM–IPS image analysis system, a Cambridge Model 120 Scanning Electron Microscope, a Kevex Level I Energy Dispersive X–Ray System, a Microtrac X100 particle size analyzer, and a Philips XRF analyzer. The facilities of the surface chemistry laboratory include a Perkin Elmer UV spectrophotometer, an FTIR spectrophotometer, a Tronac Model 550 isothermal/isoperibol microcalorimeter, a Gilson model FM–324 flow microcalorimeter, a PAR potentiostat and programmer equipped with a Hewlett–Packard X–Y recorder, a turbidimeter, a surface tensiometer, electrophoresis apparatus, induction time apparatus, ellipsometer, Anutech surface force analyzer, atomic force microscope, and a Langmuir trough. In addition, an entire suite of coal analysis equipment is avail–able for determining proximate analysis, sulfur, Btu and ash fusion temperature.

Graduate students in the department have exclusive access to numerous terminals within the department which allow use of the university's computer systems. The depart–ment has its own mini– and micro–computer systems which are used to run experiments and for graduate research.

GRADUATE COURSES (MINE)

5015,5016: ADVANCED MINING ENGINEERING
Selected concepts and principles in the discipline including factors in pillar design, contiguous bed mining, and technical problems in deep mining; mineral beneficiation, coal technology, hydrometallurgical, and pyrometallurgical processes. Pre: 4074. (3H,3C).

5025,5026: ADVANCED MINING DESIGN
Selected advanced design problems in mining including roof control, shafts, material handling, transportation, drainage, and ventilation. Advanced work in creative quantitative design or ore milling and coal preparation plants. (3H,3C).

5035,5036: ADVANCED GROUND CONTROL
Recent developments in ground control are considered from a theoretical and practical viewpoint. Various integrated support systems are compared operationally, structurally, and economically to optimize their individual contributions. Pre: 4184. (3H,3C).

5045,5046: ADVANCED MINERAL PROCESSING
The theory of reactions in flotation systems and application of physical chemistry to mineral beneficiation. Advanced studies in electrostatic and magnetic separation. Theory and application of differential gravity separations. Advanced studies in comminution, grinding systems, and coal preparation plant design, simulation, and control. Pre: 3554. (3H,3C) I,II.

5055,5056: QUANTITATIVE DECISION–MAKING IN MINING
Application of quantitative decision–making techniques to problems in mining industries. Identification of problems, formulation, and solution methodologies. (3H,3C).

5065,5066: MINERAL RESOURCES & ECONOMICS
The interrelation of the legal, financial, economic, environmental, political, and physical components of the resources exploitation environment. Market and non–market determinants of resources to reserve conversions. Domestic and international impact of the mining industry. Pre: 4114. (3H,3C).

5084: STABILITY OF ROCK SLOPES
Factors affecting the stability and stabilization of rock slopes, geological site studies, mechanical properties of joints, calculations, influence of ground water, geometry, seismic effects, and case histories. Pre: GEOS 4414. (2H,3L,3C).

5094: PARTICULATE PROCESS MODELING
Statistical and mechanistic approaches to modeling of mineral processing and other particulate systems. Population balance modeling of particulate systems. Representation of particle distributions. Numerical simulation techniques using the digital computer. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Two written or oral presentations to be made by all graduate students on their thesis topics; also participation in all other graduate student, visiting lecturer, and faculty member presentations during their scholastic tenure. Required of all students for graduation. All graduate students in the department are required to enroll in the seminar for two semesters and to attend all the seminars. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6015–6016: ADVANCED ROCK MECHANICS
Applications of continuum mechanics to underground opening design; concepts of rock testing and failure; dynamic stresses in drilling, blasting, and protective construction; model testing, underground instrumentation, observations, and case studies. Pre: 4154, ESM 5014, GEOL 4414. (3H,3C).

6034: CHEMISTRY OF FLOTATION
Surface and colloid chemistry as applied to the technology of froth flotation; surface energetics, thermodynamics of adsorption, electrification of interfaces, chemistry of surfactants, oxidation and reduction of sulfide minerals, electrochemistry of sulfide flotation systems, and hydrodynamics of bubble–particle adhesion. (3H,3C).

6044: ADVANCED MINING ANALYSIS
Advanced study of decision–making problems with critical applications of quantitative techniques in mineral industries. Pre: 5055. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (MINE)

The following 4000–level courses have been approved for graduate credit:

4054: COMPUTER APPLICATIONS IN MINING
Applications of computer programs to the estimation of ore reserves, the scheduling and planning of mine activities, the optimization of mine production, and the design and selection of equipment and support systems. Pre: 2524, 3564. (2H,2C).

4074: COAL PREPARATION
Unit operations of cleaning coals by physical and chemical processes, coal analysis and characterization, flowsheet design, evaluation of plant performance, process control, and simulation of coal preparation plants. Pre: 3554. (2H,3L,3C).

4124: MINING LAW
Land ownership and mineral rights, withdrawals, environmental laws, locatable and leasable minerals, exploration permits, lease management, and mineral taxation. Pre: 2524. (2H,2C).

4154: INTERMEDIATE ROCK MECHANICS
Theory and application of field instrumentation, simulation laws, and modeling in rock mechanics; dynamic response of rock; theory of rock bursts; stability of rock slopes, computer techniques of modeling, and monitoring. Pre: 3054. (3H,3C).

4164 (MSE 4164): PRINCIPLES OF MATERIALS CORROSION
Introduction to the scientific principles of materials corrosion and corrosion protection. Topics include: thermodynamics of materials corrosion, including potential–PH (Pourbaix) diagrams, kinetics of corrosion reactions and mixed potential theory, types of corrosion (uniform, galvanic, crevice, pitting, fatigue, stress corrosion cracking, intergranular, and hydrogen embrittlement), material/environmental factors that promote or prevent the various types of corrosion, and methods and techniques of corrosion testing. Co: MSE 4034 or ME 3114 or ME 3124 or ME 3134. Pre: CHEM 1074. (3H,3C).

4604: MINERAL PROCESSING SIMULATION AND CONTROL
Principles of processing minerals and coal including analysis of flowsheets and unit operations, mass balance calculations, mathematical modeling, simulation and control of mineral and coal processing operations. Pre: 3554. (3H,3C).

MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY

John McDowell, Chair (2004–05)

Web: www.biotech.vt.edu/education/mcbb.html

Contemporary research in the life sciences is becoming increasingly unified. New techniques in biochemistry, cell biology, immunology and molecular genetics have made possible the purification, mutation and reintroduction of modified gene products into cells. Practitioners of fields once considered distant from each other use these molecular cell biology approaches and now speak the same technical language. The Molecular Cell Biology and Biotechnology Option (MCBB) is a curriculum of courses intended to reflect this change. It functions as a supplement to existing master's and doctoral degree programs in applied and basic disciplines of biological and agricultural and life sciences. The purpose of an option is to provide training in broad fundamentals which can be then applied to individual problems pertaining to particular disciplines. On successful completion of the core curriculum in MCBB, students will be able to apply concepts of molecular cell biology directly to their own field of interest and research.

The participating departments are:

Animal and Poultry Sciences
Biochemistry
Biology
Biomedical Sciences and Pathobiology
Chemical Engineering
Crop and Soil Environmental Sciences
Dairy Science
Entomology
Fisheries and Wildlife Sciences
Food Science and Technology
Horticulture
Human Nutrition, Foods, and Exercise
Plant Pathology, Physiology, and Weed Science

REQUIREMENTS FOR STUDENT PARTICIPATION AND AWARDING OF OPTION ON TRANSCRIPT

PH.D. CANDIDATES

A. *A Ph.D. student's participation in the option must be endorsed by the major professor and will be part of the student's program of study.*

Students in the program must complete ALS/PPWS 5344, Molecular Biology for the Life Sciences (or BCHM 4116/5116); BCHM 5214, Molecular Biology of the Cell; ALS/BIOL/BCHM/PPWS 6024, Topics in Molecular Cell Biology and Biotechnology; and ALS/BIOL/BCHM/PPWS 5064, Seminar in Molecular Cell Biology and Biotechnology. There is a requirement as well for a seminar presentation. This can be completed by a presentation in ALS/BIOL/BCHM/PPWS 5064 while registered A/F or by advertising the terminal seminar as an MCBB seminar. The seminar course may be repeated.

Submission of MCBB registration form (available on MCBB homepage) should be completed with program of study. Certification in the MCBB option will occur at the time of the preliminary examination. The major professor will indicate to the MCBB Steering Committee that the candidate has exhibited proficiency in these areas during the examination.

B. *Students Entering with Advanced Standing*

Students entering with appropriate advanced standing, e.g., M.S. in a relevant discipline, and desiring to be MCBB option students will submit their credentials for review by the MCBB Steering Committee. Typically, such students will be required only to take the Topics and Seminar courses and complete MCBB certification.

M.S. CANDIDATES

An M. S. student's participation in the option must be endorsed by the major professor and will be part of the student's program of study.

M.S. candidates in the option must complete ALS/PPWS 5344, Molecular Biology for the Life Sciences (or BCHM 4116/5116); BCHM 5214, Molecular Biology of the Cell; ALS/BIOL/BCHM/PPWS 6024, Topics in Molecular Cell Biology and Biotechnology; and ALS/BIOL/BCHM/PPWS 5064, Seminar in Molecular Cell Biology and Biotechnology P/F. M.S. candidates are not required to present a seminar.

CORE COURSES

PPWS/ALS 5344: MOLECULAR BIOL. FOR THE LIFE SCI.
A multi–disciplinary treatment of gene organization and expression in animal and plant systems. Emphasis on the applications of molecular biology to current problems in applied biology and biotechnology. Pre: BCHM 4116 or BCHM 5124. (3H, 3C).

BCHM 5214: MOLECULAR BIOLOGY OF THE CELL
Current concepts of the molecular organization of animal and plant cells and the biosynthesis and assembly of cellular structures. Topics include membrane structure and function, biosynthesis of cellular organelles, cytoskeleton, extracellular matrix, chemical signalling between cells, and the production of engineered proteins in cells. Pre: 4116 or 5116 or 5124 or ALS 5344. (3H, 3C).

PPWS/BIOL/ALS/BCHM 5064 : SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty and outside speakers. Students give formal presentations of research results or current literature. May be taken on pass–fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A–F basis. Pre: Graduate status in participating MCBB departments; (1H,1C)..

PPWS/BIOL/ALS/BCHM 6024: TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle assembly, and of growth and development, structure and function of proteases, bacterial virulence factors and vaccines, methanogens will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: BCHM 5214;.

MOLECULAR CELL BIOLOGY AND BIOTECHNOLOGY RELATED GRADUATE LEVEL COURSES (ARRANGED WITHIN EMPHASIS AREA)

ANIMAL/BIOMEDICAL

BIOL 6010: The Cell Cycle
BIOL 6704: Topics in Immunology
BCHM 5204: Molecular Biology of Eucaryotic Gene Expression
BCHM 5224: Protein Structure & Function
BCHM 5504: Metabolic Regulation
HNFE 5144: Molecular Aspects of Nutrition and Disease

MICROORGANISMS

BCHM 5034: Comparative Studies in Nucleic Acids
BCHM 5044: Comp. Metabolism of Anaerobic Bacteria
BCHM 5054: Molecular Biology of Prokaryotic Gene Regulation
BIOL 5634: Microbial Physiology
BIOL 6644: Topics in Microbial Genetics (a rotating topics course)
BIOL/PPWS 6654: Topics in Virology
VMS 5024: Selected Topics in Veterinary Pathogenic Bacteriology

PLANTS

BIOL 5304/PPWS 5304: Plant Stress Physiology
CSES 5844: Molecular Genetics for Crop Improvement
HORT 5404: Plant Tissue Culture
HORT 5304: Gen. & Breeding of Hort. Crops
PPWS 5114: Plant Disease Agents: Fungi & Prokaryotes
PPWS 5124: Plant disease agents: Viruses and Nematodes
PPWS 5654: Plant Growth & Development
PPWS 5724: Herbicide Action & Metabolism
PPWS/HORT 5524: Advanced Plant Physiology & Metabolism I
HORT/PPWS 5534: Advanced Plant Physiology & Metabolism II

MUSIC

John S. Husser, Jr., Head

Professors: A.H. Bachelder; C.V. Burnsed; K.A. Holliday; J.R. Sochinski; D.R. Widder
Associate Professors: P.F. Casey; R.C. Cole; W.J. Crone; W.E. Easter; J.M. Floyd; W.J. Glazebrook; J.R. Howell; J.S. Husser; D.C. Jacobsen; E. Sheinberg
Assistant Professors: T.E. Cowden; B.W. Gendron; N.B. McDuffie; A.S. Weinstein
Instructors: M.E. Dunston; D.M. McKee; G.R. McNeill
Career Advisor: (231–5685)

E–mail: john.husser@vt.edu
Web: www.music.vt.edu

The courses listed below are available to qualified graduate students in education and other disciplines.

GRADUATE COURSES (MUS)

5014: MICROCOMPUTERS & MUSIC
Basic programming techniques for the development of microcomputer software for music instruction. Review of the commercially available software for music instruction via microcomputers. (3H,3C).

5024: VOCAL–CHORAL ARRANGING
Techniques of arranging for vocal/choral ensembles. Emphasis is on contemporary techniques for show, swing, and jazz ensembles. Lecture, transcription, analysis, and writing assignments. Requires music equivalent background or consent. (3H,3C).

5134: BAND & WIND ENSEMBLE LITERATURE
Survey of band and wind ensemble literature with attention to historical development and aesthetics. Extensive listening. (3H,3C).

5224: BEHAVIORAL ASPECTS OF MUSIC
Behavioral foundations of music research examining the influence of music on the performer and the listener. Perception, reaction, moods, powers of discrimination, and musical acoustics. (3H,3C).

5234: MUSIC RESEARCH
An introduction to musicology and the use of music reference and research materials. Additional work in music historiography and bibliography for music educators. (3H,3C)..

5314: INSTRUMENTAL ENSEMBLE MUSIC
Instruction and participation in the various instrumental musical performance ensembles under direction of members of the music faculty. May be repeated. Consent and audition required. (3H,1C).

5414: CHORAL ENSEMBLE MUSIC
Instruction and participation in the various choral ensembles under the direction of the music faculty. May be repeated. Consent and audition required. (3H,1C).

5514: GRADUATE INDIVIDUAL APPLIED VOICE
Individual instruction in voice at an advanced level. May be repeated. Consent required. Variable credit course.

5524: GRADUATE INDIVIDUAL APPLIED KEYBOARD
Individual instruction in keyboard at an advanced level. May be repeated. Consent required. Variable credit course.

5534: GRADUATE INDIVIDUAL APPLIED VIOLIN
Individual instruction in violin at an advanced level. May be repeated. Consent required. Variable credit course.

5544: GRADUATE INDIVIDUAL APPLIED VIOLA
Individual instruction in viola at an advanced level. May be repeated. Consent required. Variable credit course.

5554: GRADUATE INDIVIDUAL APPLIED CELLO
Individual instruction in cello at an advanced level. May be repeated. Consent required. Variable credit course.

5564: GRADUATE INDIVIDUAL APPLIED BASS
Individual instruction in bass at an advanced level. May be repeated. Consent required. Variable credit course.

5574: GRADUATE INDIVIDUAL APPLIED FLUTE
Individual instruction in flute at an advanced level. May be repeated. Consent required. Variable credit course.

5584: GRADUATE INDIVIDUAL APPLIED OBOE
Individual instruction in oboe at an advanced level. May be repeated. Consent required. Variable credit course.

5594: GRADUATE INDIVIDUAL APPLIED CLARINET
Individual instruction in clarinet at an advanced level. May be repeated. Consent required. Variable credit course.

5614: GRADUATE INDIVIDUAL APPLIED SAXOPHONE
Individual instruction in saxophone at an advanced level. May be repeated. Consent required. Variable credit course.

5624: GRADUATE INDIVIDUAL APPLIED BASSOON
Individual instruction in bassoon at an advanced level. May be repeated. Consent required. Variable credit course.

5634: GRADUATE INDIVIDUAL APPLIED HORN
Individual instruction in horn at an advanced level. May be repeated. Consent required. Variable credit course.

5644: GRADUATE INDIVIDUAL APPLIED TRUMPET
Individual instruction in trumpet at an advanced level. May be repeated. Consent required. Variable credit course.

5654: GRADUATE INDIVIDUAL APPLIED TROMBONE
Individual instruction in trombone at an advanced level. May be repeated. Consent required. Variable credit course.

5664: GRADUATE INDIVIDUAL APPLIED BARITONE
Individual instruction in baritone at an advanced level. May be repeated. Consent required. Variable credit course.

5674: GRADUATE INDIVIDUAL APPLIED TUBA
Individual instruction in tuba at an advanced level. May be repeated. Consent required. Variable credit course.

5684: GRADUATE INDIVIDUAL APPLIED PERCUSSION
Individual instruction in percussion at an advanced level. May be repeated. Consent required. Variable credit course.

5714: GRADUATE INDIVIDUAL APPLIED HISTORICAL WIND INSTRUMENTS
Individual instruction in historical wind instruments at an advanced level. May be repeated. Consent required. Variable credit course.

5724: GRADUATE INDIVIDUAL APPLIED HISTORICAL STRING INSTRUMENTS
Individual instruction in historical string instruments at an advanced level. May be repeated. Consent required. Variable credit course.

5734: GRADUATE INDIVIDUAL APPLIED COMPOSITION
Individual instruction in composition at an advanced level. May be repeated. Consent required. Variable credit course.

5744: GRADUATE INDIVIDUAL APPLIED CONDUCTING
Individual instruction in conducting at an advanced level. Consent required. Variable credit course.

5834: GRADUATE RECITAL
Preparation of a public full recital featuring performances of works by established or student composers, or lecture–demonstrations devoted to major works by established composers. Consent required. (1H,1C)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course

NATURAL RESOURCES

David L. Trauger, Director, College of Natural Resources National Capital Region Programs
Robert J. Bush, Associate Dean for Research and Graduate Studies
Gary R. Evans, Director, Natural Resources Distance Learning Consortium

Web: http://natrespro.nvgc.vt.edu
E–mail: dtrauger@vt.edu

Natural Resources is an interdisciplinary program offered by the College of Natural Resources and based in the National Capital Region. The program offers study leading to the Master of Natural Resources (M.N.R.) degree. The M.N.R. is a professional, non–thesis program open to students with a variety of backgrounds. A Certificate of Graduate Study in Natural Resources is available for non–degree–seeking students. In addition, the College offers the Master of Science (M.S.), Master of Forestry (M.F.), and Doctor of Philosophy (Ph.D.) degrees through the departments of Forestry; Fisheries and Wildlife Sciences; Geography; and Wood Science and Forest Products.

The programs offered by the College of Natural Resources in the National Capital Region focus on natural resource management and on urban ecology, with special emphasis on fishery, wildlife, and forest resources in the rapidly changing rural–urban environment. Programs are interdisciplnary and have the dual objectives of training graduates for professional employment in natural resources management and policy positions, while developing the conceptual and critical thinking skills necessary for lifelong learning and career development. Graduates are able to assume professional responsibilities in a variety of positions in public service and in the private sector.

The program is affiliated with the Virginia Tech Metropolitan Institute, the Department of Urban Affairs and Planning and the Department of Landscape Architecture. Concentrations in Urban and Regional Planning are available to students having an interest in combining work in this area with natural resources. In conjunction with the Center for Public Administration and Policy, the program offers graduate course work leading to the Master of Public Administration (M.P.A.) with a natural resource concentration.

DEGREE REQUIREMENTS

Students may study on a part–or full–time basis. Typically, students complete two classes per semester to progress toward the 33–credit–hour degree requirement for the M.N.R. Credit hours may be transferred from graduate work completed at another accredited institution in accordance with policies and procedures of the Virginia Tech Graduate School. Each M.N.R. candidate develops a plan of study in conjunction with his or her graduate advisory committee. Plans of study reflect the student's background, goals and area of desired specialization. While the required core (12 credits) provides "generalist" theories and skills, more than

one–half of the overall curriculum (15–18 credits) is in the student's area of concentration and provides substantive skills in this area. Students studying toward the M.N.R. and M.F. complete a capstone paper, which accounts for three to six hours of credit. Requirements of the M.S., M.F., and Ph.D. programs are department–specific (see Forestry; Fisheries and Wildlife Sciences; Geography; or Wood Science and Forest Products).

GRADUATE COURSES (NR)

Additional applicable courses are listed under Fisheries and Wildlife Sciences (FIW), Forestry (FOR), Geography (GEOG), and Wood Science and Forest Products (WOOD).

5114: GLOBAL ISSUES IN NATURAL RESOURCES
Study of the global economic and environmental consequences of the use of renewable natural resources. Emphasis is on the world's forest, fisheries, and wildlife resources and on sustainable management. Seeks to enhance knowledge and understanding of the world's natural resources and the management of related industries from a global perspective. (3H,3C).

5324: BIOLOGICAL IMPLICATIONS OF NATURAL RESOURCE POLICY & MANAGEMENT
Provides the biological background and the social, political and economic implications associated with natural resource policy and management decisions. Focus will be on renewable natural resources including forests, wildlife, water and soil. Pre: Baccalaureate degree; previous graduate–level coursework or consent of instructor. (3H,3C).

5714: ECOSYSTEM MANAGEMENT
Problem–based learning format to explore the application of ecological, economic, social, and management principles to natural resource management. Examines the changes in social values, technologies and demographics driving the ecosystem management model. Contrasts how the major federal agencies and other organizations implement ecosystem management. Pre: Graduate standing. (3H,3C).

5724: CONSERVATION ECOLOGY
Explores the interdisciplinary knowledge, theories, and research related to natural resource management and conservation. Emphasis will be on the synthesis and integration of knowledge, skills and abilities required to develop innovative approaches to sustain resource development as conservation issues become more complex. Graduate standing required. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5964: FIELD STUDY
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable crfedit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

PHILOSOPHY

Joseph C. Pitt, Head

Professors: R. Ariew; R.M. Burian; V. Hardcastle; J.C. Klagge; D.G. Mayo; J.C. Pitt
Associate Professor: M. Gifford
Assistant Professors: A.M. Baxley; B. Epstein; W. FitzPatrick; R.M. Mayorga; L. Perini
Adjunct Professors: J.M. Buchanan (University Distinguished Professor Emeritus of Economics and Philosophy); I.J. Good (University Distinguished Professor Emeritus of Statistics); M.G. Grene (Honorary Distinguished Professor)
Professors Emeritus: H.B. Miller; P. Talbutt, Jr.
Career Advisor: J. Klagge (2 31–8487; james.c.klagge@vt.edu)
Director of Graduate Studies: W. FitzPatrick (231–7543; wfitzpat@vt.edu)

Departmental E–mail: tzapata@vt.edu
Web: www.phil.vt.edu

MASTER OF ARTS (THESIS OR NON-THESIS)

The M.A. requires a minimum of 30 semester hours of graduate–level course work, including successful completion of a thesis or passing of comprehensive exams. Those students pursuing a thesis option will engage in an independent research project closely supervised by a committee of three faculty members, a majority of whom are members of the department. Such students are required to submit and orally defend a thesis proposal in the academic term preceding the semester in which they plan to write the thesis. The completed thesis will be evaluated by the student's faculty committee and must be successfully defended before that committee in an oral examination.

Those students pursuing a non–thesis option must receive permission to do so from the student's advisor and advisory committee. These students must successfully pass a written comprehensive exam. Exams normally will be administered in the spring semester.

All students must complete PHIL 5505 (or receive a waiver of the logic requirement according to department procedures), PHIL 5334 or 5344, two graduate courses in the history of philosophy, and at least one course in two of the following three areas: metaphysics, epistemology, philosophy of science. For further details concerning degree requirements, students should consult the *Department of Philosophy Graduate Student Handbook*.

Students will be encouraged to take appropriate courses in cognate disciplines with the prior approval of the director of graduate studies.

GRADUATE COURSES (PHIL)

5204: TOPICS IN THE HISTORY OF PHILOSOPHY
An advanced course focusing on particular topics in the history of philosophy. Special emphasis will be placed on ideas and disputes which were historically influential and continue to be philosophically significant. Consent required. (3H,3C).

5305,5306 (STS 5305, 5306): MAIN THEMES IN THE PHILOSOPHY OF MODERN SCIENCE & TECHNOLOGY
Problems, literature, and schools in the philosophy of science and technology. 5305: explanation and confirmation; 5306: theory change. Pre: 3505 for 5305; 5305 for 5306. (3H,3C).

5334: ETHICS
A study of principal theories and issues in and about morality. (3H,3C).

5344: HISTORY OF ETHICS
Examination of the work of selected figures representative of important positions in the history of ethical theory from the Classical Age to the modern period. (3H,3C).

5505,5506: SYMBOLIC LOGIC
Modern deductive symbolic logic and its metatheory. 5505: Development of a system of first order logic. Truth functional sentential logic, monadic predicate calculus with identity. Proof techniques and translation between natural and artificial languages. 5506: Logical metatheory: consistency, completeness, and decidability of logical systems. (3H,3C).

5904: PROJECT & REPORT
Only for students pursuing a Master of Arts degree with a non-thesis option. Variable credit course. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6014: SPECIAL TOPICS IN PHILOSOPHY
Close examination of a discipline, topic, or group of questions from a major philosophical tradition. Such areas as philosophy of language, philosophy of logic, and philosophy of mathematics, and such issues as causation, the nature of space and time, mental representation, logical positivism, and the linguistic turn will be examined. May be repeated for credit, with permission and different content, for a maximum of 6 hours. Completion of at least one of the philosophy M.A. core courses required. (3H,3C).

6204: ADVANCED TOPICS IN THE HISTORY OF PHILOSOPHY
Intensive study of a particular figure, school, or group in the history of philosophy, in cultural and theoretical context, such as Socrates in the Athenian "polis," Stoicism in the Hellenistic age, or Hume and the Scottish Enlightenment. May be repeated for credit, with permission, for a maximum of 6 hours. Completion of at least one of the philosophy M.A. core courses required. (3H,3C).

6314 (STS 6314): HISTORY OF THE PHILOSOPHY OF SCIENCE
Philosophers of science from 1650 to 1900 with particular attention to the historical development of views about the methods of induction and hypothesis and accounts of theory testing. Pre: 5305, 5306. (3H,3C).

6324: ADVANCED TOPICS IN ETHICS & POLITICAL PHILOSOPHY
A seminar closely examining a topic or group of topics in moral, social, or political theory. Such issues as the foundaitons of ethics, practical reason, the concept of 'virtue', political obligation, the bounds of moral and political community, paternalism, liberty, and privacy will be explored. Views considered may include moral realism and antirealism, contractarianism, egalitarianism, libertarianism, and communitarianism. May be repeated, with permission, for a maximum of 6 hours. (3H,3C).

6334 (STS 6334): ADVANCED TOPICS IN PHILOSOPHY OF SCIENCE
Variable topics in advanced philosophy of science, including major theories of scientific explanation and their criticisms; philosophical foundations of statistics; naturalized philosophy of science. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6504: ADVANCED LOGIC
Advanced study of the concept of logical proof and introduction to the theory of models for first-order logical systems. Topics may include: the sequent calculus, Herbrand's Theorem, construction of models by consistency families, products and ultraproducts, elementary equivalence, complete theories and Lindstrom's characterization of first-order logic. Pre: 3505, 3506. (3H,3C).

6514 (STS 6514): COGNITIVE STUDIES OF SCIENCE & TECHNOLOGY
Applications of cognitive science to science and technology studies. Includes category theory, cognitive error theory, and computer modelling as research tools in projects linking history, philosophy, and sociology of science. (3H,3C).

ADVANCED UNDERGRADUATE COURSES (PHIL)

The following 4000-level courses have been approved for graduate credit:

4204: PHILOSOPHY OF MIND
Current issues in the philosophy of mind such as relation of mind and body, status of the mental, knowledge of one's own and other minds, personal identity, consciousness, mentality of animals and machines, topics in the philosophy of psychology. 3 Philosophy credits required. (3H,3C).

4214: METAPHYSICS
Examination of some of the central problems of metaphysics. Topics may include: existence, necessary truth, the problem of universals, causation, the identity of the self through time, free will. Attention will be given both to the historical development of these problems and to contemporary philosophical responses to them. 3 Philosophy credits required. (3H,3C).

4224: EPISTEMOLOGY
Theory of knowledge. Is all knowledge based on experience? Does knowledge have a foundation? Can knowledge of the present and the nearby give us reasons for beliefs about the future, the past, or about events far away? 3 Philosophy credits required. (3H,3C).

4304: TOPICS IN SOCIAL & POLITICAL PHILOSOPHY
Study of topics such as distributive justice, equality exploitation, alienation, individual rights, anarchy, constitutional government, the justification of political authority, and liberation. Topics to be announced each semester course is offered. 3 Philosophy credits required. (3H,3C).

4604: PHILOSOPHY OF BIOLOGY
This course is designed primarily for students of biology or philosophy students with a strong interest in biology. Topics vary from year to year, but include the changing character of biology as a science, the special character of biological explanations and methods, and the place and value of reduction (e.g., of Mendelian to molecular genetics) in biology. One course at the 3000 level or higher in biology and 3 credits in philosophy required. (3H,3C).

4614: PHILOSOPHY OF SCIENCE
An examination of the structure and methodology of science as well as key concepts such as explanation, confirmation, realism, and instrumentalism. One year of science and 3 philosophy credits required. (3H,3C)

PHYSICS

UNIVERSITY EXEMPLARY DEPARTMENT *

Royce K. P. Zia, Department Chair

Professors: M. Blecher; L.N. Chang[1]; G.J.M. Indebetouw; L.E. Piilonen; R.S. Raghavan; B. Schmittmann; J. Slawny; R. Zallen; R.K.P. Zia
Associate Professors: J.R. Heflin; T. Mizutani; M. Pitt; A.L. Ritter; J.H. Simonetti; W. Spillman; U. Taeuber; T. Takeuchi; B. Vogelaar
Assistant Professors: G.A. Khodaparast; R.V. Kulkarni; D. Minic; H.D. Robinson
Adjunct Professors: B.L. Bressler; F.X. Hartmann; Y. Liang; B.A. Mecking; H.L. Phillips; C.E. Reese; E.S. Smith
Affiliated Faculty: L. Guido[2]
Career Advisor: A.L. Ritter (231–5369)

[1] Dean, College of Science
[2] Regular appointment with Materials Science & Engineering and Electrical & Computer Engineering.

E–mail: gradphys@vt.edu
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The graduate physics program course work and research lead to the M.S. (thesis optional) and/or to the Ph.D. Research specialization is available in experimental and/or theoretical aspects of astronomical, biophysics, condensed–matter, elementary–particle, mathematical, medium–energy, optical, and statistical physics, and in physics teaching. The department also has programs which are directed toward improvement in physics teaching and include the testing of model physics courses, development of multimedia techniques for learning enhancement, and creation of computer simulations.

The department offers an Applied and Industrial Physics Option which leads to a degree of M.S. in physics and prepares a student to apply broad physics principles to technological problems of interest to industry. The program combines courses with applied and technological relevance with a research project that is carried out either in an industrial laboratory or on campus. Additional emphasis is placed on enhancing the communication skills of the student and on preparing the student to work with a team. The requirements for the degree include a research project leading to a written report and the successful completion of a program of study. Courses in physics, chemistry, materials science engineering, and business may be combined to satisfy the course requirements for the degree. The program can be completed in four semesters.

SPECIAL FACILITIES

Experimental laboratories within the Department of Physics include facilities employing Raman scattering, far–infrared to near–ultraviolet spectroscopy, conventional and superconducting magnets, thin–film electron scattering, susceptometry, sol–gel studies, laser holography and spatial filtering, and pulsed laser nonlinear optical measurements such as harmonic generation and degenerate four–wave mixing, and clean–room. Other techniques and materials are available via collaborative programs with the Departments of Chemistry, Chemical Engineering, and Materials Science.

Facilities are maintained in the Department of Physics to prepare experiments and analyze data collected by the radio astronomy and medium/high energy nuclear/particle groups which are currently working at national and international research centers, including FermiLab, Brookhaven, TJNAF (Newport News), ORNL (Oak Ridge Laboratory), Gran Sasso (Italy), KEK (Japan), Los Alamos (New Mexico) Kimballton underground science and engineering facility, and National Radio Astronomy Observatory (including the VLA and VLBA). Also housed in the department is the university's Institute for Particle Physics and Astrophysics. Many theorists are members of the University Center for Stochastic Processes in Science and Engineering which, comprised of faculty from the departments of Chemistry, Electrical Engineering, Geosciences, Materials Engineering and Mathematics, promotes interdisciplinary research in a wide variety of topics, ranging from quantum field theory and phase transitions to wave propagation in random media.

The Department of Physics has numerous microcomputers, minicomputers, and workstations in research laboratories, and a computer room for physics graduate students and majors, as well as acccess to a 25–node Beowulf cluster for exclusive use of department personnel, a 220 processor Beowulf cluster, which is shared with select departments in the College of Engineering, and the university's System X with 2300 processors which was recently (November 2004) ranked seventh in the world and first among university facilities worldwide. Access to supercomputers is also available through national and international networks.

ADMISSIONS REQUIREMENTS

Applicants for admission to the graduate program are required to take the GRE General and Physics tests. International students are also required to take the TOEFL. Ph.D. candidates are required to pass an oral preliminary examination (administered by the student's Ph.D. advisory committee). The student is expected to present the intended dissertation research and to demonstrate a firm grasp of the content of the core courses (PHYS 5354, 5405–6, 5455–6, 5705, 5714). Passing will officially admit the student to candidacy for the Ph.D. To complete the degree, the student's committee must accept a dissertation describing the student's research findings.

SPECIAL DEGREE REQUIREMENTS

The experiences gained by physics graduate students in carrying out the duties attached to graduate project assistantships, graduate research assistantships, graduate teaching assistantships, and graduate assistantships are viewed by the department as essential ingredients in the training required for the physics master's and doctoral degrees. It is therefore required that on–campus master's students hold an assistantship (of one or more of the indicated types) for at least two semesters and on–campus

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

doctoral students for at least eight semesters (past the bachelor's degree) during their programs of study.

A brochure detailing the graduate physics program may be requested from the Graduate Programs Coordinator by calling (540) 231–8728.

GRADUATE COURSES (PHYS)

5354: CLASSICAL MECHANICS
Theory of classical Lagrangian and Hamiltonian mechanics of particles and rigid bodies, including canonical transformations and Hamilton–Jacobi theory. Consent required. (3H,3C).

5405–5406: CLASSICAL ELECTROMAGNETISM
Classical theory of electromagnetism and its applications. 5405: Electrostatics and magnetostatics; Maxwell's equations and electromagnetic waves; wave guides, apertures, and antennae. 5406: Special relativity and Lagrangian and Hamiltonian formulations; Lienard–Wiechert potentials, motion, radiation, and energy loss be charged particles; self–fields and radiative damping; magnetic monopoles and field theories. Consent required. Co: 5714. (3H,3C).

5455–5456: QUANTUM MECHANICS
General principles of nonrelativistic quantum mechanics from the point of view of advanced dynamics, with applications to problems of atomic and nuclear structure. Consent required. (3H,3C).

5504: NUCLEAR & PARTICLE PHYSICS
Properties of nuclei, two–nucleon systems, nuclear force, nuclear models, nuclear reactions, alpha and beta decay, and fission. Relativistic kinematics, invariance principles, quantum numbers, strange particles, weak interactions, formation and production reactions, and symmetries. Consent required. (3H,3C).

5555–5556: SOLID–STATE PHYSICS
Solidity, crystal structure, k–space, quantum mechanics of covalent bonding, phonon excitations, thermal energy, the nearly–free–electron approximation, Bloch electrons, E(k) energy bands in semiconductors and metals, density of states, optical properties of solids, donors and acceptors in semiconductors, excitons, plasmons, polaritons, electrical properties, magnetic materials, the percolation model and phase transitions, metal–insulator transitions, and amorphous solids. Consent required. (3H,3C).

5604: FOURIER OPTICS AND HOLOGRAPHY
Principles of scalar diffraction theory, Fresnel, and Fraunhofer diffraction, coherent optical imaging systems, optical filtering and optical data processing, and holography. Pre: 4614. (3H,3C).

5614: INTRODUCTION TO QUANTUM ELECTRONICS
Theory of laser oscillation, optical resonators, interaction of radiation and atomic systems, giant pulsed lasers, laser systems, wave propagation in nonlinear media, modulation of optical radiation, noise in optical detection and generation, and interaction of light and sound. Pre: 4614. (3H,3C).

5705–5706: STATISTICAL MECHANICS
Theory of classical and quantum statistical mechanics. Derivation of thermodynamics. 5705: ensembles, fluctuations and ideal gas systems. 5706: modern developments and advanced topics. Pre: 5456. (3H,3C).

5714: METHODS OF THEORETICAL PHYSICS
Selected topics in mathematical physics. Review of analytic function theory. Matrices, spectral theory of operators in Hilbert Space with applications to quantum mechanics. Solution of partial differential equations of mathematical physics, boundary–value problems, and special functions. Distribution theory and Green's functions. Consent required. (3H,3C).

5794: COMPUTATIONAL PHYSICS
Survey of computational methods in physics. Applications of Fourier analysis, curve fitting, solving differential equations, solving integral equations, Monte Carlo simulations, symbolic mathematics, and graphic simulations in mechanics, electromagnetism, nuclear physics, atomic physics, molecular physics, and condensed matter physics. Pre: 4455. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5944: SEMINAR
Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6354: ADVANCED CLASSICAL DYNAMICS
Conservative systems: Geometry of phase space, integrable systems, perturbation theory and introduction to Kolmogorov–Arnold–Moser (KAM) theory. Dissipative systems: local bifurcation theory and introduction to chaos. Pre: 5354. (3H,3C).

6455–6456: ADVANCED QUANTUM THEORY
Classical field theory; Noether's theorem and symmetries; second quantization and many–body formalism; free quantum Klein–Gordon, Dirac, and Maxwell fields; and interacting fields, S–matrix and covariant perturbation theory. Feynman diagrams; quantum electrodynamics; renormalization; path–integral formulation; non–Abelian gauge theories; and elements of electro–weak theory. Pre: 5354, 5406, 5456. (3H,3C).

6504: THEORETICAL NUCLEAR PHYSICS
Basic concepts and methods of theoretical nuclear physics for energies up to 1 GeV. General nuclear properties, nuclear force, conserved quantitites, symmetries, and nuclear models. Pre: 5406, 5456. (3H,3C).

6555–6556: ADVANCED SOLID–STATE PHYSICS
Applications of field–theory techniques to many–body aspects of solid–state physics. 6555: Green functions, Feynman diagrams, lattice Hamiltonian, neutron scattering, electron gas, Fermi–liquid theory, and linear–response theory. 6556: Electron–phonon interaction in metals and semiconductors, polarons, optical properties, excitons, superconductivity, and excitations in magnetic materials. Pre: 5456, 5555. (3H,3C).

6655,6656: ADVANCED ASTROPHYSICS
Concepts and methods of astrophysics. 6655: Stellar structure and evolution; radiative and convective energy transfer; white dwarfs, neutron stars and black holes; stellar nucleosynthesis. 6656: Interstellar medium; star formation; galaxies and large scale structure; active galactic nuclei and quasars. Pre: 5406, 5456. (3H,3C).

6675–6676: GENERAL RELATIVITY & COSOMOLOGY
6675: Differential geometry; equivalence principle; general theory of relativity; classical tests; post–Newtonian approximation; special solutions. 6676: Black holes; observational basis of cosmology; relativistic model universes; nucleosynthesis; cosmoic background radiation; dark matter; inflation. Pre: 5354, 5406. (3H,3C).

6714: SELECTED TOPICS IN THEORETICAL PHYSICS
Topics of current interest in theoretical physics as announced in Timetable. May be repeated for credit with permission. Consent required. (3H,3C).

6725–6726: ELEMENTARY PARTICLE PHYSICS
Symmetry principles, quark model, scattering–theory and particle–theory processes, weak interactions, quantum chromodynamics, spontaneous symmetry breaking, and unified field theories. Consent required. Co: 6455, 6456. (3H,3C).

6725–6726: ELEMENTARY PARTICLE PHYSICS
Symmetry principles, quark model, scattering–theory and particle–theory processes, weak interactions, quantum chromodynamics, spontaneous symmetry breaking, and unified field theories. Consent required. Co: 6455, 6456. (3H,3C).

6755–6756 (MATH 6755– 6756): MATHEMATICAL FOUNDATIONS OF QUANTUM MECHANICS
Advanced course in mathematical physics which encompasses the frontiers of research in quantum theory. Content varies from year to year and includes scattering theory, spectral and perturbation theory, and many–body quantum dynamics. This course frequently taken concurrent with thesis research. The course alternates with Math 6745–6746 and may be taken a second time with instructor's consent. Pre: 5456, MATH 6256. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (PHYS)

The following 4000–level courses have been approved for graduate credit:

4315–4316: MODERN EXPERIMENTAL PHYSICS
Representative apparatus, techniques, and phenomena of contemporary research. Includes electrical measurements, computers, thermometry, vacuum deposition, machine shop, nuclear spectra, experimentation related to major developments of modern physics. Pre: 3314. (6L,2C).

4404: MAGNETICS
Macroscopic magnetic phenomena and utilization of magnetic fields and materials. Criteria for materials selection and device design of electromagnets, transformers, relays, permanent magnets, motors, shielding, recording, and other energy and information storage techniques. Pre: 2306, MATH 2214. (3H,3C).

4455–4456: INTRODUCTION TO QUANTUM MECHANICS
Experimental bases; postulates; conservation theorems and symmetry; one–dimensional and two–dimensional problems; angular momentum and problems in three dimensions; matrix mechanics and spin; applications to atomic and molecular physics; perturbation theory; scattering. Pre: 3356, 3406. (3H,3C).

4504: INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS
Structure and properties of atomic nuclei and elementary particles, theoretical interpretations based on elementary quantum mechanics. Symmetries; various nuclear models; interactions at small distances; classification of elementary particles. Consent required. Co: 4456. (3H,3C).

4554: INTRODUCTION TO SOLID STATE PHYSICS
Basic concepts of solid state physics including crystal structure, lattice vibrations, electron states, energy bands, semiconductors, metals. Consent required. Co: 4456. (3H,3C).

4714: INTRODUCTION TO BIOPHYSICS
Selected topics from the general area of biomechanics, bioelectricity, radiation biophysics, molecular biophysics, and thermodynamics and transport in biological systems. Emphasis on the physical aspects of biological phenomena and biophysical measurement techniques and instrumentation. Pre: 2206 or 2306. (3H,3C).

PLANT PATHOLOGY, PHYSIOLOGY, & WEED SCIENCE

Professors: J.F. Derr; J.D. Eisenback; R. Grene; E.S. Hagood; C.S. Johnson; C.L. Nessler; P.M. Phipps; F.M. Shokes; E.L. Stromberg; S.A. Tolin; H.P. Wilson; K.S. Yoder.
Associate Professors: A.B. Baudoin; B.I. Chevone; E.A. Grabau.
Assistant Professors: S. Askew; C. Hong; J.J. Jelesko; J.M. McDowell; J.H. Westwood
Research Scientist: C.J. Denbow
Instructor: M.A. Hansen

Adjunct Faculty: J.R. Elkins; J.G. Foster; K.K. Oishi; D.P. Roberts

E–mail: ppws@vt.edu
Web: www.ppws.vt.edu

The plant pathology, physiology, and weed science department offers graduate programs leading to the M.S. (thesis and non–thesis) and Ph.D. The department also participates in interdisciplinary graduate programs in Plant Physiology (IPPP), Life Sciences, Genetics, and Molecular and Cell Biology and Biotechnology (MCBB). Depending upon degree of preparedness, M.S. programs usually require two to three years, while a Ph.D. program may require four or more years beyond the B.S.

Entering graduate students are expected to have successfully completed undergraduate work in chemistry, physics, mathematics, botany, microbiology, soils, and genetics. Qualified students who lack prerequisite courses will be admitted with the understanding that deficiencies will be made up and will not carry graduate credit. Plant science courses beyond introductory botany (e.g., plant anatomy, taxonomy, plant pathology, plant physiology, biochemistry or molecular biology) are highly desirable.

Graduate programs offer training in applied and/or basic plant pathology, weed science, plant physiology, and plant biotechnology through a combination of graduate courses, research programs, and teaching experience. Teaching experience of one semester for the M.S. and two semesters for the Ph.D. is required. Research is the most important part of the graduate learning experience. Thesis or dissertation research topics are designed to familiarize students with applied or knowledge–driven basic research and provide them with maximum opportunity to use contemporary techniques and instrumentation.

Each student, in consultation with a major advisor and advisory committee, plans an individual program of study, which must be approved by the student's advisory committee. Core and supporting courses will vary according to the student's background and area of desired specialization. Research opportunities for graduate education in each departmental discipline are currently available in the following areas: *plant pathology* (disease physiology; disease epidemiology; ecology of root diseases; genetics of host–parasite interactions; phytobacteriology; plant virology; nematology; mycology; biological disease control; fungicide–plant–soil interactions; disease control in major crops; integrated disease management), *weed science* (weed biology and ecology; parasitic weeds; weed management in major crops; herbicide action; herbicide metabolism; herbicide–resistant crops and weeds; integrated weed management), *plant physiology* (plant growth regulation; plant stress physiology; air pollution damage to plants), and *plant biotechnology* (plant genetic engineering for disease, stress, and herbicide resistance; mechanisms of subcellular targeting and protein processing; bioproduction of human therapeutics in transgenic plants; plant genetic engineering for improving nutrient availability in animal diets and reducing environmental phosphorus pollution; regulation of plant gene expression).

Research laboratories within the department and facilities available at the university contain a wide range of specialized equipment and glasshouses for conducting cutting–edge research in the departmental disciplines. Field plots are located a few miles away on a 1,600–acre research farm and at the nearby Turfgrass and Glade Road Research centers. Seven departmental faculty members work off–campus at Agricultural Research and Extension Centers of Virginia Tech located at Blackstone, Painter, Suffolk, Winchester, and Virginia Beach. Computing facilities are accessible from many personal computers available at on– and off–campus departmental locations.

Graduates of our programs are prepared for careers as professional plant pathologists, plant physiologists, weed scientists, or plant biotechnologists. Occupational opportunities are available in research, teaching, or extension at colleges and universities; in regulatory or research activities with state and federal governments; in administration, sales, research, or product development in agribusiness and agrichemical or biotechnology industry; or in private consulting.

GRADUATE COURSES (PPWS)

5004: SEMINAR
Review, discussion, invention, analysis, and synthesis of principles and concepts in plant pathology, plant physiology, and weed science. May be repeated. (1H,1C).

5034: CLINIC & FIELD EXPERIENCE
Student interns will participate in either a plant disease or a weed–oriented clinic experience. Student interns will learn to diagnose and make recommendations for control of plant diseases from specimens received by the Plant Disease Clinic, or will learn to identify and make recommendations for control of weeds received by the Weed Clinic. Each of the two options within the course may be taken once for credit. Pre: 4754. (3L,1C).

5064 (ALS 5064) (BCHM 5064) (BIOL 5064): SEMINAR IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Review and discussion of current problems and literature in molecular cell biology and biotechnology by students, VPI&SU faculty and outside speakers. Students give formal presentations of research results or current literature. May be taken on pass–fail basis. Students enrolled in the MCBB Ph.D. option will be required to give one formal presentation on an A–F basis. (1H,1C).

5114: PLANT PATHOGENIC PROKARYOTES
Part of a series of courses on agents causing plant disease. Identification, taxonomy, classification, cytochemistry, anatomy, genetics, plant–pathogen interactions, disease physiology, and control of plant pathogenic prokaryotes. (1H,3L,2C).

5124: PLANT PATHOGENIC VIRUSES
Part of a series of courses on plant pathogenic agents that are a basis for contemporary graduate studies in plant pathology and related fields. Virus classification, isolation, chemical and structural properties, replication and pathogenicity, symptomatology, identification, ecology, vector dissemination, and control. Molecular biology of host–virus interactions, resistance mechanisms, and genetic engineering for control. (2H,3L,3C).

5134: PLANT PATHOGENIC FUNGI
Part of a series of courses on plant pathogenic agents forming the basis for contemporary graduate studies in plant pathology. Morphology, taxonomy, and ecology of fungi which cause diseases of plants with emphasis on techniques for experimental plant pathology. Pre: 3104, BIOL 4244. (2H,3L,3C).

5144: PLANT PATHOGENIC NEMATODES
Part of a four–part series of lectures and laboratories on plant pathogenic agents that are a basis for graduate studies in plant pathology. Nematode morphology, systematics, taxonomy, reproduction, distribution, sampling, and management strategies. Nematodes as vectors of viruses, disease interactions, evolution of parasitism and pathogenesis, and mechanisms of resistance. (1H,3L,2C).

5204: PRINCIPLES OF PLANT DISEASE MANAGEMENT
Methods of plant disease management, and theories and effectiveness of their application. Discussion based on epidemiological principles. Methods include: cultural practices, resistance, chemical, and biological control. Laboratory 5214 supplements this course. Pre: 3104. (3H,3C).

5214: DISEASES OF CROP PLANTS
Laboratory designed to supplement 5204. Symptoms, pathogen morphology, etiology, epidemiology, and practical application of control principles to important diseases of major crops including cereal, oilseed and legume, forage, vegetable, and fruit. Pre: 3104. Co: 5204. (3L,1C).

5304 (BIOL 5304): PLANT STRESS PHYSIOLOGY
Analysis of physiological responses of agricultural and native plants to environmental stresses such as extremes of temperature, availability of water and nutrients, and presence of air pollutants. Emphasis on linking stress caused changes in carbon gain, water loss, nutrient utilization, and energy balance with changes in growth. Laboratory to introduce equipment and research approaches used in greenhouse and field studies. (3H,3L,4C).

5314 (GBCB 5314): BIOLOGICAL PARADIGMS FOR BIOINFORMATICS
This course is an intensive introduction to the central paradigms of molecular cell biology for bioinformatics. Material from cell molecular biology and genetics will be presented, and placed in a genomics context. The course prepares students in mathematical disciplines to interact in teams in the pursuit of bioinformatics research. Pre: Senior or graduate standing in mathematically based disciplines such as computer science, statistics, mathematics or engineering. (3H,3C).

5334 (FOR 5334): PLANT WATER RELATIONS
Properties and status of water in the plant and thermodynamics in relation to water and solute movement; measuring water deficits and drought tolerance; and transpiration and stomatal action. (2H,3L,3C).

5344 (ALS 5344): MOLECULAR BIOLOGY FOR THE LIFE SCIENCES
A multi–disciplinary treatment of gene organization and expression in animal and plant systems. Emphasis on the applications of molecular biology to current problems in applied biology and biotechnology. Pre: BCHM 4116 or BCHM 5124. (3H,3C).

5404: GENETIC AND EPIDEMIOLOGICAL PRINCIPLES OF PLANT PATHOLOGY
The study of plant disease in plant populations and the effects of the pathogen, host, and environment on the development of plant disease epidemics. Inheritance of resistance to disease in plants, of pathogenicity in parasites, and the relation of complementary inheritance in host and pathogen to crop improvement. Pre: (3104, 4224) or (5204. (3H,3L,4C).
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5454: PLANT DISEASE PHYSIOLOGY & DEVELOPMENT
Principles and concepts of infection and colonization of plants. Role of host's and pathogen's physiology and biochemistry in disease susceptibility and resistance, recognition, and disease specificity. (3H,3C).

5524 (HORT 5524): ADVANCED PLANT PHYSIOLOGY & METABOLISM I
Plant metabolism and its regulation, cell and organ structure and function. Current understanding of photosynthesis, respiration, nitrogen fixation, mineral nutrition, water and ion transport in plant cells and tissues, ecophysiology and responses of plants to the environment. Restricted to undergraduate majors in biology or related discipline. (3H,3C).

5534 (HORT 5534): ADVANCED PLANT PHYSIOLOGY & METABOLISM II
Presentation of the current understanding of metabolic and functional relationships among primary and secondary metabolites and storage products and their impact on the whole plant. Biosynthesis of phytohormones. Mechanisms controlling responses to phytohormones including: impact on carbon/nitrogen partitioning, senescence, development of higher plant structures such as vascular tissue and flowers. Restricted to undergraduate majors in Biology or related discipline. (3H,3C).

5654: PLANT GROWTH & DEVELOPMENT
Role of auxins, gibberellins, cytokinins, ethylene, abscisic acid, and other naturally occurring plant growth regulators on growth and differentiation of cells, tissues, and organs. Also, the interaction of plant growth regulators with the intrinsic and extrinsic plant environment in controlling growth and development. (3H,3C).

5754: HERBICIDE ACTION & METABOLISM
The study of the properties and characteristics of herbicides, the fundamental processes and principles involved in their action, and their metabolic detoxification by higher plants and microorganisms. Principles of herbicide selectivity and modern approaches to increase it. Pre: 4754. (2H,3L,3C).

5894: FINAL EXAM (NON–THESIS).
For students pursuing a non–thesis Master's degree, who have completed all other course work. Pass/Fail only. (3C).

5904: PROJECT & REPORT
For students pursuing a non–thesis master's degree. Projects may involve guided research or an internship. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: ADVANCED TOPICS IN PLANT PATHOLOGY, PHYSIOLOGY, & WEED SCIENCE
In depth presentations and discussions on selected advanced topics in plant pathology, physiology, and weed science. May be repeated. Variable credit course.

6024 (ALS 6024) (BCHM 6024) (BIOL 6024): TOPICS IN MOLECULAR CELL BIOLOGY & BIOTECHNOLOGY
Specific areas such as the molecular biology of plant and animal disease resistance, of photosynthesis, of oncogenes, of organelle assembly, and of growth and development, structure and function of polyamines and of proteases will be discussed. Students will give presentations and critically analyze current literature. May be repeated. Variable credit course. Pre: BCHM 5214..

6654 (BIOL 6654): TOPICS IN VIROLOGY
Readings and discussion in a specific area of virology. Topic will vary and course may be taken for credit more than once. Pre: BCHM 4116. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (PPWS)

The following 4000–level courses have been approved for graduate credit:

4264 (ENT 4264): PESTICIDE USAGE
An interdisciplinary study of pesticides used in urban and agricultural environments. Topics studied will include: classification, toxicology, formulation, application techniques, safety, legal considerations, environmental impact, and research and development of new pesticides. Pre: CHEM 2515 or CHEM 2536. (2H,3L,3C).

4524 (ENT 4524) (FOR 4524): PEST AND STRESS MANAGEMENT OF TREES
Ecology of biotic and abiotic influences on forest and landscape tree health. Emphasis will be placed on developing a theoretical and practical understanding for managing pests and stresses of trees in both the forest and landscape setting. Insects and diseases of trees will be reviewed. Pre: 3104 or FOR 3324 or FOR 3354. (2H,3L,3C).

4754: WEED SCIENCE: PRINCIPLES AND PRACTICES
Weeds and human affairs; costs and losses; emphasis on weed biology, weed identification and weed–crop ecology; agronomic, physiological, and chemical principles underlying prevention, eradication, and control of undesired vegetation; methods of weed control available for modern agronomic, forestry, horticultural, and non–crop situations. Pre: BIOL 2304, CHEM 1036. (2H,3L,3C).º

PLANT PHYSIOLOGY

G. Gillaspy, Chair (2002–03)

Professors: C.L. Cramer; D. Dean; A. Esen; R. Grene; C. Hagedorn; E.S. Hagood; J.L. Hess; R.P. Marini; E.T. Nilsen; D.J. Parrish; M. Potts; R.E. Schmidt; J.R. Seiler; S.A. Tolin; R.E. Veilleux; R.D. Wright
Associate Professors: E.P. Beers; B.I. Chevone; G. Welbaum; T. Wolf

Major work in plant physiology leading to the M.S. and Ph.D. is offered through the Interdepartmental Plant Physiology Program. Faculty and research facilities are available from the following participating departments in the College of Agriculture and Life Sciences, the College of Arts and Sciences, and the College of Natural Resources: biochemistry and anaerobic microbiology; biology; crop and soil environmental sciences; forestry; horticulture; and plant pathology, physiology, and weed science.

Areas of specialization available to program participants include cell wall physiology, crop physiology, enzymology, growth regulation, gene expression, herbicidal action and metabolism, photosynthesis and photorespiration, physiological interrelationships of higher and lower plants, physiology of disease, regulation of metabolism, stress physiology, ecophysiology, and other fields in the agricultural and natural plant sciences.

Degree candidates in the Interdepartmental Plant Physiology Program are plant physiology–oriented graduate students majoring in one of the participating departments. Students are recruited and selected by the departments participating in the program. Admission will be based upon the requirements of the Graduate School and the chosen department.

To satisfy program requirements, M.S. students must take either PPWS/HORT 5524 or 5534 and ALS 5014, the Seminar in Plant Physiology, plus elective courses for a total of 6 credits. Ph.D. students must take PPWS/HORT 5524 and 5534, ALS 5014, and elective courses for a total of 13 credits. Both Ph.D. and M.S. students may select from the following list of elective courses: FOR/PPWS 5334, Plant Water Relations; PPWS 5654, Plant Growth and Development; HORT 5984, Advanced Plant Physiology Lab; PPWS/BIOL 5304, Plant Stress Physiology; CSES 5844, Molecular Genetics of Crop Improvement; PPWS/ALS 5344, Molecular Biology for Life Science; ALS/BIOL/PPWS 6024, Topics in Molecular Cell Biology and Biotechnology; BCHM 5214, Molecular Biology of the Cell; or other course approved by the student's Graduate Committee. To enroll in the IPPP program, the comments section of the student's approved program of study must state "courses listed on the student's program of study fulfill the requirements for the Interdepartmental Plant Physiology Program, and 'plant physiology' should be added to the student's official transcripts upon completion of the program of study."

GRADUATE COURSES

ALS 5014: SEMINAR IN PLANT PHYSIOLOGY
Formal presentation of principles and concepts in plant physiology. Review, discussion and critical evaluation of current primary literature and research data. May be repeated. Pass/fail only. (1H, 1C).

HORT/PPWS 5524: ADVANCED PLANT PHYSIOLOGY & METABOLISM I
Plant metabolism and its regulation, cell and organ structure and function. Current understanding of photosynthesis, respiration, nitrogen fixation, mineral nutrition, water and ion transport in plant cells and tissues, ecophysiology and responses of plants to the environment. Pre: undergraduate major in biology or related discipline. (3H,3C).

HORT/PPWS 5534: ADVANCED PLANT PHYSIOLOGY & METABOLISM II
Presentation of the current understanding of metabolic and functional relationships among primary and secondary metabolites and storage products and their impact on the whole plant. Biosynthesis of phytohormones. Mechanisms controlling responses to phytohormones including: impact on carbon/nitrogen partitioning, senescence, development of higher plant structures such as vascular tissue and flowers. Pre: undergraduate major in Biology or related discipline. (3H,3C).

POLITICAL SCIENCE

Ilja A. Luciak, Department Chair
Deborah J. Milly, Director of Graduate Studies

University Distinguished Professor: T.W. Luke
Edward S. Diggs Professor in the Social Sciences: E. Weisband
Professors: K.M. Hult; I.A. Luciak; R.C. Rich; C.L. Taylor; C.E. Walcott
Associate Professors: D.A. Borer; D.J. Milly; W.D. Moore; R.D. Shingles
Assistant Professors: C. L. Brians; C.I. Clement; S.G. Nelson

E–mail: djmilly@vt.edu
Web: http://www.psci.vt.edu

The graduate program in political science leads to the master of arts degree. It is designed to provide students with a firm grounding in the scope of the discipline and a strong foundation in research methods. It is especially appropriate for students who want to acquire analytic skills before pursuing a Ph.D. in political science or entering a public or private career requiring research skills.

The program consists of a core of methods and theory courses balanced by elective courses in the fields of American government, comparative politics, international relations, and policy analysis leading to the writing of a master's thesis. The degree is normally completed in four semesters of full–time study, although it can be compressed into three semesters and a summer under some conditions.

In addition to the resources of the university, full–time graduate students are provided with office space and access to the department's computer lab to facilitate their research. Graduate assistantships, which provide students with experience in teaching and research, are awarded on a competitive basis.

Applicants must submit three letters of recommendation, transcripts of prior academic work, and scores on the verbal, quantitative and analytical writing portions of the Graduate Record Exam. Residents of non–English–speaking countries also must submit scores on the Test of English as a Foreign Language. Applicants are encouraged to complete all application procedures by March 31 in order to be considered for admission in the following fall semester. New students can enter the off–campus program only in the fall.

The department also offers the M.A. through entirely on–line course work. Details of this program are available at the department's web address given above.

For additional information on the on–campus or on–line M.A. programs, contact the director of graduate studies in the Department of Political Science. The department strongly encourages applications from women and persons of color.

GRADUATE COURSES (PSCI)

5115–5116: RESEARCH METHODS
The purposes, problems, and strategies of political science research, emphasizing concept and hypothesis formulation, operationalization, research design, data collection techniques, data processing, and multivariate data analysis. (3H,3C).

5124: ADVANCED RESEARCH ISSUES
Advanced work in research methods including the conceptual issues underlying measurement and data analysis. Covers appropriate techniques for addressing those issues. Pre: 5115, 5116. (3H,3C).

5214: CONTEMPORARY POLITICAL THEORY
Selected topics in contemporary political theory, including different models of social science inquiry and the use of basic concepts like power, ideology, rationality, and the state in the study of politics. (3H,3C).

5224: ALTERNATIVE PERSPECTIVES IN POLITICAL THEORY
Analysis of selected perspectives on politics including: rational choice theory, critical theory, neo–marxism, neo–conservatism, post–industrialism, and post–structuralism. (3H,3C).

5314: LEGISLATIVE BRANCH
The legislative process in American state and federal governments including recruitment of members, organization and functioning of legislative systems, and relations with both constituents and other branches. (3H,3C).

5324: THE EXECUTIVE BRANCH
The executive office and bureaucracy of American state and federal governments including recruitment, organization of executive branches, decision making, leadership styles, and relations with other branches. (3H,3C).

5334: THE JUDICIAL BRANCH
The American judicial system including recruitment of personnel, uses of the courts, judicial policy, relations with other branches, judicial behavior, and the impact of court decisions. (3H,3C).

5344: POLITICAL BEHAVIOR
Approaches to the study of political behavior including political psychology, rational choice, biopolitics, socialization, communication, public opinion, and political participation. (3H,3C).

5354: PUBLIC POLICY ANALYSIS
Approaches to policy analysis and program evaluation including the techniques appropriate to various stages of the policy process. (3H,3C).

5414: INDUSTRIAL DEMOCRACIES
Political patterns and processes of development in selected democracies in Europe, North America, and Asia emphasizing the political problems of contemporary industrial societies and their likely evolution in a "post–industrial" era. (3H,3C).

5424: COMMUNIST & POST–COMMUNIST SYSTEMS
Political processes and developmental trends in communist and post–communist systems in Russia and other CIS states, Eastern Europe, the People's Republic of China, and the Third World. Current economic, political, and social issues and their likely development. (3H,3C).

5434: POLITICS OF DEVELOPING AREAS
Political structures, economic growth, and cultural frameworks of developing nations in Asia, Africa, and Latin America emphasizing the political and economic challenges of industrial development in a global economy. (3H,3C).

5444: INTERNATIONAL POLITICS
Theories of international organizations and relations among nations focusing on research in foreign policy formulation and implementation, international integration, conflict resolution, and global political economy. (3H,3C).

5454 (SPIA 5454): ADVANCED TOPICS IN INFORMATION TECHNOLOGY AND PUBLIC POLICY
In–depth study and critical evaluation of selected complex issues related to information technology, society, governance, and public policy. Focused attention is given to theoretical and methodological foundations of the area of inquiry and to specific domains of policymaking and implementation. Topics will be selected from IT–related issues in such areas of concern as: cities, local communities, nonprofit organizations, governments, and global networks. May be repeated on a different topic. Must meet prerequisite or have permission of the instructor. Pre: UAP 5564. (3H,3C)

5554 (SPIA 5554): CULTURE, POLITICS AND SOCIETY IN NETWORK ENVIRONMENTS
Historical origins, institutional foundations, and theoretical interpretations of cultural, political, and social interaction through computer mediated communication are examined. Particular attention is given to new types of discourse, sources of power, and structures of society at all geographical levels in global computer and communications networks. (3H,3C)

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C)

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (PSCI)

The following 4000–level courses have been approved for graduate credit:

4214: SENIOR SEMINAR IN POLITICAL BEHAVIOR
Political behavior: socialization, voting, opinion formation and expression, decision–making in government, as explained by personality, rationality, culture, class, and institutional roles. Topics vary from semester to semester as announced. Must have senior standing and any two of the prerequisites. Pre: 3214, 3224, 3234, 3244, 3264, 3274. (3H,3C).

4314: SENIOR SEMINAR IN POLITICAL INSTITUTIONS
Selected topics in political institutions, including decision–making, types and structures of political institutions, internal and external influences on institutional behavior. Topics vary from semester to semester. Must have senior standing and any two of the prerequisites. X–grade allowed. Pre: 3314, 3324, 3334, 3515, 3516, 3524. (3H,3C).

4324: SENIOR SEMINAR IN CONSTITUTIONAL LAW
Cases, law review articles, and related materials containing describing, or commenting on major decisions of the U.S. Supreme Court. Topics vary from semester to semester as announced. Must have senior standing and any two of the prerequisites. Pre: 3334, 3345, 3346. (3H,3C).

4414: SENIOR SEMINAR IN PUBLIC ADMINISTRATION.
Selected topics in public administration, including norms of practice, government personnel, administrative process, administrative law, privatizing, and contracting. Topics vary from semester to semester as announced. Must have senior standing and any two of the prerequisites. Pre: 3415, 3416, 3424. (3H,3C).

4514: SENIOR SEMINAR IN COMPARATIVE POLITICS
Selected topics in the comparative analysis of political behavior, processes, and institutions; cross–national institutional and aggregate data analysis. Topics vary from semester to semester as announced. Must have senior standing and any two of the prerequisites. Pre: 3515, 3516, 3524, 3554, 3564. (3H,3C).

4614: SENIOR SEMINAR IN INTERNATIONAL RELATIONS
Selected topics in international relations, including objectives of national policy, dimensions and components of national power, comparative diplomacy, international conflict and cooperation, instruments for conflict resolution. Topics vary from semester to semester as announced. Must have senior standing and any two of the prerequisites. Pre: 3615, 3616, 3625, 3626, 3734. (3H,3C).

4714: SENIOR SEMINAR IN POLICY ANALYSIS
Theoretical, analytical, and methodological approaches used to assess government activities and public policy. Topics vary from semester to to semester as announced. Must have senior standing an any two of the prerequisites. Pre: 3724, 3734. (3H,3C).

4724: SENIOR SEMINAR IN POLITICAL THEORY
Selected topics in analytic political philosophy, contemporary ideologies, and democratic theory. Topics vary from semester to semester as announced. Senior standing required. Must have senior standing and any two of the prerequisites. Pre: 3015 or 3016 or 3764 or 3754 or 3774. (3H,3C).

PSYCHOLOGY

UNIVERSITY EXEMPLARY DEPARTMENT *

Jack W. Finney, Chair

University Distinguished Professor: T.H. Ollendick
Heilig–Meyers Professor: R.A. Winett
Professors: G.A. Clum; H.J. Crawford; J.W. Finney; E.S. Geller; R.T. Jones
Associate Professors: D.K. Axsom; M.A. Bell; J.J. Donovan; R. J. Foti; B.H. Friedman; J. Germana; D.W. Harrison; R.J. Harvey; N.M.A. Hauenstein; R. Panneton; A. Scarpa; R.S. Stephens
Assistant Professors: L.D. Cooper; J.C. Dunsmore
Visiting Assistant Professor: K.A. Hoffman
Affiliated Faculty: P.M. Barrett; R.J. Beaton; D.L. Brinberg; K. Carlson; B.V. Corsino; W.D. Crews; R.H. Crouse; J.E. Horton; B. Klein; C. Lease; R.S. Schulman; R.W. Seidel; T.L. Smith–Jackson; D.R. Southard; D. Tatar; J.B. Weaver; R.C. Williges

Web: www.psyc.vt.edu

The psychology department offers graduate studies leading to the M.S. (thesis required) and Ph.D. in clinical psychology, industrial and organizational psychology, and psychological sciences.

Virginia Tech's graduate programs in psychology are designed to help assure that all students receive strong preparation in the research and theoretical literature of basic psychology as an experimental behavioral science. The program in clinical psychology is fully accredited by the American Psychological Association and is based on the scientist–professional training model. It resides within a broad behaviorally based framework and is neither tied to traditional viewpoints nor committed to narrow models which might otherwise limit the range of scientific inquiry. It is designed to train students not only in the most up–to–date techniques and methods of inquiry, but also to develop skills in asking relevant questions and seeking solutions to problems which may not have been within the traditional realm of clinical psychology in the past. The program in industrial and organizational psychology trains industrial/organizational psychologists within a scientist–professional model. Training in this program emphasizes a theoretical and quantitative approach to solving problems in industry and business. The program in psychological sciences is committed to training students in experimental psychology with research specialities in biobehavioral or developmental psychology. The focus in the master's program is on providing graduate students with a broad understanding of the main areas of experimental psychology, along with course

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

work leading to a biobehavioral and/or developmental concentration. Subsequent doctoral work is based on a mentorship model, in which the student works closely with a faculty mentor and the doctoral committee to develop an individualized program of study that allows intensive training in theory and research in biobehavioral or developmental psychology.

SPECIAL FACILITIES

Graduate student research is facilitated through access to a communications network that includes voice, video, and computer data transmission to offices, classrooms, laboratories, and dormitory rooms; a teleport of satellite dishes for receiving and transmitting; and a computing and communications complex that provides the university community with access to information systems and resources worldwide. A Psychological Services Center and Child Study Center are located off-campus and provide the foundation for practicum and research training. Computers are available 24 hours a day throughout the department and campus. Additional department resources include computer interactive facilities, physiological recording and feedback instruments, videotape, and closed circuit television.

There are two state-of-the-art laboratories that are dedicated to undergraduate and graduate teaching and research. The psychophysiological laboratory includes eight computer workstations, five EEG/Evoked Potential work stations (32 channel Neuroscan; Neurosearch-24), eye tracker equipment, Coulbourn physiological units, and extensive perception equipment. The other laboratory includes 25 computer workstations with cognitive and neurophysiological experiments, SAS and SPSS statistical packages, Bilog and Multilog programs. Graduate students also have access to PC and Macintosh computers for word processing and Internet access.

GRADUATE COURSES (PSYC)

5115–5116: INDUSTRIAL PSYCHOLOGY
Industrial psychology with emphasis on psychological theories and findings of empirical research. 5115: Contexts of industrial psychology, psychometrics, personnel recruiting, predictors of performance, job analysis, and criterion-related issues. 5116: Personnel selection, placement/classification, job environments, training and development, careers, work environments, engineering psychology. (3H,3C).

5125–5126: ORGANIZATIONAL PSYCHOLOGY
5125: Topics include organizational entry, work motivation, job satisfaction, occupational stress, organizational withdrawal, and work group influence. 5126: Topics include work group processes, leadership theories, leader-subordinate interactions, organizational theory and structure, and changing behavior in organizations. (3H,3C).

5134: ADVANCED PSYCHOMETRIC THEORY
Treatment of psychological test theory and measurement. Emphasis on classical test theory, psychometric methods, and applications to field settings. Pre: 5315, 5316. (3H,3C).

5144: SENSORY PROCESSES
Mechanisms which determine what stimuli become information in the nervous system, the psychophysical and physiological methods by which these mechanisms are identified and studied, and the theories which attempt to integrate the data of the various studies. (3H,3C).

5214: INTRODUCTION TO CLINICAL PSYCHOLOGY
Basic foundations of clinical psychology as a scientifically based discipline. Topics include historical perspectives, behavioral assessment and interviewing, professional problems, and ethical issues. The relationship between research and clinical practice is emphasized. (3H,3C).

5224: ASSESSMENT OF HUMAN INTELLIGENCE
Foundations of psychological testing. Emphasis on the relationship of research to clinical practice. Supervised practice in intelligence and achievement testing, neuropsychological screening, and communication of assessment information. (3H,3C).

5234: PERSONALITY ASSESSMENT
Foundations of clinical psychology particularly emphasizing the relationships between research and clinical practice in such assessment methods as observation, interviewing, role playing, and tests; communication of such assessment information and professional and ethical issues. (3H,3C).

5244: BEHAVIORAL ASSESSMENT AND TREATMENT
Theory and techniques of assessment and behavior change, including the application of operant, social learning, and cognitive principles of behavioral intervention. (3H,3C).

5254: INTERVENTIONS IN PSYCHOLOGICAL SYSTEMS
Emphasis on theoretical bases for clinical intervention in social systems involving two or more individuals, e.g., couples, families, treatment groups. Topics include social roles, communication systems, social support, and behavior change mechanisms. Pre: 5214, 5244. (3H,3C).

5274: PERSONALITY PROCESSES
Theory, research, and application in contemporary personality psychology. (3H,3C).

5284: PSYCHOPATHOLOGY
Fundamental theory and research in the area of psychopathology. Emphasis on empirically derived theories and data concerned with assessment and description of psychopathological behavior. (3H,3C).

5294: PSYCHOPHYSIOLOGY
Intensive study of the distinct psychophysiologcial methodology and approach to the problem of physiological-behavioral correlation. Several primary areas of psychophysiology are presented: autonomicsomatic integration and the measurement of psychophysiological activity, the orienting reflex and habituation, the psychophysiological correlates of learning, and patterning factors in psychophysiological response. (3H,3C).

5314: PSYCHOLOGICAL PERSPECTIVES IN SOCIAL PSYCHOLOGY
Examines reinforcement, field theoretic, cognitive, and role theory, and social learning theory and aggression, social exchange theories, social facilitation, group dynamics, attribution theory, environmental psychology, and impression management. (3H,3C).

5315–5316: RESEARCH METHODS
Advanced treatment of a variety of research-related issues germane to the discipline of psychology, including: the scientific method, elements of the research process, alternative strategies for operationalizing variables, sampling, research ethics, experimental research, quasi-experimental research, non-experimental research, research artifacts, non-traditional research strategies, quantitative literature reviews, and legal problems in research. (3H,3C).

5344: COGNITIVE PSYCHOLOGY
Survey of theoretical and empirical issues in cognitive psychology, including information processing models, attention, memory, problem solving, knowledge, reasoning, neurocognition and intelligence. Historical and current approaches will be considered. (3H,3C).

5354: INFORMATION PROCESSING
Study of human capacities and limitations with emphasis on its implications for design of complex systems. Methods and models by which the presumed mechanisms of encoding, storage, and retrieval are identified and studied from the human performance perspective. (3H,3C).

5374: HEALTH PSYCHOLOGY
Theoretical and methodological contributions of the behavioral sciences to problems in the health sciences. Topics include psychosocial factors contributing to health and disease, health promotion, and psychological approaches to the prevention and treatment of physical disabilities. (3H,3C).

5404: BIOLOGICAL BASES OF BEHAVIOR
History, methods, and special topics relevant to the biological foundations of behavior. Emphasis placed on anatomy, physiology, and pharmacology of nervous system and behavioral correlates including perception, learning memory, motivation, and language. (3H,3C).

5534: DEVELOPMENTAL PSYCHOLOGY
Examines the processes underlying cognitive and social development through the life span. In addition to the critical examination of theories exploring changes in cognition and social behavior, the relative role of phylogeny and ontogeny are explored and evaluated. (3H,3C).

5544: COGNITIVE DEVELOPMENT
Cognitive development throughout the life–span. Emphasis on Piaget's theory of cognitive development, information–processing approaches, perceptual development, memory development, language development, and alternatives to Piagetian theory. Coverage of the development of social–cognition, particularly communication. Pre: 5534. (3H,3C).

5554: SOCIAL DEVELOPMENT
Development of social competence and interactive style during infancy and childhood. Both prenatal and postnatal determinants of normal social behavior, aggression, sex role development, and nonoptimal child–environment intereactions. Pre: 5534. (3H,3C).

5664: PROSEMINAR IN LEARNING
Overview of the area of learning and memory in humans and animals. Topics for study are: paradigms of Pavlovian and instrumental conditioning, biological and cognitive constraints on learning, verbal learning and symbolic representation, information processing, transfer and retention phenomena, current theories of learning and memory. (3H,3C).

5965,5966: CLINICAL PRACTICUM
Supervised training appropriate to the student's level of coursework and experience in interviewing, assessment, intervention techniques, community consultation, and applied research in a variety of on– and off–campus settings. Maximum of 3 credit hours per course. Approximately 16 hours per week will be the normal training assignment for 3 hours credit; approximately 11 hours per week for 2 hours credit; and approximately 6 hours per week for 1 hour credit. Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6004: CONTEMPORARY LITERATURE IN APPLIED PSYCHOLOGY
Current empirical and theoretical literature in applied psychology. Topics vary from year to year and may include training, personnel selection, motivation, human factors, social power, quantitative methods, accident prevention. Pre: 5315, 5316, 5134, 6014. (3H,3C).

6014: QUANTITATIVE TOPICS IN APPLIED PSYCHOLOGY
Seminar that provides for the in–depth consideration of one or more current or emergent quantitative topics relevant to the field of applied psychology. Examples of topics that may be considered are utility analysis and validity generalization procedures. May be repeated to a maximum of 6 hours. Pre: 5315, 5316. (3H,3C).

6024: APPLIED RESEARCH IN INDUSTRIAL/ORGANIZATIONAL PSYCHOLOGY
This course combines theory and practice through the review and critique of current literature in industrial/organizational psychology and the application of this knowledge to solve applied problems in the workplace. May be repeated for up to six credit hours. Requires consent of the instructor. Pre: 5134 or 6014. (3H,3C).

6254: ADVANCED TOPICS IN CLINICAL PSYCHOLOGY
Seminar covering specialized topics in clinical psychology. The course will be concerned with such topics as clinical neuropsychology, pediatric psychology, the psychology of aging, biochemical theories of schizophrenia, and professional and ethical issues. May be repeated to a maximum of 9 hours. (3H,3C).

6264: CHILD PSYCHOPATHOLOGY
An examination of theoretical issues and current research in the assessment, treatment, and prevention of child behavior disorders. Special emphasis will be placed upon developmental factors and system–wide variables as they impact on the growing child. Pre: 5284. (3H,3C).

6274: ADVANCED PSYCHOTHERAPY
Research and strategies in intensive psychotherapy. Emphasis on borderline and resistant clients and those for whom intensive therapy strategies are appropriate. Pre: 5284. (3H,3C).

6284: COMMUNITY PSYCHOLOGY
Origins and evolution of this subspecialty, preventive approaches, models of community psychology, applications of social marketing, field–based research, cost–effectiveness, cost–benefit analyses. Applications to diverse systems through program development, consultation, and training. (3H,3C)

6404: BEHAVIOR MANAGEMENT IN LARGE–SCALE SYSTEMS
Theoretical and empirical overview of the management of human behavior in community, institutional, and organizational environments. Methodologies for evaluation and refining specific intervention procedures. (3H,3C).

6934: ADVANCED TOPICS IN APPLIED PSYCHOLOGY
Seminar that provides for the in–depth consideration of theoretical perspectives, research findings, and research strategies currently used in the study of specific applied psychology topics. May be repeated to a maximum of 12 hours. Pre: 5315, 5316. (3H,3C).

6944: ADVANCED TOPICS IN DEVELOPMENTAL PSYCHOLOGY
Seminar covering specialized topics in developmental psychology. The course will be concerned with such topics as the life–span perspective, early identification of at–risk newborns, preventive interventions, and new conceptual foundations. May be repeated to a maximum of 9 hours. (3H,3C).

6954: ADVANCED TOPICS IN PSYCHOLOGICAL SCIENCES
Seminar covering advanced, specialized biobehavioral topics in Psychological Sciences. The course will be concerned with such topics as biobehavior, psychophysiology, cognitive neuroscience, sensation and perception, learning and cognitive psychology. May be repeated to a maximum of 12 hours. (3H,3C).

6965,6966: CLINICAL PRACTICUM
Supervised training appropriate to the student's level of coursework and experience in interviewing, assessment, intervention techniques, community consultation, and applied research in a variety of on- and off-campus settings. Maximum of 3 credit hours per course. Approximately 16 hours per week will be the normal training assignment for 3 hours credit; approximately 11 hours per week for 2 hours credit; and approximately 6 hours per week for 1 hour credit. Pass/Fail only. Variable credit course.

6984: SPECIAL STUDY
Variable credit course.

7965,7966: INTERNSHIP
During the third or fourth year the clinical student shall be involved in a full-time supervised internship program in a clinical setting approved by his advisory committee and the director of clinical psychology training program. The minimum duration shall be 11 months. Pass/Fail only. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (PSYC)

The following 4000-level courses have been approved for graduate credit:

4014: HISTORY AND SYSTEMS IN PSYCHOLOGY
Overview of modern theories in psychology by consideration of current historical controversies. Traces roots of psychology in natural and social sciences. Considers the diversity of psychological study and the future of psychology. Senior standing in psychology required for undergraduate credit. Graduate standing required for graduate credit. (3H,3C).

4024: INDUSTRIAL AND ORGANIZATIONAL PSYCHOLOGY
Overview of psychological theories, research findings, and methods relevant to studying the behavior of individuals in organizations. Topics covered may include prediction of job performance, personnel testing, training and development, and leadership. Pre: 2004, STAT 3604. (3H,3C).

4034: ADVANCED DEVELOPMENTAL PSYCHOLOGY
Development of attention, cognition, social skills, language, personality, and intelligence throughout the life-span: an in-depth, critical evaluation of current research and theory. Pre: 2004, 2034. (3H,3C).

4044: ADVANCED LEARNING
Critical analysis of basic paradigms of Pavlovian and Instrumental Conditioning with emphasis on general theories of learning and issues involved in cognition, reinforcement, and memory. Pre: 2004, 2044, 2094. (3H,3C).

4054: PERSONALITY RESEARCH
Research techniques used in contemporary personality psychology: case histories, correlational methods, experimentation, archival studies, and psychobiography. Pre: 2004, 2054, 2094, STAT 3604. (3H,3C).

4064: PHYSIOLOGICAL PSYCHOLOGY
Presentation of concepts important for the study of neuroscience and behavior with a special emphasis on the classic topics of physiological psychology: brain-behavior relations, sensory integration, physiological correlates of motivation and emotion. Pre: 2004, 2064, 2094. (3H,3C).

4074: SENSATION AND PERCEPTION
Overview of sensory and perceptual systems and their integration in influencing behavior. Emphasis on sensory receptor characteristics, neural structure, psychophysical data, perceptual phenomena and issues, theories about the human perceptual process. Pre: 2004, 2064, 2094. (3H,3C).

4084: ADVANCED SOCIAL PSYCHOLOGY
Examines social behavior from four major theoretical orientations: reinforcement, field theory, cognitive, and role theory. Topics may include social learning, social exchange theories, group processes, attitude, and person perception. Pre: 2004, 2084. (3H,3C).

4094: THEORY OF PSYCHOLOGICAL MEASUREMENT
Theory of psychological measurement and techniques used to develop and evaluate psychological measures. Coverage of standardization, measurement scales, reliability, validity, score transformations, composite scores, weighted scores, and test construction. Pre: 2004, 2094, STAT 3604. (3H,3C).

4104: MOTIVATION
Overview of concepts, phenomena, principles, and theories of motivation from biological, learning, social and cognitive viewpoints. Pre: 2004, 2044, 2094. (3H,3C).

4114: COGNITIVE PSYCHOLOGY
An experimentally-oriented survey of human cognitive processes which include attention, memory, and decision making. Role of individual difference variables in each area. Pre: 2004, 2044, 2094. (3H,3C).

4124 (EDCI 4124): PSYCHOLOGICAL FOUNDATIONS OF EDUCATION FOR PRESERVICE TEACHERS
Emphasizes applying human learning and developmental theories to the classroom setting with a focus on instructional processes and procedures, student motivation, classroom management, and assessment strategies. Participation in a 4-year or 5-year teacher eduction program. Junior level standing. Pre: 2004 or HD 1004. (3H,3C).

4174 (EDCI 4174): STUDENTS WITH EMOTIONAL AND BEHAVIORAL DISORDERS
This course examines the characteristics and needs of individuals with emotional abd behavioral disorders. Topics include history, definitions and causes of emotional and behavioral disorders, major research findings, identification procedures, educational programming and current issues. Co: EDCI 3144. (2H,2C).

PUBLIC ADMINISTRATION & POLICY

Larkin S. Dudley, Chair, Blacksburg Campus, and Interim Advisor, Richmond Campus
James Wolf, Associate Director, Alexandria Campus

Professors: K. Hult; P.S. Kronenberg; J. A. Rohr; G.L. Wamsley; J.F. Wolf
Emeritus Professor: J. W. Dickey; G.T. Goodsel; O.F. White, Jr.
Associate Professors: L.S. Dudley; A. Khademian; J.V. Rees
Assistant Professor: S. Hirt
Research Scientists: C. Kuhns; R.G. Loeffler
Visiting Professors: R. Pethtel
Adjunct Professors: R. Becerra; T. Hickock; K. Long; W. Murray; M. Ridenour; C. Woodward

E–mail: cpap@vt.edu

The Center for Public Administration and Policy (CPAP) is committed to the enhancement of public service at local, state, and national levels. The interdisciplinary programs of the Center are conducted by its core faculty and staff, by special visiting guest faculty, and by cooperating units of the university. The programs include master's and doctoral graduate studies, basic and applied research, and a broad range of public service outreach and continuing education activities designed to meet the needs of Virginia and its citizens. CPAP programs are offered at the Blacksburg campus, Alexandria campus, and the Richmond campus. CPAP's research and outreach arm encompass a wide range of issues in the public arena and in governmental jurisdictions. In addition to projects conducted directly by the CPAP staff, a number of activities are initiated by the Center on a cooperative basis with government agencies.

CPAP's instructional activities include two degree programs: the Master of Public Administration (MPA) and the Ph.D. in Public Administration/Public Affairs and two non–degree programs, the Commonwealth Campus Specialty program of 6 semester hours and the Certificate of Advanced Graduate Study (CAGS) for 69 hours of advanced post–master's work.

The MPA program prepares pre–career students for opportunities primarily in the public and independent sectors. In–career MPA students are offered continued professional development in the management and policy fields.

The Ph.D. program is intended for those who desire to be at the leading edge of thought and practice in the management of public sector organizations or the analysis of public policy. Some who pursue the Ph.D. are oriented toward the roles of professors and researchers on university faculties. Others plan careers as senior managers in public sector or not–for–profit organizations or as researchers, consultants, or as staff analysts in corporations and public agencies.

The Commonwealth Specialty Program provides mid–career public service professionals an opportunity to take tailored courses to advance their careers without working toward a formal degree. The CAGS program enables students to develop an advanced level of post–master's courses.

DEGREE REQUIREMENTS

The MPA degree provides nine required courses and three electives with an internship for pre–entry students and professional paper project for in–career students. A thesis option is also available. Students take required courses in public management, public policy, and public service concepts and ethics as well as three electives in policy areas (e.g., environment, health, social policy) or management (e.g., local government, human resources, financial administration).

The Ph.D. requires a minimum of 99 semester hours of graduate study, 30 hours of which are dissertation hours. The other 69 hours are drawn from CPAP courses, from approved courses in cooperating departments and colleges, and/or from non–course activities and projects. Up to fifty percent of the graded credit hours may be obtained at an accredited institution other than Virginia Tech with faculty approval. Ph.D. students organize their study plans around the following five core areas of the Center's curriculum: context, organization, policy, management, and ethics. Students without prior administrative experience must participate in a sequence of experiential and problem–oriented learning situations. All students must possess a concentration of substantive competence, gained from past and future graduate course work.

The Center curriculum includes four levels of courses:

1. master's level courses, open to students at that level only;
2. foundation courses for the doctoral program, also available to interested master's students;
3. advanced topics courses designed to expose the student to an in–depth analysis of some specialized aspect of a core area of the Center's curriculum; and
4. capstone seminars (open to doctoral students only) intended to approach the leading edge of thought through original conceptualization and publishable research.

GRADUATE COURSES (PAPA)

5014: CONCEPTS & APPROACHES TO PUBLIC ADMINISTRATION
Covers the origins and development of the administrative state. Surveys major theoretical approaches to public administration. Discusses the problem of values in administration, the political environment of bureaucracy, and questions of ethical behavior in administration. (3H,3C).

5204 (SOC 5204): DATA ANALYSIS
Examination of data analysis designs used in sociology with emphasis on the sociological interpretation of different kinds of analyses; practical applications as used in current research. Three hours of statistics required. (3H,3C).

5214 (SOC 5214): RESEARCH METHODS
Research methods in sociology including survey methods, qualitative methods, and experimental design. The link between social theory and social research. Measurement, validity, reliability, and the logic of data analysis. (3H,3C).

5315–5316: GOVERNMENT ADMINISTRATION
The first of a sequence of two, provides theoretically grounded but practical knowledge on behavorial skills necessary for the public manager. These include the ability to lead, to supervise, to organize, and to communicate in public settings and in agencies serving the community and society. 5316: The second of a sequence of two, teaches the techniques and technology necessary to manage public organizations efficiently and effectively and to be held accountable for administrative actions and programs. (3H,3C).

5604 (SOC 5604): ORGANIZATIONS IN SOCIETY
Review of major theories and dimensions of modern organizations, especially technological and managerial arenas influenced by class and power. Labor processes internal to organizations and power networks among organizations. Includes cross–national comparisons. (3H,3C).

5614 (STS 5614): INTRODUCTION TO SCIENCE & TECHNOLOGY POLICY
Strategies for science and technology policy; science education; scientific and technical information for societal uses; government and public policy; resource allocation; economy and global exchanges of science and technology; approaches to policy evaluation. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5954: INTERNSHIP IN PUBLIC ADMINISTRATION/PUBLIC AFFAIRS
For students without substantial previous management or staff experience and for students changing positions or career. Supervised work and academic experience. Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6014: PUBLIC ADMINISTRATION THEORY
Examines the epistemological–ontological basis of public administration study; recent and current issues in the practice of public administration; and perspectives of the Center faculty concerning the direction of the field. (3H,3C).

6024: THE CONTEXT OF PUBLIC ADMINISTRATION
Examines the history of public administration as a field of study; the politico–economic context of public administration as an element of governance; and international comparisons of public administrative behavior. (3H,3C).

6114: COMPLEX PUBLIC ORGANIZATIONS
Examines the principal conceptual and theoretical bases for understanding the structure and environment of complex public organizations; also explores the problems bureaucracy poses for democratic theory and for vigorous economy. (3H,3C).

6124: BEHAVIOR & CHANGE IN PUBLIC ORGANIZATIONS
Dynamics of the behavior and change process in public sector organizations are examined for: (1) their implications for individuals, groups, and society; and (2) their impact upon organizational productivity and public policy. Critical dimensions of leadership as a sociopsychological process in management are emphasized with special reference to the public sector and public executives. The course also surveys the various types and strategies for planned change in public sector organizations. (3H,3C).

6154: ADVANCED TOPICS IN PUBLIC ORGANIZATIONS
Selected topics of theory, methodology, and design in current research literature on complex public organizations and large–scale bureaucratic systems. The political environment of such systems will be emphasized. X–grade allowed. (3H,3C).

6194: CAPSTONE SEMINAR IN PUBLIC ORGANIZATIONS
Advanced doctoral seminar involving original conceptualization and research into specific aspects of collective behavior, leadership, and change processes of complex, formal, public organizations. Foci for analysis include dynamics within, and linkages among, small groups, organizations, and interorganizational networks. X–grade allowed. (3H,3C).

6214: PUBLIC POLICY PROCESSES & ANALYTICAL APPROACHES
Examines in a general way, the field of public analysis in and for government. Covers the traditions and assumptions of the field; notes and critiques the literature; examines relationships to other fields and topics of public administration; and discusses the processes of policy–making and techniques of analysis. (3H,3C).

6224: DESIGN, IMPLEMENTATION, & EVALUATION OF PUBLIC POLICY & PROGRAMS
The general purpose of this course is to develop an understanding of the process by which policy is formulated, analyzed, implemented, and evaluated. The focus will be on such actions as undertaken by policy analysts in and out of government. The methodological issues and techniques used to accommodate the major social, economic, political, and behavioral aspects of policy analysis in an organizational context will be discussed. (3H,3C).

6254: ADVANCED TOPICS IN PUBLIC POLICY
Selected topics in public policy analysis and program evaluation. Theoretical perspectives, methodological issues, and current research on selected policies and programs at international, national, or subnational levels, etc. (3H,3C).

6264: ADVANCED TOPICS IN POLICY SYSTEMS MANAGEMENT
Focus on critical integration of policy and management concerns in national strategy that represent a point of synthesis of external and internal policy arenas in such selected areas as: national and international security, politico–economic risk in overseas operations of U.S. institutions, crisis and emergency management, technoscience and resource systems, and information resource systems. (3H,3C).

6294: CAPSTONE SEMINAR IN PUBLIC POLICY
Conceptualization and research into the processes of policy analysis and program evaluation in the public sector. Selected conceptual, methodological, organizational, and ethical problems associated with the analysis, implementation, and evaluation of public policies and programs. X–grade allowed. (3H,3C).

6314: PUBLIC BUDGETING PROCESSES & THEIR POLICY IMPLICATIONS
Surveys the public budgeting processes of public organizations. The contrasting norms and behaviors of participants, their impacts on policy, and their implications for democracy are examined. Processes studied include the work of budgeteers, decision making processes, control and financial accounting, and intergovernmental interaction. (3H,3C).

6324: PUBLIC PERSONNEL PROCESSES & THEIR POLICY IMPLICATIONS
Surveys the key personnel processes of public organizations, the contrasting norms and behaviors of participants, their impacts on policy, and their implications for democracy. (3H,3C).

6354: ADVANCED TOPICS IN PUBLIC MANAGEMENT
An examination at an advanced level of a selected managerial process in the public sector (civil and military), the norms and participant behavior associated with the process, its efficacy in planned change, and its overall impact on policy making and implications for democracy. X–grade allowed. (3H,3C).

6394: CAPSTONE SEMINAR IN PUBLIC MANAGEMENT
Original conceptualization of and research into specific aspects of management processes in the public sector. Opportunities and problems in using management processes to institute planned change. (3H,3C).

6414: NORMATIVE FOUNDATIONS OF PUBLIC ADMINISTRATION
The course will examine the discretionary judgments of administrators as the central normative issue in the field of public administration and will look to constitutional principles for guidance in the responsible exercise of administrative discretion. Particular emphasis will be placed on selected court decisions to compare and contrast legal and moral reasoning. X–grade allowed. (3H,3C).

6454: ADVANCED TOPICS IN ETHICS & THE PUBLIC SECTOR
This is an advanced course in the Center's curriculum area dealing with ethics and the normative theory of the state. It will examine the theoretical basis of ethical standards in the field of public administration. Special emphasis will be placed on the Ethics in Government Act of 1978 and the Code of Ethics of the American Society for Public Administration. X–grade allowed. (3H,3C).

6494: CAPSTONE SEMINAR IN ETHICS & THE PUBLIC SECTOR
Original research into specific aspects of professional ethics in the public sector. Emphasis on particular problems for career personnel. X–grade allowed. (3H,3C).

6514 (SOC 6514): PUBLIC ADMINISTRATION & POLICY INQUIRY
Provides students with a general background in the design and execution of inquiry in public administration and policy. Includes examination of concepts, issues and problems of inquiry design, measurement, data collection, analysis, and the application of computers, and other information processing tools to support research and decisionmaking in public administration and policy. (3H,3C).

6664 (STS 6664): ADVANCED TOPICS IN SCIENCE & TECHNOLOGY POLICY
Variable topics in science and technology policy. Includes advanced study of science, technology, and economy; science, technology, and power; strategies for research and development policy –public and private sector; transfer of technology; technological forecasting; government regulation and responses; science policy assumptions and challenges, specialist knowledge and expertise; state and academic knowledge production; issues of race, class, gender, and national identity in policy work. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6984: SPECIAL STUDY
Variable credit course.

7954: INTERNSHIP IN PUBLIC ADMINISTRATION/PUBLIC AFFAIRS
For students without substantial previous management or staff experience and for students changing positions or career. Supervised work and academic experience. Pass/Fail only. Variable credit course.

7964: FIELD STUDY
Applied research and/or evaluation study in cooperating government agency as part of a team of advanced graduate students and faculty. Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

PUBLIC & INTERNATIONAL AFFAIRS

The master of public and international affairs (MPIA) and the Ph.D. stream in public and international affairs (PIA) of the College of Architecture and Urban Studies (CAUS) environmental design and planning program (EDP) are offered through the Government and International Affairs (GIA) program of the School of Public and International Affairs (SPIA). SPIA also includes Public Administration and Policy and Urban Affairs and Planning, and has affiliate members: Agricultural and Applied Economics, Geography, and Science and Technology Studies. See GIA for MPIA, EDP for Ph.D., and other SPIA programs for related graduate degree and course offerings.

SCIENCE & TECHNOLOGY STUDIES

Valerie Gray Hardcastle, Director

Professors: L. Arnold; J. Bohland; J. Browder; R. Burian; G. Downey; E. Fuhrman; J. Garrison; V. Hardcastle; R. Hirsh; K. Hult; T. Luke; D. Mayo; J. Pitt; D. Porter; R. Rich; J. Ryan; J. Scarpaci; D. Zallen
Associate Professors: B. Allen; M. Barrow; D. Breslau; E. Crist; B. Hausman; K. Jones; A. La Berge; D. Milly; A. Puckett
Assistant Professors: J. Abbate; J. Collier; B. Goldstein; S. Halfon; L. Perini; L. Sung
Visiting Assistant Professors: S. Brown; M. Goodrum; L. Zwanziger
Instructor: B. Reeves

E–mail: karenks@vt.edu
Web: www.sts.vt.edu

The graduate program in Science and Technology Studies (STS) explores the relationship between science, technology, and society using both disciplinary and interdisciplinary approaches. Students in the STS program come from a wide range of backgrounds including: history, anthropology/sociology, philosophy, the natural and physical sciences, engineering, and numerous professional disciplines. The research and scholarly pursuits of students and faculty cross a wide range of disciplinary boundaries: some rely on fieldwork, others are immersed in historical or governmental archival research, still others develop social theories or answer philosophical or ethical questions. Graduates emerge with an ability to identify and examine the conceptual and social dimensions of science and technology simultaneously and in historical perspective.

Achieving this capability at the master's level enhances a range of undergraduate backgrounds, preparing graduates for intensive research training at the Ph.D. level or qualifying them for positions in government and industry that require addressing and managing complex problems with both technical and non–technical aspects. In addition, the master's degree can serve as a career enhancement for those whose technical training does not fill their job needs, as a means for opening new career opportunities, and as a broadening experience for those who desire a degree for its own sake.

Completing the Ph.D. further enables students to contribute to knowledge development in some area of science and technology studies, preparing graduates for careers with a significant research component. With proper planning, opportunities include academic positions in an increasingly diverse range of interdisciplinary programs as well as disciplinary programs in history, philosophy, social studies, cultural studies, or policy studies of science and technology. Graduates may also qualify for more senior positions in government or industry, depending upon the individual configuration of background experience and Ph.D. research.

The STS program is a cooperative venture of the departments of history, philosophy, political science, sociology, and science and technology in society. Participating faculty in the program also come from such diverse disciplines as architecture, communication studies, English, geography, teaching and learning, urban affairs, and woman's studies. Courses leading to the M.S., the Ph.D., and the Graduate Certificate are available at two sites: Virginia Tech's main campus in Blacksburg and the Northern Virginia Centers in Falls Church, a suburb of Washington, D.C., and Old Town Alexandria.

Degree Structure

Master of Science Program

The 30 semester–hour master of science program includes options in history, philosophy, and social/policy studies of science and technology. M.S. candidates select four to six courses from the three core areas of history, philosophy, and social/cultural studies of science and technology. Students selecting four core courses take two additional courses in their area of concentration. Two advanced courses are required in an elective field as well as a thesis, or two advanced interdisciplinary courses in STS for non–thesis students.

Ph.D. Program

The Ph.D. includes options in history of science and technology, philosophy of science and technology; social and cultural studies of science and technology, and politics and policy studies of science and technology, in addition to the general option in science and technology studies. Ph.D. students take six of seven available core courses and an additional 24 credits past the master's degree, including a Ph.D. capstone seminar. Ph.D. students also must complete a preliminary exam, a foreign language requirement (reading knowledge of one language), and a dissertation. Students may be offered graduate assistantships in the STS or in one of the participating departments.

Graduate Certificates

STS offers five different graduate certificates, with options in history of science and technology, philosophy of science and technology, social and cultural studies of science and technology, and politics and policy studies of science and technology, in addition to a general option in science and technology studies. Graduate certificate students take two required core courses, plus two elective courses, for a total of twelve hours credit.

Graduate Courses (STS)

5105,5106: CONTEMPORARY ISSUES IN SCIENCE & TECHNOLOGY STUDIES
Theoretical and methodological issues addressed in the interdisciplinary social study of contemporary science and technology. 5105: social studies of science; 5106: social studies of technology. X–grade allowed. (3H,3C).

5205,5206 (HIST 5205, 5206): MAIN THEMES IN THE HISTORY OF SCIENCE & TECHNOLOGY
Methods and concepts in the history of science and technology. 5205: research methods, interpretive approaches, and contemporary issues in the history of science; 5206: research methods, interpretive approaches, and contemporary issues in the history of technology. X–grade allowed. (3H,3C).

5305,5306 (PHIL 5305, 5306): MAIN THEMES IN THE PHILOSOPHY OF MODERN SCIENCE & TECHNOLOGY
Problems, literature, and schools in the philosophy of science and technology. 5305: explanation and confirmation; 5306: theory change. Pre: PHIL 3505 for 5305; 5305 for 5306. (3H,3C).

5404 (HIST 5404): DEVELOPMENT OF MODERN AMERICAN SCIENCE
Development of the sciences and the community of scientists in the American national context. Emphasis on scientific, institutional, and social events from 1830s through 1980s, including the circumstances surrounding the creation of nuclear weapons and the emergence of "big science." An interdisciplinary perspective, exploring traditional and contemporary historiographical and methodological issues and approaches. (3H,3C).

5424: TOPICS IN SCIENCE & TECHNOLOGY STUDIES
Variable topics in science and technology studies such as role of values in science and technology, risk assessment, and past and present relations of religion to science and technology. May be repeated to a maximum of 6 hours. X–grade allowed. Pre: 5105, 5205, 5305. (3H,3C).

5444: ISSUES IN BIOETHICS
Identification and analysis of ethical issues arising in basic and applied biological, medical, environmental, ecological, and energy studies. (3H,3C).

5514: RESEARCH DESIGNS & PRACTICES FOR STS
Examines research designs and practices that uncover historical relationships between knowledge contents and social dimensions of science, technology, and medicine. Includes archival research, archaeology of instruments and physical spaces, interviewing for knowledge content, logical and conceptual analysis, participant observation, questionnaires, and proposal preparation. X–grade allowed. (3H,3C).

5614 (PAPA 5614): INTRO. TO SCIENCE & TECHNOLOGY POLICY
Strategies for science and technology policy; science education; scientific and technical information for societal uses; government and public policy; resource allocation; economy and global exchanges of science and technology; approaches to policy evaluation. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6224 (HIST 6224): SCIENCE, TECHNOLOGY & THE ENLIGHTENMENT
Science, technology, and medicine and their social and cultural interrelationships in the eighteenth and early nineteenth centuries. The modern agenda; nature, knowledge, and progress. Early social science. (3H,3C).

6234 (HIST 6234): ADVANCED TOPICS IN THE HISTORY OF MODERN SCIENCE, TECHNOLOGY & MEDICINE
Variable topics in history of science, technology, and medicine after 1800, such as the atomic age; space science; science, technology, and institutions; scientific and technological medicine; and environmental history. May be repeated with a different topic for a maximum of 6 credits. X–grade allowed. (3H,3C).

6314 (PHIL 6314): HISTORY OF THE PHILOSOPHY OF SCIENCE
Philosophers of science from 1650 to 1900 with particular attention to the historical development of views about the methods of induction and hypothesis and accounts of theory testing. Pre: 5305, 5306. (3H,3C).

6334 (PHIL 6334): ADVANCED TOPICS IN PHILOSOPHY OF SCIENCE
Variable topics in advanced philosophy of science, including major theories of scientific explanation and their criticisms; philosophical foundations of statistics; naturalized philosophy of science. May be repeated with a different topic for a maximum of 6 credits. X–grade allowed. (3H,3C).

6514 (PHIL 6514): COGNITIVE STUDIES OF SCIENCE & TECHNOLOGY
Applications of cognitive science to science and technology studies. Includes category theory, cognitive error theory, and computer modelling as research tools in projects linking history, philosophy, and sociology of science. (3H,3C).

6524: CRITICAL APPROACHES TO SCIENCE & TECHNOLOGY
Explores diverse traditions of criticism of Western science and technology. Focuses on feminist, Marxist, and ecological perspectives, as well as responses to critics from the scientific community. Prepares students for wider cultural debates about the costs and benefits of science and technology to society. (3H,3C).

6534: CULTURAL STUDIES OF SCIENCE, TECHNOLOGY, & MEDICINE
Examines the articulation of science, technology, and medicine in diverse cultural contexts. Focuses on exchange of metaphors and forms of discourse with other cultural activities. Includes knowledge forms in popular domains, cultural performances, fashioning of selves, power relations across boundaries, cross–cultural comparisons, and cultural critiques. (3H,3C).

6614: ADVANCED TOPICS IN TECHNOLOGY STUDIES
Variable topics in technology studies, including development and structure of knowledge in technology and engineering, social construction of technology, knowledge and power in technology, gender and technology, engineering in society, human/nonhuman relations in technology. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6624: ADVANCED TOPICS IN THE LIFE SCIENCES & MEDICINE
Variable topics in the life sciences and medicine, such as the reception of Darwinism, conceptual foundations of biology, history of genetics, scientific and technological medicine, public health and epidemiology. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6634: ADVANCED TOPICS IN NATURAL PHILOSOPHY
Variable topics in natural philosophy, including natural history up to the early modern period, such as ancient astronomical and cosmological theories, Peripatetic physics, Stoic physics, Scholastic theories of space and time, Renaissance atomism, Cartesian cosmology. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6644: ADVANCED TOPICS IN PHYSICAL SCIENCES
Variable topics in physical sciences in the nineteenth and twentieth centuries. Includes electromagnetic theory from Faraday to Einstein; development of physics and engineering in national contexts; histyorical and philosophical development of relativity and quantum theory. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6664 (PAPA 6664): ADVANCED TOPICS IN SCIENCE & TECHNOLOGY POLICY
Variable topics in science and technology policy. Includes advanced study of science, technology, and economy; science, technology, and power; strategies for research and development policy–public and private sector; transfer of technology; technological forecasting; government regulation and responses; science policy assumptions and challenges, specialist knowledge and expertise; state and academic knowledge production; issues of race, class, gender, and national identity in policy work. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6674: ADVANCED TOPICS IN ALTERNATE PERSPECTIVES ON SCIENCE, TECHNOLOGY & MEDICINE
Variable topics in alternate perspectives. Includes science from scientists' perspectives, indigenous knowledge forms, alternative medicine, New Age science, cyborg theorizing, heterodox perspectives. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6824 (SOC 6824): NORMATIVE STRUCTURING OF SCIENCE & TECHNOLOGY
Surveys approaches to the structuring of science and technology in society. Key questions include accounting for modes of legitimation; gender, race, and class relations; reward structures; modes of communication; and other relations of knowledge and power. (3H,3C).

6834 (SOC 6834): ADVANCED TOPICS IN SOCIAL STUDIES OF SCIENCE, TECHNOLOGY, & MEDICINE
Variable topics in social studies of science, technology, and medicine, including studies of disciplines, institutions, boundaries, discourses, knowledges, and practices. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (STS)

The following 4000–level courses have been approved for graduate credit:

4704 (WS 4704): GENDER AND SCIENCE
Investigates the gender dimensions of science in both historical and contemporary perspectives. Discusses feminist studies of science, exploring strengths and limitations. Assess implications of cultural assumptions about gender for practicing scientists. A 3000–level course in science or engineering may satisfy the prerequisite. Pre: 1504 or WS 2244. (3H,3C).

SOCIOLOGY

John Ryan, Chair

Distinguished Professor: W.E. Snizek
Professors: A.E. Bayer; C.D. Bryant; T.M. Calasanti; K. dePauw; C.J. Dudley; E.R. Fuhrman; T.D. Fuller; M. Hughes; J. Ryan; D.J. Shoemaker
Associate Professors: C.A. Bailey; J. E. Hawdon; B.R. Hertel; K.J. Keicolt; T. Kershaw; D.W. Wimberley
Assistant Professors: P.L. de Wolf; E.T. Graves; A.K. Harrison; C. T. Rowley; A. Vogt Yuan
Adjunct Professors: R. Blieszner; E. Crist; G.L. Downey; P.D. Metz; K. Moore; S. Poulson; J.M. Shepard; R.G. Turner
Career Advisor: (231–8971)

E–mail: soc@vt.edu
Web: http://www.sociology.vt.edu

The sociology department offers the M.S. and the Ph.D. programs of graduate study emphasizing theoretical and methodological tools that prepare students to design and conduct their own research in either academic or applied settings. By affiliating with one of the research projects within the department, students gain practical experience in social research, learning to design studies, construct questionnaires, interview, prepare data for analysis, and organize and interpret results.

Training in the major theories and methods of the discipline, from the more conventional and traditional to the most recent and innovative, constitutes the core of the graduate program. In addition, students may specialize in such areas as Social Inequality, Work and Technology, Medical Sociology, Criminology, Culture, and Africana Studies.

Doctoral students are encouraged to conduct their own independent research and to participate at professional meetings while in the graduate program.

Assistantships, tuition scholarships, and fellowships are available for qualified students.

Applicants are required to take the Graduate Record Examination, in addition to the normal requirements of the Graduate School.

More specific information on the graduate programs and requirements is contained in the *Handbook for Graduate Students in Sociology*, available on request from the department and available through our website.

GRADUATE COURSES (SOC)

5024: POWER IN INSTITUTIONS
Perspectives on the social bases of power, focusing on reciprocal relationships between the state and other social institutions such as the economy, law, and religion. Historical and comparative analyses of the rise of the modern nation–state and other social institutions, causes and consequences of social and political movements to change existing power structures, and the role of ideology in social institutions. (3H,3C).

5034: SOCIAL INEQUALITY
Perspectives on the sources and consequences of social inequality. Comparative analyses of the dynamic social construction of differentiation based on such markers as class, race, ethnicity, gender, age, religion, and sexual orientation, and the opportunities and constraints for life chances afforded by these processes. (3H,3C).

5104: HISTORY OF SOCIOLOGICAL THOUGHT
Examination of the social thinkers of the classical period in the development of sociological theory (e.g., Marx, Durkheim, Weber, Ward). Particular attention to the theories, methods, and goals developed by early sociologists. (3H,3C).

5114: CONTEMPORARY SOCIOLOGICAL THEORY
Focus on sociological theorists since World War II, including Parsons, Merton, Dahrendorf, Coser, Homans, Blau, Blumer, Kuhn, and Garfinkel. (3H,3C).

5204 (PAPA 5204): DATA ANALYSIS
Examination of data analysis designs used in sociology with emphasis on the sociological interpretation of different kinds of analyses; practical applications as used in current research. Three hours of statistics required. (3H,3C).

5214 (PAPA 5214): RESEARCH METHODS
Research methods in sociology including survey methods, qualitative methods, and experimental design. The link between social theory and social research. Measurement, validity, reliability, and the logic of data analysis. (3H,3C).

5304: SOCIOLOGICAL PERSPECTIVES IN SOCIAL PSYCHOLOGY
Sociological issues in social psychology. Development and current status of theoretical approaches to the analysis of social interaction and group process. Concepts, principles, research methods, and substantive topics associated with each approach. (3H,3C).

5414: CRIME, CONTROL, & SOCIAL INEQUALITY
Dimensions of crime and systems of social control within a framework of social inequality; examines issues of social inequality, such as discrimination, relative to race and ethnicity, social class, and gender, in crime and systems of social control; international scope. (3H,3C).

5444: WORKPLACE DEVIANCE & CRIME
Examination of deviant and criminal behavior in work settings. Stresses and problems in the work system that induce or facilitate deviance and crime. Dimensions of work structure and culture that are conducive to deviance and crime, and the opportunity structures that work systems provide. Emphasis on the theoretical analysis of workplace deviance. (3H,3C).

5504: POPULATION PROCESSES & POLICIES
Historical and comparative studies of population processes (fertility, mortality, migration); contemporary issues related to consequences of population change; population policies designed to modify population trends. Graduate standing required. (3H,3C).

5524 (UAP 5524): INTERNATIONAL DEVELOPMENT
Social and cultural factors in the development of societies, including the role of women in development. Contemporary developing countries, and historical material from developed countries; policy issues facing governments of developing countries and those interested in assisting their development. (3H,3C).

5604 (PAPA 5604): ORGANIZATIONS IN SOCIETY
Review of major theories and dimensions of modern organizations, especially technological and managerial arenas influenced by class and power. Labor processes internal to organizations and power networks among organizations. Includes cross-national comparisons. (3H,3C).

5614: WORK SYSTEMS IN COMPARATIVE PERSPECTIVE
Work and occupation in cultural context. Differential organization and perceptions of work in folk, transitional, and industrial societies. The social influence and import of work for individuals. (3H,3C).

5624: WOMEN & WORK
The analysis of the economic activities of women in contemporary society. The past and present relationship between women's domestic and market labor is examined, followed by an in-depth investigation of women's labor force experiences. Competing sociological explanations are examined, providing the basis for exploring occupational segregation, inequalities of outcomes and comparable worth. (3H,3C).

5644 (GEOG 5204) (UAP 5204): GEOGRAPHY OF THIRD WORLD DEVELOPMENT
Geographical, historical, and ecological perspectives on Third World development. Applicability of development theory to particular case studies. Problems in planning and constraints on economic development. (3H,3C).

5654 (GEOG 5654): THE GLOBAL DIVISION OF LABOR
Theory and research on the globalization of the division of labor during the recent past as well as over the past several centuries. Examines the development of the capitalist world-system including the role of technological forces; the roles of transnational corporations and states in the global economy; the effects of globalization on work and quality of life in the U.S., other developed countries, and the Third World; analyses of globalization in the manufacturing and service sectors; and possible solutions for problems associated with globalization. (3H,3C).

5714: AGING IN SOCIAL CONTEXT
Social, political, and economic environments of aging in a variety of cultures with emphasis on aging problems in American society. Evaluation of the major social theories of aging, their roles in defining problems of the elderly, and focusing on current social policy. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5914: ORIENTATION TO THE DISCIPLINE
Orientation for beginning graduate students to the organization of sociology, with emphasis on historical and departmental program areas and to the perspectives and specialties of departmental faculty; systematic and critical review of roles of sociologists, with particular reference to teaching, writing, professional association participation, and professional ethics. Pass/Fail only. (2H,2C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6014: ADVANCED STUDY IN THE FAMILY
Theory and methods in research on the family. Problems in theory construction and research design. Applications of theory and methods to research problems. (3H,3C).

6104: ISSUES IN SOCIOLOGICAL THEORY
Current issues in sociological theory including the nature and methods of scientific discourse, roles of theory and practice, power, politics and the state, and economy and class. European theorists as well as North American. Pre: 5104, 5114. (3H,3C).

6114: THEORY CONSTRUCTION
Examination of alternative approaches to constructing sociological theories with emphasis on the formulation of researchable problems. Focus on the interface between theory and research methods. Pre: 5104 or 5114 or 5214. (3H,3C).

6204: SURVEY RESEARCH METHODS
Survey research techniques used in sociological research including applied sampling techniques, measurement, scale construction reliability, response effects, administration of survey instruments, data management, and data processing. Pre: 5204, 5214, STAT 4524. (3H,3C).

6304: SOCIAL STRUCTURE & PERSONALITY
Relating social structures and processes to individual personality and behavior. Effects of variables such as social class, religion, race, and gender on social interaction and individual values and attitudes. Pre: 5304. (3H,3C).

6314: CURRENT ISSUES IN SOCIAL INEQUALITY
Seminar providing in-depth analysis of one or more current or emergent topics in social inequality. Examples of topics include homelessness, environmental racism, welfare policy, and health care access. May be repeated for a maximum of 6 credit hours. (3H,3C).

6514 (PAPA 6514): PUBLIC ADMINISTRATION AND POLICY INQUIRY
Provides students with a general background in the design and execution of inquiry in public administration and policy. Includes examination of concepts, issues and problems of inquiry design, measurement, data collection, analysis, and the application of computers, and other information processing tools to support research and decisionmaking in public administration and policy. (3H,3C).

6664 (EDRE 6664): APPLICATION OF STRUCTURAL EQUATIONS IN EDUCATION
Applications of structural equation causal models in educational research and discussion of the methodological questions pertaining to such models. Topics include recursive and nonrecursive models, measurement errors in causal models, latent unobserved variables, and covariance structures. Pre: EDRE 6634. (3H,3C).

6824 (STS 6824): NORMATIVE STRUCTURING OF SCIENCE & TECHNOLOGY
Surveys approaches to the structuring of science and technology in society. Key questions include accounting for modes of legitimation; gender, race, and class relations; reward structures; modes of communication; and other relations of knowledge and power. (3H,3C).

6834 (STS 6834): ADVANCED TOPICS IN SOCIAL STUDIES OF SCIENCE, TECHNOLOGY, & MEDICINE
Variable topics in social studies of science, technology, and medicine, including studies of disciplines, institutions, boundaries, discourses, knowledges, and practices. May be repeated with a different topic for a maximum of 6 credits. (3H,3C).

6904: PROSEMINAR IN SOCIOLOGY
Preparation for successful completion of the Ph.D. and post-doctoral professional roles in the discipline of sociology. Employment sectors for professionals and workforce roles; pedagogical training and techniques in teaching sociology; critical writing skills, identifying publication sources and manuscript preparation requirements; roles in professional associations; proposal preparation and processes for seeking funding for sociological research; ethics in teaching and in research practice. Ph.D. standing in Sociology. Pass/Fail only. (2H,2C).

6984: SPECIAL STUDY
Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (SOC)

The following 4000-level courses have been approved for graduate credit:

4014: SOCIOLOGY OF THE FAMILY
The family as a basic social institution: similarities and variations in family systems, their interrelationships with other social institutions, and patterns of continuity and change. Taught alternate years. Pre: 2014. (3H,3C).

4024: SOCIOLOGY OF RELIGION
Religion as a social structure as well as an institution; with special attention to the functions of religion for individuals, groups and societies, social organization; and the interplay between religion and other social institutions including economics and polity. Taught alternate years. Pre: 1004. (3H,3C).

4034: SOCIOLOGY OF EDUCATION
Analysis of the structure, functions, and consequences of schooling in America, the social processes affecting academic achievement, and the implications of current knowledge for educational reform. Taught alternate years. Pre: 1004. (3H,3C).

4044: MILITARY SOCIOLOGY
The military institution and its relationship to society. Emphasis on the role of the military and its social organization; recruitment, socialization, career, combat, deviant behavior, changes in the military, and future trends. Taught alternate years. Pre: 1004. (3H,3C).

4304: SMALL GROUPS
Attitudes and behavior of individuals in small groups and the organizational structure, dynamics, and performance of groups as units. Analysis of formal and informal groups in laboratory and natural settings. Taught alternate years. Pre: 2304. (3H,3C).

4404: SOCIOLOGY OF LAW
The functions of law as a form of social control. The social forces in the creation, enforcement, and change of the law. The nature of law as a force in social change. Taught alternate years. Pre: 1004. (3H,3C).

4514: RURAL SOCIOLOGY
Study of rural life. Social consequences of agricultural change and demographic changes in both national and international contexts. Taught alternate years. Pre: 1004. (3H,3C).

4604: ORGANIZATION OF THE WORKPLACE
Focus on work environments. Study of the development of modern technologies and forms of management, women in organizations, power, politics, and social relations in the workplace. A historical and an internationally comparative approach. Taught alternate years. Pre: 3604. (3H,3C).

4614: OCCUPATIONS IN SOCIAL CONTEXT
Study of work and occupational specialty in society. The social meaning and organization of occupational behavior and relationships in a variety of work systems. Attention given to social factors associated with preparation for work, occupational mobility, career patterns, and occupational specialization. Taught alternate years. Pre: 3604. (3H,3C).

4704: MEDICAL SOCIOLOGY
Social and cultural response to illness and infirmity. Emphasis on the sick role, patient role, practitioner role, organization and politics of health care delivery, stratification, professionalism, and socialization of health practitioners. Taught alternate years. Pre: 1004. (3H,3C).

4714: SOCIOLOGY OF MENTAL ILLNESS
Mental illness and social systems, historically and in contemporary society. Distribution of mental illness with special reference to stratification, role, and deviance theories. Mental health occupations and organization of treatment. Implications for social policy. Taught alternate years. Pre: 1004. (3H,3C).

4724: SOCIOLOGY OF DEATH
Social implications of death and its relationship to social behavior and institutions. Social contexts of suicide, terminal illness, execution, and accidents. Death-related processes of funeralization, bereavement, and inheritance. Death in cross-cultural perspective. Pre: 1004. (3H,3C).

4764 (GEOG 4764) (UAP 4764): INTERNATIONAL DEVELOPMENT POLICY AND PLANNING
Examination of major development theories and contemporary issues and characteristics of low-income societies (industrialization, urbanization, migration, rural poverty, hunger, foreign trade, and debt) that establish contexts for development planning and policy-making. Junior standing required. (3H,3C).

4804: SOCIOLOGY OF SCIENCE
Focus on the institution of science and its systems: normative, reward, and stratification. Concentrates on the interaction between science and other basic social institutions: political, economic, and religious. Taught alternate years. Pre: 1004. (3H,3C).

STATISTICS

G. Geoffrey Vining, Head
Jeffrey B. Birch, Director of Graduate Programs

Professors: J.B. Birch; I. Hoeschele; D.R. Jensen; A.M. McGuirk [2]; J.P. Morgan; M.R. Reynolds, Jr.[1]; E.P. Smith; G.G. Vining; W.H. Woodall
Associate Professors: G.I. Holtzman; R.S. Schulman; G.R. Terrell; K. Ye
Assistant Professors: S. Prins; D.J. Spitzner
Instructor: L. Harrell; M. McGill
Lecturer: M. Box
Visiting Assistant Professor: A. Patterson

[1] Joint with Forestry.
[2] Joint with Agricultural and Applied Economics.

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The Department of Statistics offers graduate programs leading to the Master of Science degree (with thesis and non-thesis options) and the Doctor of Philosophy degree with four concentrations or "tracks." Students who expect to specialize in graduate work in statistics are advised to study as much mathematics as possible during their undergraduate years. A course in advanced calculus is required by all students applying to the graduate program. Some experience in an area of application (physical sciences, agriculture, engineering, economics, biology, or psychology) is also highly desirable.

The M.S. plan of study requires 34 semester hours of work, of which 31 semester hours must be taken within the department. These include the core courses 5014, 5024, 5034, 5044, 5104, 5114, 5124, and 5204 (see below for description of courses). Complete and current descriptions of all courses may be found at our web site. All master's students are required to pass one section of Special Topics in Statistics (STAT 5984, 1 hour each). Students are expected to complete the M.S. within 18 months. Additional courses rounding out a plan of study may be taken at the graduate level in applied or theoretical statistics, mathematics, or in approved areas of application. Each student must pass a qualifying examination after completing the core courses and a final oral examination after completing the plan of study.

Flexibility is provided to the graduate program through four Ph.D. concentrations or "tracks", which include the Traditional Track, the Industrial Track, the Bioinformatics Track, and the Environmental Track. The Traditional Track encompasses the general pursuit of research in statistical theory and methods, allowing considerable freedom in choice of coursework within and outside the department. The Industrial, Bioinformatics, and Environmental Tracks offer more specialized statistical training geared toward application areas in which the department has particular expertise. In accord with their specialized nature, these three tracks are more stringent in requirements for relevant coursework than the Traditional Track. An option in Bioinformatics is also available. A thorough description of each track and the Bioinformatics option is given on our web page.

Doctoral students, regardless of track, are expected to

complete the entire set of M.S. core courses listed above, unless equivalent courses are approved for transfer credit. All Ph.D. students must complete two sections of Special Topics in Statistics (STAT 5984, 1 hour each). All Ph.D. students, regardless of track, must take STAT 6114 and three other 6000–level statistics courses from an approved list of courses. These courses, which vary by track, and other requirements for the individual tracks are given on our web page.

The Ph.D. plan of study requires a minimum of 90 semester hours of work beyond the baccalaureate, including at least 59 semester hours of course work and at least 30 semester hours of research toward the dissertation. Each candidate for the Ph.D. must pass the qualifying examination (see above) at the Ph.D. level.

To expose students to contemporary topics, and to facilitate departmental research, graduate students, undergraduate students, and faculty jointly participate in a series of research and topical seminars. Teaching and research skills are presented to graduate students through a variety of workshops. The department employs a mentoring system where faculty mentor graduate students who, in turn, mentor undergraduate students.

Graduate students are encouraged to participate in internships at companies and industries for the summer (three–month internships) or for extend periods of time (up to seven months for Ph.D. students). Course credit is available for a properly monitored and mentored internship experience (STAT 5984, for three to six credits). See our web page under "Internship in Statistics" for more details.

Through the Statistical Consulting Laboratory, students, in cooperation with faculty members, become involved in on–campus consulting activities. M.S. students are required to participate in statistical consulting for at least one semester, and Ph.D. students for at least three semesters. The department has several laboratiries housing state–of–the–art Unix and PC networks. Students have access to these for consulting, course work, and research. Students gain extensive experience with modern statistical software for experimental design, data management and analysis, and computer programming for statistical purposes.

In addition to the regular graduate assistantships (teaching or research), special assistantships are occasionally provided by federal and state agencies.

Graduates of the Department of Statistics are now with leading industries, government, and with some of the larger colleges and universities throughout the country and the world. The demand of industry, government, and universities for qualified statisticians is in excess of the supply.

Students interested in the statistics program should contact the Director of Graduate Programs via the e–mail address given above for additional information.

GRADUATE COURSES (STAT)

5004:

5014: INTRODUCTION TO STATISTICAL PROGRAM PACKAGES
Introduction to computing facilities and statistical program computer packages. Restricted to Statistics majors. Pass/Fail only. Co: 5044. (1H,1C).

5024: EFFECTIVE COMMUNICATION IN STATISTICAL CONSULTING
Application of statistical design, analysis and computing methods to current interdisciplinary statistical consulting projects. Skills important to effective client–statistician interactions, including interview, report–writing and oral presentation skills, will be developed. Pre: 5044. (2H,2C).

5034: INFERENCE FUNDAMENTALS WITH APPLICATIONS TO CATEGORIAL DATA
Fundamental ideas of statistical estimation and testing; principles and methods for standard one–sample settings; applications to categorial data problems. Topics include probability distributions, means, variances, and independence; point and interval estimation, including small and large sample procedures; hypothesis testing including exact and large–sample tests; goodness–of–fit; categorial data analysis; log–linear models; simple logistic regression. Pre: 5615, 4584 or MATH 4584. Co: 5014. (3H,3C).

5044: REGRESSION & ANALYSIS OF VARIANCE
Principles and methods of data analysis employing linear models for continuous response variables. Topics include both classical descriptive measures and modern computer–based techniques for data visualization; simple, multiple and weighted regression; analysis of variance for one–way and higher–way classifications; fixed, mixed, and random effects models; analysis of covariance; detection and correction of modeling flaws; statistical power. Pre: 5615, 4584 or MATH 4584. Co: 5014. (3H,3C).

5104: PROBABILITY & DISTRIBUTION THEORY
Fundamental concepts of probability, random variables and their distributions, functions of random variables, mathematical expectations, and stochastic convergence. Pre: MATH 4526. (3H,3C).

5114: STATISTICAL INFERENCE
Decision theoretic formulation of statistical inference, concept and methods of point and confidence set estimation, notion and theory of hypothesis testing, relation between confidence set estimation and hypothesis testing. Co: 5104. (3H,3C).

5124: LINEAR MODELS THEORY
A study of the theory underlying the general linear model and general linear hypothesis. Applications in linear regression (full rank) and analysis of variance. Pre: 5114, MATH 5524. (3H,3C).

5204: EXPERIMENTAL DESIGN & ANALYSIS I
Principles and concepts of experimental design; systematic overview and discussion of basic designs from the point of view of blocking, error reduction, and treatment structure; and development of analysis based on linear models. Pre: 5044 or 5616. (3H,3C).

5304: STATISTICAL COMPUTING
Computational methods for statistical computing problems. Orthogonal transformations, sweep operators, and other numerical methods applied to general optimization techniques for maximum likelihood and least squares estimation problems. Knowledge of SAS programming language required. Pre: 5124. (3H,3C).

5314: STATISTICAL SIMULATION
Special computer techniques used in statistical simulation. Pseudo–random number generators, stochastic simulation, variance reduction techniques, and Monte Carlo applications. Knowledge of Fortran required. Odd years. Pre: 5114. (3H,3C).

5324: STATISTICAL METHODS FOR ANALYZING UNBALANCED DATA
Discussion of statistical and computational aspects of methods for analyzing nonorthogonal data: estimable functions, estimation and testing of effects, and variance components for fixed, mixed, and random effects linear models; interpretation of output from existing computer packages. Pre: 5124 or 5204 or 5606 or 5616. (3H,3C).

5334: EXPLORATORY & ROBUST DATA ANALYSIS
Analysis of data by graphical and numerical techniques, statistical analysis of non–Gaussian data, topics in robust estimation for location, regression and correlation models, and the jackknife and bootstrap techniques. CMS. Even years. Pre: 5114. (3H,3C).

5344: LINEAR AND NONLINEAR PROGRAMMING
Mathematical formulation and solution of linear and nonlinear programming problems; simplex algorithms (Kuhn–Tucker conditions, duality theory); and discussion of various applications in statistics. Matrix Algebra required. Pre: 4106 or 4706. (3H,3C).

5354: STRUCTURED PROCESS IMPROVEMENT
An introduction to the selection, management, leadership and execution of structured process improvement projects. Topics include effective roadmaps for process improvement, team facilitation and leadership, project selection and management, sampling, process capability analysis, data transformation, variance component analysis, response surface methodology (including full and fractional factorial designs, Plackett–Burman designs, central composite designs, Box–Behnken designs, analysis of variance, regression, and multi–response optimization), and statistical process control. Pre: 5044 or 5624. (3H,3C).

5404: NONPARAMETRIC STATISTICS
Introduction to theory and methods of nonparametric statistical inference. General linear rank statistics, tests and estimation of location, dispersion, regression, and association. Selected topics. Odd years. Pre: 5044, 5114. (3H,3C).

5414: TIME SERIES ANALYSIS I
Analysis of data when observations are not mutually independent, stationary and nonstationary time series, linear filtering, trend elimination, prediction, and applications in economics and engineering. Even years. Pre: 5114. (3H,3C).

5424: STATISTICAL DECISION THEORY
Decision theoretic approach to statistics including admissibility, minimax, and Bayes decisions. Theory and applications of Empirical Bayes. Odd years. Pre: 5114. (3H,3C).

5434: MARKOV CHAINS AND RENEWAL THEORY
Basic definitions and characterization of states; limiting and hitting probabilities; Poisson process; pure jump Markov chains; renewal process and function; and renewal theorem. Pre: 5104. (3H,3C).

5444: BAYESIAN STATISTICS
Introductory course of Bayesian statistics on basic concepts of probability, Bayesian inference of Normal, Binomial, Poisson, Uniform and other common distributions, selections of prior information, Bayesian decision theory, Bayesian analysis of regression and analysis of variance and Bayesian foundation. Even years. Pre: 5114. (3H,3C).

5454: RELIABILITY THEORY
Basic concepts of lifetime distributions, types of censoring, inference procedures for exponential, Weibull and extreme value distributions, nonparametric estimation of survival function, kernel density estimation, accelerated life testing, and goodness of fit tests. Pre: 4106. (3H,3C).

5464 (ISE 5464): QUEUEING THEORY
Classic models of queues including M/M/1, M/GI/1, and GI/M/s. Topics in queue length processes, waiting time processes, busy period processes, and traffic processes. Pre: 5434 or ISE 5414. (3H,3C).

5474 (ISE 5474): STATISTICAL THEORY OF QUALITY CONTROL
Development of statistical concepts and theory underlying procedures used in quality control applications. Sampling inspection procedures, the sequential probability ratio test, continuous sampling procedures, process control procedures, and experimental design. Pre: 5104, 5114. (3H,3C).

5484: SEQUENTIAL ANALYSIS
Introduction to sequential tests, sequential probability ratio and other tests, approximation to OC and ASN function, tests for continuous parameter processes, sequential tests between three hypotheses, invariant tests, and sequential estimation. Pre: 5114. (3H,3C).

5504: MULTIVARIATE STATISTICAL METHODS
Methods of inference for multivariate distributions. Multivariate distributions, location and dispersion problems for one and two samples, multivariate analysis of variance, linear models, repeated measurements, inference for dispersion and association parameters, principal components, discriminant and cluster analysis, and simultaneous inference. Emphasis on robustness. Use of SAS. Knowledge of CMS required. Even years. Pre: (4204 or 4706 or 5004 or 5616), (MATH 5524). (3H,3C).

5514: REGRESSION ANALYSIS
Classical and modern techniques in regression analysis. Use of modern regression techniques to diagnose collinearity, leverage, and outliers. Model discrimination using cross validation techniques. The study of transformations, biased estimation, and nonlinear regression. Pre: 5124 or 5616. (3H,3C).

5524: SAMPLE SURVEY THEORY
Theory of sample surveys including major sampling designs, sample size determination, estimation and interval estimation, and questionnaire design. Even years. Pre: 5034., 5044 (3H,3C).

5534: ANALYSIS OF MULTIVARIATE CATEGORICAL DATA
Log–linear models for unconstrained and ordinal multidimensional contingency tables; testing and estimation; random and structural zeros; model building; logit models and logistic regression; and use of major statistical packages. Knowledge of CMS required. Pre: 5124. (3H,3C).

5544: SPATIAL STATISTICS
Spatial data structures: geostatistical data, lattices and point patterns. Stationary and isotropic random fields. Autocorrelated data structures. Semivariogram estimation and spatial prediction for geostatistical data. Mapped and sampled point patterns. Regular, completely random and clustered point processes. Spatial regression and neighborhood analyses for data on lattices. Pre: 5124. (3H,3C).

5554: VARIANCE COMPONENTS
Theoretical treatment of the general problem of estimating and testing hypotheses about variance components within the framework of random effects and mixed linear models; derivation of different estimation procedures and their statistical properties; and discussion of balanced and unbalanced data and of designs for estimating variance components. Pre: 5124. (3H,3C).

5564: STATISTICAL GENETICS
Statistical methods for linkage mapping of quantitative trait genes in populations ranging from inbred lines to complex pedigrees. Statistical methods to fine–map genes using linkage disequilibrium. Population genetic analyses of DNA sequence data. Statistical methods include multiple regression, (co)variance components estimation, Maximum Likelihood and Bayesian analyses. Algorithms to implement these methods include Expectation–Maximization, Markov chain Monte Carlo, neural networks, and genetic algorithms. Data are discrete or continuous. Pre: 5044 or (5615, 5616), ALS 5105. (3H,3C).

5574: RESPONSE SURFACE DESIGN & ANALYSIS I
Use of response surface analysis to design and analyze industrial experiments. First and second order models. First and second order experimental designs. Use of model diagnostics for finding optimum operating conditions. Even years. Pre: 5204. (3H,3C).

5584 (AAEC 5584): BASIC ECONOMETRICS
Introduction to the concepts and methods in application of econometric analysis to problems of economic research. Pre: 4724. (3H,3C).

5594: TOPICS IN BIOSTATISTICS
Course with variable content; specialized application of statistical theory and methodology to biological and medical sciences; topics include bioassay, epidemiology, survival analysis, and statistical ecology. May be repeated for credit with different topics. Odd years. Pre: 5114. (3H,3C).

5605–5606: BIOMETRY
5605: The normal distribution, estimation, hypothesis testing, simple linear regression, and one–way analysis of variance with applications to the biological sciences. 5606: Experimental design, nested and factorial analysis of variance, linear regression and correlation, and the use of SAS, with applications to the biological sciences. (3H,3C).

5615–5616: STATISTICS IN RESEARCH
5615: Concepts in statistical inference, including basic probability, estimation, and test of hypothesis, point and interval estimation and inferences; categorical data analysis; simple linear regression; and one–way analysis of variance. 5616: Multiple linear regression; multi–way classification analysis of variance; randomized block designs; nested designs; and analysis of convariance. One year of Calculus. CMS. (3H,3C).

5624: MANAGERIAL STATISTICS
Introduction to statistical concepts and methods: descriptive statistics, probability, and distributions; inferences for means, variances, and proportions; and regression and correlation. X–grade allowed. (3H,3C).

5634: STATISTICS FOR BEHAVIORAL SCIENCES
Basic statistical methods used in research in the behavioral sciences with emphasis on the applications of these methods. Descriptive statistics, correlational analyses, and intermediate inferential methods will be discussed. X–grade allowed. (3H,3C).

5644: NONPARAMETRIC STATISTICAL METHODS
Applications of rank–order statistics, sign statistics, the empirical distribution function, and runs to commonly occurring data structures. Emphasis on concepts, assumptions, comparisons to normal theory methods, and hands–on data analysis with the computer. Knowledge of CMS required. Pre: 3006 or 4706 or 5044 or 5606 or 5616. (3H,3C).

5654: MEASURES OF ASSOCIATION
Statistical methods of measuring association between nominal, ordinal, or interval level variables. Tests for significance of association. Use of two–group tests and analysis of variance to explore mixed mode relationships, such as between nominal and interval level variables. Prediction models for interval level measurements. (3H,3C).

5665–5666: STATISTICS FOR SOCIAL SCIENCE RESEARCH
5665: Basic concepts of statistical inference, including probability, point and interval estimation, hypothesis testing logic; one–sample and two–sample tests on means, variances and proportions; one–way and two–way analysis of variance; multiple comparison procedures. 5666: Multi–way analysis of variance; nested designs; repeated measures experiments; correlation for discrete and continuous variables; simple and multiple linear regression. College Algebra required. CMS. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5924: GRADUATE SEMINAR
Special topics in statistical theory and applications. May be taken for credit two times (max. 2C). Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6105–6106 (MATH 6105–6106): MEASURE & PROBABILITY
Development of measure theoretic foundations of probability theory. 6105: sigma fields, probability, and general measures; random variables, measurability and distributions, integration, and expectation; product measures; Radon–Nikodym theorem and conditioning. 6106: Random variables and strong and weak laws of large numbers; characteristic functions, central limit theorem and martingales; stochastic processes and Brownian motion. 6105 partially duplicates Math 5225. Must be enrolled in Ph.D. program. Pre: 5104 or MATH 4525. (3H,3C).

6114: ADVANCED TOPICS IN STATISTICAL INFERENCE
Advanced course in the theory of inference for graduate students in statistics and other qualified graduate students. Develops foundations, sufficiency, information, estimation, hypothesis testing, invariance, and unbiasedness. Pre: 5114, 6105. (3H,3C).

6404: ADVANCED TOPICS IN NONPARAMETRIC STATISTICS
Topics of current interest in research for nonparametric theory and methods, using recent advanced texts and journal articles. Even years. Pre: 5404, 6114. (3H,3C).

6414: TIME SERIES ANALYSIS II
Weakly and strictly stationary stochastic processes; ergodic and ensemble theory; time and frequency domain; spectral decomposition theory; Hilbert space geometry; and multivariate spectra. Even years. Pre: 5414. (3H,3C).

6424: MULTIVARIATE STATISTICAL ANALYSIS
Foundations of multivariate analysis. Distribution theory of vectors and matrices, inequalities, limit theory, the structure of some multivariate location–scale parameter families, derived distributions, invariant distributions, the principle of invariance in estimation and testing for multivariate location and scale parameters, and robust aspects of normal–theory multivariate procedures. Pre: 5504. (3H,3C).

6434: STATIONARY AND RELATED PROCESSES
Stationary processes, harmonic analysis, prediction, ARMA and moving average processes, martingales, and elementary stochastic integrals and differential equations. Pre: 5104. (3H,3C).

6464 (ISE 6464): QUEUEING NETWORKS
Applications of queueing theory results to queueing networks. Topics include reversibility, insensitivity, product forms for queue length processes, and traffic processes including traffic flow within the network. Pre: ISE 5644, ISE 6504. (3H,3C).

6484 (ISE 6484): SEMINAR IN APPLIED PROBABILITY
Working seminar open to anyone doing research in applied probability. The purpose is to review student research progress through a series of seminars offered by them and to present new research results offered by faculty attending. May be taken more than once. (1H,1C).

6494: ADVANCED TOPICS IN MATHEMATICAL STATISTICS
Advanced treatment beyond standard course offerings in topics such as theory of inference, nonparametrics, sequential analysis, and limit theory. May be repeated for credit with different topics. Pre: 5114. (3H,3C).

6504: EXPERIMENTAL DESIGN & ANALYSIS II
Theoretical treatment of construction and analysis of various types of incomplete block and factorial designs. Pre: 5124, 5204. (3H,3C).

6514: ADVANCED TOPICS IN REGRESSION
Advanced notions in modern regression techniques and diagnostics. The underlying theory and concepts associated with estimation methods for handling collinearity. Theory behind modern criteria for selection of candidate models. The development of single and multiple outlier and influence diagnostics. Odd years. Pre: 5124, 5514. (3H,3C).

6574: RESPONSE SURFACE DESIGN & ANALYSIS II
Advanced techniques and theory in response surface analysis and design. Robustness of designs. Thorough study of the notion of rotatability. Optimal design criteria and designs for estimating slopes of response surfaces. Mixture designs. Study of model misspecification. Even years. Pre: 5574. (3H,3C).

6584 (AAEC 6584): ADVANCED TOPICS IN ECONOMETRICS
Advanced topics in the theory of econometrics, and the uses of advanced techniques in application to empirical problems. Pre: 5584. (3H,3C).

6634 (EDRE 6634): ADVANCED STATISTICS FOR EDUCATION
Multiple regression procedures for analyzing data as applied in educational settings, including curvilinear regressions, dummy variables, multicollinearity, and introduction to path analysis. Pre: 5634. (3H,3C).

6644 (EDRE 6644): ADVANCED RESEARCH DESIGN AND METHODOLOGY
Principles of experimental design with applications to the behavioral sciences emphasizing appropriate statistical analysis. Pre: 5634. (3H,3C).

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (STAT)

The following 4000–level courses have been approved for graduate credit:

4004: METHODS OF STATISTICAL COMPUTING
Computationally intensive computer methods used in statistical analyses. Statistical univariate and multivariate graphics; resampling methods including bootstrap estimation and hypothesis testing and simulations; classification and regression trees; scatterplot smoothing and splines. Pre: (4105, 214), (MATH 3414 or CS 3414). (4H,3C).

4105–5106: THEORETICAL STATISTICS
4105: Probability theory, counting techniques, conditional probability; random variables, moments; moment generating functions; multivariate distributions; transformations of random variables; order statistics. 4106: Convergence of sequences of random variables; central limit theorem; methods of estimation; hypothesis testing; linear models; analysis of variance. Pre: MATH 2224. (3H,3C).

4204: EXPERIMENTAL DESIGNS
Fundamental principles of designing and analyzing experiments with application to problems in various subject matter areas. Discussion of completely randomized, randomized complete block, and latin square designs, analysis of covariance, split–plot designs, factorial and fractional designs, incomplete block designs. Project. Knowledge of WIN/MAC required. Pre: 3006 or 3616 or 4106 or 4706 or 5605 or 5615. (3H,3C).

4214: METHODS OF REGRESSION ANALYSIS
Multiple regression including variable selection procedures; detection and effects of multicollinearity; identification and effects of influential observations; residual analysis; use of transformations. Non–linear regression, the use of indicator variables, and logistic regression. Use of SAS. Project. Knowledge of WIN/MAC required. Pre: 3006 or 3616 or 4106 or 4706 or 5606 or 5616. (3H,3C).

4504: APPLIED MULTIVARIATE ANALYSIS
Non–mathematical study of multivariate analysis. Multivariate analogs of univariate test and estimation procedures. Simultaneous inference procedures. Multivariate analysis of variance, repeated measures, inference for dispersion and association parameters, principal components analysis, discriminant analysis, cluster analysis. Use of SAS. Project. Knowledge of WIN/MAC required, even years. Pre: 3006 or 4706 or 5606 or 5616. (3H,3C).

4514: CONTINGENCY TABLE ANALYSIS
Statistical techniques for frequency data. Goodness–of–fit. Tests and measures of association for two–way tables. Log–linear models for multidimensional tables. Parameter estimation, model selection, incomplete tables, ordinal categories, logistic regression. Use of SAS and SPSSx. Project. Knowledge of WIN/MAC required, even years. Pre: 3006 or 3616 or 4106 or 4706 or 5606 or 5616. (3H,3C).

4524: SAMPLE SURVEY METHODS
Statistical methods for the design and analysis of survey sampling. Fundamental survey designs. Methods of randomization specific to various survey designs. Estimation of population means, proportions, totals, variances, and mean squared errors. Design of questionnaires and organization of a survey. Project. Odd years. Pre: 3006 or 3616 or 4106 or 4706 or 5606 or 5616. (3H,3C).

4584 (MATH 4584): ADVANCED CALCULUS FOR STATISTICS
Introduction to those topics in advanced calculus and linear algebra needed by statistics majors. Infinite sequences and series. Orthogonal matrices, projections, quadratic forms. Extrema of functions of several variables. Multiple integrals, including convolution and nonlinear coordinate changes. Pre: MATH 1114, MATH 1205, MATH 1206, MATH 2224. (3H,3C).

4604: STATISTICAL METHODS FOR ENGINEERS
Introduction to statistical methodology with emphasis on engineering applications: probability distributions, estimation, hypothesis testing, regression, analysis of variance, quality control. Only one of the courses 3704, 4604, 4705, and 4714 may be taken for credit. Knowledge of WIN required. Pre: MATH 1206. (3H,3C).

4705–5106: PROBABILITY AND STATISTICS FOR ENGINEERS
Basic concepts of probability and statistics with emphasis on engineering applications. 4705: Probability, random variables, sampling distributions, estimation, hypothesis testing, simple linear regression correlation, one–way analysis of variance. 4706: Multiple regression, analysis of variance, factorial and fractional experiments. Only one of the courses 3704, 4604, 4705, and 4714 may be taken for credit. Knowledge of WIN/MAC required. Pre: MATH 2224 for 4705; 4705 for 5106. (3H,3C).

4714: PROBABILITY AND STATISTICS FOR ELECTRICAL ENGINEERS
Introduction to the concepts of probability, random variables, estimation, hypothesis testing, regression, and analysis of variance with emphasis on application in electrical engineering. Only one of the courses 3704, 4604, 4705, and 4714 may be taken for credit. Pre: MATH 2224. (3H,3C).

4724: STATISTICAL THEORY FOR ECONOMISTS
Probability, random variables, marginal and conditional distributions, mathematical expectations, sampling distributions, properties of estimators, maximum likelihood and least squares estimation, confidence intervals, hypothesis tests, linear regression. Emphasis on preparation for graduate study in econometrics. Pre: 3006, MATH 2015. (3H,3C).

4804 (AAEC 4804): ELEMENTARY ECONOMETRICS
Economic applications of mathematical and statistical techniques: regression, estimators, hypothesis testing, lagged variables, discrete variables, violations of assumptions, simultaneous equations. Pre: (3005 or 3604), (AAEC 1006). (3H,3C).

SYSTEMS ENGINEERING

K.P. Triantis, Chair
M.P. Deisenroth, co–Chair

E–mail: systems@vt.edu

Systems engineering is the application of scientific and engineering efforts to transform an operational need into a defined system configuration through the iterative process of functional analysis, synthesis, optimization, and design integration. The systems engineer considers reliability, maintainability, human factors, logistic support, safety, producibility, economic, and related parameters as they apply to the total engineering effort. Systems engineering recognizes the hand–in–hand relationship between systems and processes.

The systems engineering process, in its evolving of functional detail and design requirements, has as its goal the achievement of the proper balance among operational, technical, economic, human, and logistics factors. A major aspect of systems engineering is the concern for the total life cycle of the system. The life cycle includes analysis, design, development, testing, production, operations, sustaining support, and disposal.

A complex system, such as an organization, has technical, economic, and social components. Relationships between technical and human components are important. So are relationships among human components. The systems engineer can design system components and processes and integrate those components and processes to achieve measurable desired system performance. The systems engineer can implement and improve systems and processes to meet changing human needs.

The key to systems engineering is for the systems engineer to internalize the systems approach. He or she must develop an effective mix of ability and skill in the science and art of the systems approach. The systems approach involves an understanding of the role of each technical, human, and economic system component to meet the aim of the system and a generalist perspective for transfering lessons learned from system to system.

One objective of the systems engineering graduate program is to prepare the student to deal jointly with physical, economic, human, and other factors relevant to complex systems. The systems engineer must be sensitive to operational feasibility during the early stages of system development and must assume the responsibility for life cycle engineering, largely neglected in the past. Thus, students must develop a facility with modeling, simulation, optimization, control, human interactions, and the system approach.

The cross–disciplinary program in systems engineering, leading either to the M. Eng. or the M.S., is administered through the Department of Industrial and Systems Engineering. The cross–disciplinary aspect is achieved through selection of the appropriate combination of systems–oriented, design–related, and analytical courses from several engineering and non–engineering areas. In addition to general graduate school requirements, plans of study are developed

in systems engineering in accordance with the following guidelines:

- All students take two required three–credit systems engineering courses, one in systems engineering principles (ENGR 5004) and the other in systems modeling and systems thinking (ENGR 5104). Then the program of study becomes very flexible.

- Each student selects an area of specialty (a track) for his or her program of study. A track is a series of four three–credit courses chosen from a discipline–focused list Virginia Tech faculty have assembled to ensure and certify understanding of that discipline at the masters degree level of academic maturity. In addition to basic electrical, civil, mechanical, and industrial engineering tracks, students can find more–specialized tracks in management systems engineering, engineering administration, transportation systems, environmental systems, telecommunications, and many more.

- In addition to the chosen track, the student will take three additional three–credit courses before taking the capstone course in conducting a project under the systems engineering approach. The student has several options for the three additional courses. One option is to take two courses in an engineering discipline outside the list of courses in the chosen track and to take one free elective outside engineering. The second option is to take three courses in business from a list assembled by the faculty in the Pamplin College of Business. The third option is to take three courses in the computer science department.

- The total number of courses is ten. The student may elect to take the capstone project–oriented course (ISE 5984) or to complete the requirements for degree through a project and report (ENGR 5904). The objective of the required capstone project course is to instruct and coach the systems engineering process as applied to any system or process. Upon completion of the ten courses including the capstone project course with a B average or better, the student receives the master's degree in systems engineering.

TEACHING & LEARNING

John K. Burton, Chair

Professors: S.B. Asselin; J.K. Burton; J.W. Garrison; J.K. Nespor; K.J. Redican; M.E. Sanders; T.M. Sherman; J.S. Tlou; T.M. Wildman
Associate Professors: C.R. Baffi; M.A. Barksdale; B.S. Billingsly; K.M. Carico; K.S. Cennamo; T.E. Gatewood; S.W. Gilbert; G.E. Glasson; D. Hicks; R.V. Lalik; B.F. Lepczyk; B.B. Lockee; S.G. Magliaro; W.D. Nichols; P.A. O'Reilly; W.T. Price; J.L. Shrum; D.L. Stewart; R.K. Stratton; J.L. Wilkins; M. Wilson
Assistant Professors: J.L. Abraham; B.R. Brand; J. Brill; P.E. Doolittle; J.A. Krouscas; J.O. Little; K.R. Potter; A.D. Potts; C.F. Triplett; T.O. Williams; C.A. Young

Web: www.tandl@vt.edu

Teaching and Learning provides graduate programs leading to the master's (thesis and non-thesis), Ed.S., Ed.D., and Ph.D. The department offers training in psychological theory, social foundations, health promotions, instructional technology, and curriculum and instruction through a combination of graduate courses, internships, research programs, and teaching experiences. Graduate research programs may deal with a variety of educational issues including disciplinary foundations (anthropology, history, philosophy, and psychology) as well as teaching, reading, career and technical education, media, technology education, instructional design and technology, curriculum development, and evaluation of instruction. Graduate licensure programs are offered in: business and information technology, elementary, reading, English, family and consumer sciences, foreign languages, learning disabilities, emotional disturbances, marketing, mathematics, sciences, social studies, and technology education.

Research is carried on in the schools, community colleges, colleges and universities, and businesses where teaching/training, supervision, and development are ongoing. Laboratories and specialized equipment, media, and assessment instruments are also available for use by graduate students in furthering their graduate research. In addition, graduate students in the department may use the substantial computing resources of the university, as well as the school of education's technology facility which houses some 80 microcomputers as well as desktop and traditional media production and video-editing facilities, and a state-of-the-art classroom.

Cooperative working agreements with public schools and other educational agencies provide appropriate internships and practicums for students needing those services.

Special Degree Requirements

Based on a qualifying examination, and with consideration for the student's background, interests, and goals, a plan of study will be determined by the student's graduate advisory committee. In addition to their own area of research concentration, all students are expected to show proficiencies in research methodologies and foundational studies, as well as knowledge of a cognate discipline outside of education, via a comprehensive preliminary examination, prior to doctoral candidacy.

Graduate Courses (EDCI)

5004: FOUNDATIONS OF READING/LANGUAGE DEVELOPMENT & INSTRUCTION
Focuses on reading instruction and language development at the elementary and middle school levels. Surveys current methods and materials representative of modern theories and practices. Specifically examines the topics of objectives, sequencing, management evaluation, and positive reading/language environments and purposes. Emphasizes small and individualized programs based on student need and interest. (3H,3C).

5104: SCHOOLING IN AMERICAN SOCIETY
A study of the people and forces that impact on American education, analyzing the social setting of schooling and the relationships among school, curriculum, clients, personnel, and culture. Pre: 3024. (3H,3C).

5114: ADVANCED EDUCATIONAL PSYCHOLOGY
Psychological theories and models which serve as a basis for educational models and practice. Emphasis on conceptions of learning and the learning process. (3H,3C).

5144: HUMAN RELATIONS IN THE CLASSROOM
Considerations of affective, social, and cultural aspects of teaching and learning with an emphasis on the development of appropriate response sets and communication skills. (3H,3C).

5164: PRINCIPLES OF INSTRUCTIONAL DESIGN
Logical and empirical foundations for the selection of instructional events. Includes design methodologies, principles, and instructional strategies. X-grade allowed. (3H,3C).

5204: ELEMENTARY SCHOOL CURRICULUM
This course is concerned with the development of the elementary school curriculum. It deals with the structure, characteristics, problems and practices of the elementary school curriculum, the children, the environment and the school setting. The course is also concerned with the process of curriculum improvement and its implementation in contemporary elementary schools. (3H,3C).

5214: LINGUISTIC THEORY & INSTRUCTION IN READING & WRITTEN EXPRESSION
Studies the syntactic structure of questions and their function and application to selected questioning strategies in reading and writing; explores ideas for the development of a systematic approach to teaching writing in conjunction with reading; discusses the use of stylistic devices and grammars in a reading and writing program using basal readers and children's literature. Pre: 5004. (3H,3C).

5224: ADVANCED CURRICULUM & INSTRUCTION IN ELEMENTARY & MIDDLE SCHOOL SOCIAL STUDIES
Emphasizes curriculum research and recent developments in trends and materials in elementary and middle school social studies instruction. Exploration of alternative approaches in instructional strategies. (1-3H, 1-3C). Variable credit course.

5234: ADVANCED CURRICULUM & INSTRUCTION IN ELEMENTARY & MIDDLE SCHOOL MATHEMATICS
Research and recent developments in elementary and middle school math curricula; study and analysis of recent trends and materials; and examination of alternative approaches in methodology. (1-3H, 1-3C). Variable credit course.

5244: ADVANCED CURRICULUM & INSTRUCTION IN ELEMENTARY & MIDDLE SCHOOL SCIENCE
Selected study and analysis of curriculum trends, methods and materials. Emphasis on recent developments and the practical implications of research in science education. (1-3H, 1-3C). Variable credit course.

5254: ADVANCED CURRICULUM & INSTRUCTION IN ELEMENTARY AND MIDDLE SCHOOL MUSIC
A survey of contemporary trends in elementary and middle school music education, music and exceptional children, and the implications of research related to the musical characteristics of children. (3H,3C)

5264: COMPREHENDING PROCESSES & READING IN THE CONTENT AREAS
Explores basic processes involved in comprehension: the role of concepts about text structure, task demands, and the role of the reader; includes teaching strategies for comprehending and using information in content area texts and in job related materials. Pre: 5004. (3H,3C).

5274: SPECIFIC LEARNING DISABILITIES: CONCEPTS, THEORIES, CHARACTERISTICS & ISSUES
Detailed study of current concepts for identifying learning disabilities. Analysis of characteristics exhibited by individuals with specific learning disabilities and etiological theories. Examination of major field developments, current issues, and factors influencing programmatic change. Emphasis on current research findings. Pre: 5554. (3H,3C).

5284: TEACHING STUDENTS WITH SPECIFIC LEARNING DISABILITIES
Study of holistic instructional needs and specific requirements of individualized educational programs for learning disabled students. Analysis of instructional methods and materials used for individuals with learning disabilities. Examination of frequently displayed problems and strategies to accommodate varying disabilities in basic skills, content areas, and life skills. Analysis of effective procedures for program organization, instruction, evaluation, and communication. Pre: 5274. (3H,3C).

5294: METHODS OF TEACHING STUDENTS WITH EMOTIONAL & BEHAVIORAL DISORDERS
This course examines educational approaches that teachers can use to support children and youth who display social, emotional, and behavioral disorders. Emphasis will be placed on educational planning and program options, supportive interventions, and environmental and task management strategies to promote social-emotional development and well-being within the school setting. Pre: 5554 or (3144, 4174) or PSYC 4174. (3H,3C).

5304: ASSESSMENT FOR K-12 LITERACY INSTRUCTION
Examines theory and practice of assessment in literacy education. Explores the range of current paradigms, including those associated with assessment as measurement, as procedure, and as inquiry. Focuses on the reciprocal relationship between assessment and instruction in literacy practices. Explores a variety of assessment practices and their appropriateness for use with a diverse student population. Pre: 5004. (3H,3C).

5314: EDUCATIONAL APPLICATIONS OF MICROCOMPUTERS
A basic familiarization course for in-service teachers and other school personnel. Focus on computer literacy and specialized applications of microcomputers in school settings. Introduction to microcomputer hardware, CAI, and other local-school applications software. Microcomputer lab time required. (3H,3C).

5324: LANGUAGE, LITERACY, AND CULTURE (K-12)
The course assists educators in furthering their understanding of the connection between language, and the role culture plays within literacy development. Emphasizes how educators within the school context (K-12) need to be aware of, and utilize, the cultural background knowledge and linguistic resources, community needs of diverse students, and the community groups in which they belong. Major emphasis is on issues of literacy development in regard to oral, written, and multi-mediated texts. Graduate standing is required. (3H,3C).

5334: CONDUCTING LITERACY INQUIRY
Course content develops student skills in analysis of classroom research studies and development of a mind set for becoming a teacher researcher. Familiarizes students with classroom research methodologies that provide the practitioner with skills for conducting a teacher research project within school contexts. Graduate standing required. (3H,3C).

5344: REVIEW OF LITERARY RESEARCH
Examines the methods and knowledge developed through the major traditions in literacy research and the social and political forces through which these traditions have been shaped. Graduate standing is required. (3H,3C).

5354: LITERACIES AND TECHNOLOGY
The course will assist educators in the study of computer based technologies and the technological proficiency of students (K-12) within literacy development. Designed to prepare educators with knowledge of existing programs, uses of communication systems, and the development of presentation, web-based and software programs for use in the classroom. (3H,3C).

5384: EVALUATION & SUPERVISION OF INSTRUCTION
Principles and methods of evaluation applied to instruction, educational programs, materials, and personnel. Principles and practices of supervisory techniques designed to improve instruction and learning. (3H,3C).

5404: PRACTICUM IN CLINICAL READING
Diagnosis and remediation of reading problems. Each student works with children (K-12) in a clinical setting. The student is responsible for collecting relevant data, designing an appropriate program, carefully monitoring, and communicating progress in formal and informal reporting. Pre: 5004, 5304. (2H,3L,3C).

5414: THEORY AND PRACTICE FOR EARLY LITERACY INSTRUCTION (PK-3)
Examines language development and early literacy teaching and learning. Explores a wide range of curent theories and practices including phonics based and meaning based approaches to teaching. Attends to how curriculum, instruction, and assessment reflect differing agendas for literacy and schooling and different definitions of literacy. (3H,3C).

5424: THEORY AND PRACTICE IN CONTENT LITERACY INSTRUCTION (3-6)
Focuses on comprehension and literacy development in middle grades. It explores a wide range of paradigms of comprehension and attends to how curriculum, instruction, and assessment are conducted within each paradigm. Special attention is given to socio-cultural and critical perspectives within literacy pedagogy. Pre: 5414 (3H,3C).

5434: ASSESSMENT IN SCHOOL-BASED LITERACY (PK-6)
Focuses on assesment of literacy development in Pre K-Sixth grade. Explores a wide range of assessments and attends to how assessment informs instruction and curricular decision making. Pre: 5424. (3H,3C).

5464 (HD 5464): ADOLESCENT DEVELOPMENT
Advanced study of the physical, cognitive, social, and emotional development of the adolescent with emphasis on theoretical issues, research findings, and application of theory and research. Implications for education are highlighted. (3H,3C).

5474: ADAPTING CURRICULUM & INSTRUCTION FOR STUDENTS WITH DISABILITIES
Designing educational programs for students identified with disabilities, including informal assessment, curriculum modifications, instructional alternatives, and specialized materials and technology. Emphasis is on educational decision-making within a collaborative context involving educators, families, and specialists. Co: 3144, 5554. (3H,3C).

5484: MIDDLE SCHOOL CURRICULUM
Principles, purposes, determinants, organization and content underlying the development and operation of the middle school curriculum. Emphasis on translating physical, neurological, psychological, and social characteristics of early adolescents into middle school curriculum design, implementation, and evaluation. (3H,3C).

5534: APPLIED THEORIES OF INSTRUCTIONAL DESIGN
Emphasis is on translating theory to the practice of instructional systems development. Examines the application of foundational theories of instructional design (systems theory, communication theory, learning theories, & instructional theories) to the development of technology-based learning materials. Pre: 5114, 5164. (3H,3C).

5544: INSTRUCTIONAL TECHNOLOGY POLICY ISSUES, PLANNING, & MANAGEMENT
Introduces students to "behind-the-scene" dimensions of instructional technology found in educational institutions and other public or private workplaces. Examines those issues, policies, and practices which impact heavily upon the life and success of instructional technology innovations in both the public and private sector. Pre: 5164 or 5314. (3H,3C).

5554: EDUCATING EXCEPTIONAL LEARNERS ACROSS THE LIFESPAN
Analysis of purpose, rationale, and foci of educational programs, and related services for individuals with special needs. Identification of characteristics associated with each exceptionality. Review of procedures for assessment, eligibility decisions, and the development of individualized educational programs. Overview of selected instructional strategies, environmental adaptations, and special materials. Examination of findings concerning program efficacy. (3H,3C).

5555-5556: READING SPECIALIST PRACTICUM
The practicum develops the skills necessary to enhance school-based learning communities focused on literacy development (K-12) by providing professional development opportunities for teachers and paraprofessionals. The first of the sequence of two courses details the planning process of designing a literacy program within a school context that will identify and provide resources for teachers, administrators, and parents. The second course in the sequence provides the opportunity to implement and assess the literacy plan and to communicate the purposes of the literacy plan to policy makers and the community. Graduate standing is required. (3H,3C).

5564: TOPICS IN INSTRUCTIONAL TECHNOLOGY TOOLS & METHODS
Introductory or advanced, project-oriented course which examines software tools used to create and organize data for a variety of media elements such as text, graphics, images, animation, audio and video. Topics also include principles, techniques, and modern practices used to produce and/or deliver interactive, multimedia applications for education, professional training, public information, and retail marketing. May be repeated to a maximum of 9 semester hours. Variable credit course.

5584: PROGRAM & PRODUCT EVALUATION
Applied evaluation concepts and issues based on effective instructional design principles and message presentation guidelines derived from the behavioral and cognitive sciences. Students participate in the summative evaluation of a commercially-produced and implemented instructional program as well as conduct the formative evaluation and review of selected media-supported instructional products. Pre: 5164, EDRE 5404. (3H,3C.

5594: TOPICS IN INSTRUCTIONAL DESIGN PROJECT DEVELOPMENT
This project-oriented course presents various topics which provides students with opportunities to integrate and apply instructional technology theories, principles, practices, and skills in a variety of authentic client-designer settings. This course represents a "clinical" approach to project development in which students will become part of design teams assigned to work with real clients in an effort to produce real instructional solutions. Specific topics and contact times to be announced each semester offered. May be repeated to a maximum of 9 hours. Pre: 5164, 5564. (3H,3C.

5604: DISTANCE EDUCATION
This course will provide an overview of the current trends and relevant issues in the field of distance and distributed learning systems. The planning, development, and implementation of distance learning programs will be examined from student, faculty, and administrative perspectives. A variety of distance teaching technologies will be utilized to demonstrate the possibilities and implications of their use for distance instruction. (3H,3C).

5624: VISUAL LEARNING
Students will be introduced to the theoretical and practical aspects of designing, using and communicating with visuals in an educational and societal setting. Graduate standing in Instructional Technology required. Pre: 5114. (3H,3C).

5634: PRINCIPLES OF MEDIA PRODUCT DESIGN
Application of the principles of media (text, media, sound, video) design in the production of instructional materials primarily through the use of computer but applicable to all media. Graduate standing in Instructional Technology required. Pre: 4614. (3H,3C).

5644: TRENDS & APPLIED THEORIES IN PROFESSIONAL DEVELOPMENT
Students will be introduced to the theoretical and practical aspects of designing, developing, implementing and evaluating professional development programs. (3H,3C).

5654: SUPERVISION OF STUDENT TEACHERS
A special training course for graduate students who supervise student teachers. Focus is on application of general supervisory principles to the student teaching experience. Training is provided in skills needed for the practice of a clinical approach to supervising student teachers. Special attention is given to protocols for serving in a liaison role for the university to the public schools and to alternative procedures for evaluating student teachers. X-grade allowed. (1H,1C).

5674: ASSESSING INDIVIDUAL STUDENTS' EDUCATIONAL NEEDS
Examination of the purpose and process for individually assessing students' educational needs. Review of current assessment issues. Analysis of selected screening and diagnostic procedures available to regular and special education teachers. Experience in planning and conducting an individual educational assessment. Formulation of intervention strategies based on assessment findings. Pre: 4604 and 4554 or 5554. (3H,3C).

5694: SECONDARY SCHOOL CURRICULUM
Principles, purposes, characteristics, and issues of the secondary school curriculum, including the junior high and middle school. Emphasis will be given to the major components of the curriculum and the process of curriculum change for the secondary school. (3H,3C).

5705,5706: ADV CURRICULUM & INSTRUCTION: ENGL, FOR LANG, MATH, MUS, SCI, SOC STUDIES
The major issues and problems related to the teaching of English, foreign language, mathematics, music, science, or social studies; selective study and analysis of recent curriculum trends and materials; discussion and evaluation of research. Teaching experience required. (3H,3C).

5724: TEACHING IN MIDDLE & SECONDARY SCHOOLS I
Introduces concepts and methods that enhance the teaching of specific academic disciplines (English, history and social sciences, science, mathematics, foreign languages, and music) in combination with a field studies course. (3H,3C).

5744: TEACHING IN MIDDLE & SECONDARY SCHOOLS II
Intensive instruction in methods of teaching an academic discipline (English, history and social science, science, mathematics, foreign languages, and music). Emphasis on classroom management, use of instructional technology, planning and delivery. (3H,3C).

5754: INTERNSHIP IN EDUCATION
Student participation in a planned clinical experience under supervision of a university staff member in an appropriate work center. Pass/Fail only. Variable credit course.

5764: EXTERNSHIP IN EDUCATION
Special interdisciplinary problem-solving clinics for experienced educational practitioners who are engaged part-time in graduate study while continuing in positions of leadership in education. Interdisciplinary teams of faculty work with small groups of experienced supervisors or instructors in systematic analysis of current educational problems and evaluation of educational practice. Students judged on quality of their investigations, individual reports, and discussion. (Maximum 12C). Consent required. Pass/Fail only. Variable credit course.

5774: PROBLEMS IN EDUCATION
Study of problems of professional educators in such areas as supervision, instruction, and curriculum development. Variable credit course. X-grade allowed.

5784: GRADUATE SEMINAR IN EDUCATION
Selected topics in curriculum and instruction, supervision, educational foundations, special education, research, and evaluation. Variable credit course. X-grade allowed.

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5964: FIELD STUDIES IN EDUCATION
Applied study in one or more educational institutions. Research, evaluation, curricular, and instructional projects are examples of appropriate projects of study. The student is graded on the basis of the design of the project and ability to carry it through and report the results. Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course. X-grade allowed.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course. X-grade allowed.

6014: THE SHAPING OF THE AMERICAN SCHOOL
A systematic study of the development and consequences of elementary and secondary schooling in the United States. Pre: 5104. (3H,3C).

6024: THE ANALYSIS OF EDUCATIONAL CONCEPTS
Systematic introduction to the study of contemporary philosophy of education, indicating ways in which philosophy is used to analyze educational aims, content, methods, and values. Pre: 5104. (3H,3C).

6034: EDUCATION & ANTHROPOLOGY
Exploration of anthropological ideas and findings relevant to educational institutions and the teaching/learning process. Emphasis on how sociocultural patterns affect what is taught and learned. Pre: 5104. (3H,3C).

6064: THE SHAPING OF AMERICAN HIGHER EDUCATION
A systematic study of the development and consequences of higher education in the United States. Pre: 5104. (3H,3C).

6074: HISTORICAL RESEARCH IN EDUCATION
An exploration of historical methods in collecting, analyzing, synthesizing, and interpreting information as applicable to educational research. Pre: 6014 or 6064.

6114: COGNITIVE PROCESSES & EDUCATIONAL PRACTICE
Investigates complex human learning from the perspective of cognitive/information processing theories. Emphasizes methods of investigation in cognitive science as well as strategies for using a cognitive orientation in educational settings. Pre: 5114. (3H,3C).

6134: TOPICS IN INSTRUCTIONAL DESIGN
Examination of theory and empirical research applied in modern approaches to instructional design. Pre: 5114, 5164. (3H,3C).

6144: RESEARCH ISSUES IN MUSIC EDUCATION
Current issues related to music behavior and music education research. Emphasis on the review of classical and contemporary research reports. Extensive reading. Pre: EDRE 5404. (2H,2C).

6154: RESEARCH APPLICATIONS TO MUSIC EDUCATION
The study and practice of the application of quantitative findings and techniques to the research process in music. Emphasis on the actual application of experimental design and principles of statistics generally used in music education research. Pre: EDRE 6604. (3H,3C).

6505,6506: READING RESEARCH SEMINAR
Issues related to conducting and reporting research on the reading process and reading pedagogy. Includes the critical review of classical and contemporary research and an initiation to the process of conducting reading research. Special attention is given to the analysis and classification of major research paradigms. Pre: 5004, 5304 for 6505; 6505 for 6506. (3H,3C).

6534: ETHNOGRAPHIC METHODS IN EDUCATIONAL RESEARCH
Exploration of ethnographic methods for data collection and analysis: theoretical bases, procedures, issues, and applications of this approach in educational research. Pre: 6034. (3H,3C).

6604: CURRICULUM THEORY & ORGANIZATION
Examination of critical issues in curriculum including definition, theory construction, theories of human nature, structure of knowledge, school organization, and interaction with instruction. Analysis of alternative theories of curriculum in the context of the school, society, and broader theories of education. Pre: 5204 or 5484 or 5694. (3H,3C).

6614: MODELS OF TEACHING
Analysis of selected models of teaching. Emphasis on the provision of multiple theoretical bases for classroom teaching. Models based on the theoretical work of Ausubel, Bruner, Glasser, Thelen, Taba, Suchman, and others will be studied, practiced in a “peer teaching” setting, and adapted to specific educational settings. (3H,3C).

6624: COMMUNITY COLLEGE CURRICULUM
Study of the major curricular programs of the comprehensive community college including factors that influence the design and implementation, processes for assessing, and strategies for changing the curriculum for open access colleges. Pre: EDCC 6304. (3H,3C).

6644: COLLEGE TEACHING
Current educational theory and practice, related to teaching in higher education, is explored and applied. Issues such as instructional design, instructional strategies, instructional technology, assessment and grading, diverse populations, and motivation are addressed within the practice of higher education. (3H,3C).

6654: RESEARCH IN INSTRUCTIONAL TECHNOLOGY
The purpose of this course is to introduce the students of instructional technology to the development and history of research in the field, to generate research principles, to the types of research in the field, and to the current trends in research in the field. Students will be given an opportunity to review and critique a wide range of research and be required to formulate a conceptual idea and complete a literature review of a potential research topic. Post-masters standing required. Pre: EDRE 5404. (3H,3C).

6664: TRENDS & PRACTICES IN INSTRUCTIONAL TECHNOLOGY
The utilization of modern instructional media and technologies and their integration with other components of a learning system. The various electronic and computer-assisted technologies will be stressed as will the software support for classroom and individualized instructional modes. Pre: 4614. (3H,3C).

6944: PROFESSIONAL SEMINAR
Presentation and critical discussion of current literature and major topics in curriculum and instruction. Provides students an opportunity to synthesize prior course experiences and to prepare and present a draft dissertation prospectus. Pass/Fail only. Variable credit course.

7754: INTERNSHIP IN EDUCATION
Planned program of advanced clinical practice in education through assignment under direct supervision of an outstanding practitioner for periods of up to two semesters. Pass/Fail only. Variable credit course.

7964: FIELD STUDIES IN EDUCATION
Advanced applied study in one or more educational institutions. Research, evaluation, curricular, and instructional projects are examples of appropriate projects of study. The student is graded on the basis of the design of the study, ability to conduct the study, and interpret and report the results. Pass/Fail only. Variable credit course.

7994: RESEARCH & DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (EDCI)

The following 4000-level courses have been approved for graduate credit:

4124 (PSYC 4124): PSYCHOLOGICAL FOUNDATIONS OF EDUCATION FOR PRESERVICE TEACHERS
Emphasizes applying human learning and developmental theories to the classroom setting with a focus on instructional processes and procedures, student motivation, classroom management, and assessment strategies. Participation in a 4-year and 5-year teacher education program and junior level standing required. Pre: PSYC 2004 or HD 1004. (3H,3C).

4174 (PSYC 4174): STUDENTS WITH EMOTIONAL AND BEHAVIORAL DISORDERS
This course examines the characteristics and needs of individuals with emotional and behavioral disorders. Topics include history, definitions and causes of emotional and behavioral disorders, major research findings, identification procedures, educational programming and current issues. Co: 3144. (2H,2C)

4284: STUDENTS WITH SPECIFIC LEARNING DISABILITIES
This course examines the characteristics and needs of individuals with learning disabilities. Topics include history, definitions and causes of learning disabilities, major research findings, identification procedures, educational programming, and current issues. Co: 3144. (2H,2C).

4414: TEACHING COMPOSITION: METHODS AND MATERIALS
Application of relevant theory and research to instructional strategies for teaching the composing process. Emphasizes methods for generating student writing, teaching revision, and evaluating writing as well as instructional materials. (3H,3C).

4424: LITERATURE FOR ADOLESCENTS
Discussion and analysis of factors involved in selection and use of literature for junior and senior high school students and research related to that selection: reading interests and needs of adolescents, sources of literary materials for adolescents, classroom uses of various types of literature. X-grade allowed. (3H,3C).

4604: ASSESSMENT OF STUDENT LEARNING
This course examines both traditional and alternative methods of assessing student learning within a classroom environment, including the writing and evaluation of selection and supply test questions; the construction and evaluation of portfolio, informal, and alternative assessments; assessment, evaluation, and use of standardized tests; and the construction of a coherent grading plan. Pre: Junior standing required. (3H,3C).

4614: INSTRUCTIONAL TECHNOLOGY: AUDIO-VISUAL AND COMPUTER USES
An introductory instructional technology course. Principles and production of audio-visual materials and methods in instruction. Application of microcomputers in instruction, emphasizing computer literacy, programming and evaluation of instructional software. Course in methods of teaching, field teaching experience, or teaching experience required. Pass/Fail only. (2H,3L,3C).

GRADUATE COURSES (EDCT)

5114: C&I IN CTE: PROFESSIONAL PERSPECTIVES
Designed to provide provisionally licensed teachers in career and technical education (CTE) with an overview of roles and relationships within the teaching profession. Develops their knowledge of factors and resources for program planning and liability and safety issues for teachers. This is the first course in a sequence of six, one-credit courses. (1H,1C).

5124: C&I IN CTE: BASICS OF CURRICULUM
Designed to provide provisionally licensed teachers in career and technical education (CTE) with instruction in the basics of planning and developing curriculum including needs analysis, course and unit planning, and student assessment. This is course two in a sequence of six one-semester hour courses. Pre: 5114. (1H,1C).

5134: C&I IN CTE: INSTRUCTIONAL STRATEGIES
Designed to provide provisionally licensed teachers in career and technical education with instruction in developing and delivering curriculum. Further develops the teacher's ability to use a variety of teaching strategies to meet the diverse population of students. This is the third course in a sequence of six, one-credit courses. Must have prerequisite or permission of the instructor. Pre: 5124. (1H,1C).

5144: C&I IN CTE: ADVANCED INSTRUCTIONAL STRATEGIES
Designed to provide provisionally licensed teachers in career and technical education with advanced instruction in developing and delivering curriculum. Develops the teacher's ability to use technology in instruction and to supervise work-based programs. This is the fourth course in a sequence of six, one-semester credit courses. Must have prequisite or permission of the instructor. Pre: 5134. (1H,1C).

5154: C&I IN CTE: PROFESSIONAL DEVELOPMENT-PROGRAM MANAGEMENT
Designed to provide provisionally licensed teachers in career and technical education (CTE) with instruction in a variety of program management tools related to their own professional development, their student organizations, and their program administration. This is course five in a sequence of six one-semester hour courses. Pre: 5144. (1H,1C).

5164: C&I IN CTE: DIVERSE LEARNERS
Designed to provide provisionally licensed teachers in career and technical education (CTE) with an understanding of the importance of diversity in our society, schools, and the workforce. Categories and characteristics related to diversity and disabilities are discussed, and assignments develop skills in adapting curriculum and instruction to best meet student needs. This is the sixth course in a sequence of six, one-credit courses. Pre: 5154. (1H,1C).

5604: FOUNDATIONS OF CAREER & TECHNICAL EDUCATION
Focus on the history and development of career and technical education with emphasis on the philosophical bases of the field. The conduct and purposes of career and technical education under different philosophical orientations are compared. An overview of the organization and administration, the relationship of career and technical education to agencies both in and outside of education, and how economic conditions have impacted career and technical education are explored. Definition and development of a personal philosophy is required. X-grade allowed. (3H,3C).

5644: CURRICULUM AND PROGRAM PLANNING IN CAREER & TECHNICAL EDUCATION
Concepts and principles involved in curriculum and planning of career and technical education programs. Learning experiences focus on school and community needs assessment, curriculum content identification and selection, designing curricula, and assessing curriculum materials and processes. Graduate standing required. (3H,3C).

5654: STRATEGIES FOR TEACHING CAREER & TECHNICAL EDUCATION
Focus on identifying the major instructional methods that are appropriate in career and technical education and identifying and resolving problems that emerge from these methods that can have a negative impact on the overall effectiveness of the teacher. Various methods to evaluate the teacher's instructional effectiveness are addressed. Graduate standing or two years of teaching experience required. (3H,3C).

5684: EDUCATION & EMPLOYMENT PREPARATION FOR DIVERSE POPULATIONS
Study of policy and practices for developing and implementing career and technical education and employment programs that meet the needs of diverse/special needs, those youth and adults with disabilities, disadvantaged, limited English proficient, ethnic minorities, incarcerated youths, and single/teen parents. Specific attention to federal and state legislation and trends; the education foundation, programs and practices, which prepares students for career and technical education and training; and employment practices and programs. (3H,3C).

5694: CAREER & TECHNICAL EDUCATION FOR ADULTS
Focus is on the role, rationale, and teaching strategies for those adult learners enrolled in Career and Technical Education programs. Advanced content drawing heavily from contemporary trends and issues on the adult learner as synthesized from current research. Pre: 4254. (3H,3C).

5704 (EDCC 5704): POST-SECONDARY OCCUPATIONAL & COMMUNITY SERVICE EDUCATION
An anlysis of post-secondary occupational and community service education. Emphasis will be placed upon delivery through community colleges and review of other delivery systems including proprietary, military, and private business and industry will be addressed. The course will include a review of local, state, and national policies relating to the mission, curriculum, clientele, governance, finance, and evaluation of occupational and technical and community service programs. (3H,3C).

5714: EDUCATION & WORK IN A CHANGING SOCIETY
This course explores the major social, economic, and political issues and trends expected to have continuing impacts on career and technical education and the workforce. The current status and philosophies of career and technical education are evaluated relative to these changes. Alternative directions for the future are identified and analyzed, with emphasis on proactive rather than reactive strategies for educators. Pre: 5604. (3H,3C).

5734: TRANSITION PROGRAMMING FOR INDIVIDUALS WITH DISABILITIES
Indepth study of transition policy, programs, procedures and services for diverse populations. Focus of course is on the comprehensive transition process including preparation for employment, post-secondary education and training, independent living skills, skills in accessing community services, social skills, recreation and leisure skills. Effective educational programming, community services, transition planning, and collaboration between education and community services at the secondary level will be emphasized. X-grade allowed. (3H,3C).

5754: INTERNSHIP IN EDUCATION
Student participation in a planned clinical experience under supervision of a university staff member in an appropriate work center. (Max 12C). Consent required. Pass/Fail only. Variable credit course.

5764: EXTERNSHIP IN EDUCATION
Problem-solving clinics for experienced career and technical education practitioners who are engaged part-time in graduate study while continuing in positions of leadership. Involves systemic analysis of current educational problems and evaluation of educational practice. (Max 12C). Pass/Fail only. Variable credit course.

5774: PROBLEMS IN EDUCATION
Study of problems in career and technical education in such areas as administration, curriculum development, and instruction. (Max 6C per course.) Variable credit course. X-grade allowed.

5784: GRADUATE SEMINAR IN EDUCATION
Selected topics in career and technical education related to curriculum development, special education, administration, research, and evaluation. (Max 6C per course) Variable credit course. X-grade allowed.

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C)

5904: PROJECT AND REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5964: FIELD STUDY
Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH AND THESIS
Variable credit course.

6604: ADMINISTRATIVE LEADERSHIP FOR CAREER & TECHNICAL EDUCATION
Administrative structure of career and technical education at the local, state, and national levels, and in business and industry; leadership for administrative planning, facilities and support services management, personnel management, supervision of instruction, professional development, and assessment in career and technical education. Alternate years. (3H,3C).

6614: EVALUATION IN CAREER & TECHNICAL EDUCATION
Study of the theory and application of evaluation to career and technical education. Major emphasis on the unique requirements of program, personnel and student evaluation as specified in Federal and State legislation and regulations. National and state evaluations of career and technical education are assessed. (3H,3C).

6664: POLICY ANALYSIS FOR EDUCATION & THE WORKFORCE
In-depth treatment of the nature of policy and the policy-making process as they pertain to the workforce and to education, especially to career and technical education. Included are significant aspects of policy development at local, state, and federal levels; examination of the basic questions that are answered by policy decisions; appropriate organizations for formulation of policy; an examination of current policy pertaining to career and technical education at state and federal levels; and procedures for establishing policy. Pre: 5604. (3H,3C).

6674: CAREER & TECHNICAL TEACHER EDUCATION PROGRAMS
Teacher preparation programs in career and technical education are emphasized. Focus on beliefs and philosophy, contemporary issues, roles, student selection, student teaching supervision, curriculum, methodology, and organization and administration of career and technical education programs. Research and theory play an important part in the examination of each content area. Graduate standing required. Alternate years. (3H,3C).

6684: ISSUES IN CAREER TRANSITION FOR SPECIAL POPULATIONS
Examines role and function of career transition in secondary and post-secondary education, rehabilitation and social services and relates to current and future social and economic trends on a state, national, and international basis. Provides opportunities to pursue research in critical areas of need in career transition for special populations. X-grade allowed. (3H,3C).

6694: CAREER & TECHNICAL EDUCATION IN GLOBAL CONTEXTS
Examination of career and technical education's impact in global contexts: exploration of factors contributing to development and underdevelopment; discussion of culture, governmental arrangements, infrastructure, elements of successful programs, needs assessment, finance, and planning development activities. (3H,3C).

6944: PROFESSIONAL SEMINAR
Critical review, presentation, and discussion of current literature, research, and national reports in designated areas of education. (6C max. credit allowed toward program of study) Consent required. Pass/Fail only. Variable credit course.

6984: SPECIAL STUDY
Variable credit course.

7754: INTERNSHIP IN EDUCATION
Pass/Fail only. Variable credit course.

7964: FIELD STUDIES IN EDUCATION
Pass/Fail only. Variable credit course.

7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (EDCT)

The following 4000-level courses have been approved for graduate credit:

4204: MANAGING CAREER AND TECHNICAL EDUCATION WORK-BASED PROGRAMS
Responsibilities of the teacher coordinator regarding work-based program standards, student guidance, school and community relations, on-the-job training, youth organization sponsorship, work-based program coordination, and program management. Pre: 2604, (4274 or 4964). (3H,3C).

4224: TRENDS AND COMPUTER TECHNOLOGY IN CAREER AND TECHNICAL EDUCATION
A study of trends and computer technology in education, business, and industry and the implications for career and technical education; prepares the student to incorporate new trends and computer technology into career and technical education settings. Must have prerequisite or EDCT 5644 and senior or graduate status. Pre: 4234. (3H,3C).

4234: CURRICULUM FOR CAREER AND TECHNICAL EDUCATION
Provides current and prospective career and technical education teachers with research bases, resources, and available curricula for teaching content in the respective fields. Develops the ability to plan, manage, develop, and evaluate curricula. Pre: 2604 or 5604. (3H,3C).

4244: METHODS OF TEACHING CAREER AND TECHNICAL EDUCATION
Developing instructional plans, delivering and evaluating instruction, and evaluating learner performance for career and occupational education. Must have prerequisites or EDCT 5644 and senior or graduate status. Prerequisites will be waived for agricultural education students. Pre: 4234. (3H,3C).

4254: ADULT CAREER AND TECHNICAL EDUCATION PROGRAMS
Introduction to the underlying theory and procedures involved in developing, delivering, managing, and evaluating adult education programs in Career and Technical Education. Co: 4244. (3H,3C).

4274: INTERNSHIP IN BUSINESS
While employed in a business occupation, the student completes an in depth study of the firm's policies, practices, and procedures. This study, conducted under the supervision of the employer and a Career and Technical Education professor, focuses on five major aspects of the business: sales promotion, merchandising, business operation, control, and personnel. (Max 5H,5C). Variable credit course. X-grade allowed. Pre: 2604.

4324: TEACHING METHODS FOR NUTRITION
Use of learning and instructional techniques with individuals and groups. Planning, presenting, and evaluating nutrition education programs. Pre: Minimum of two (2) Human Nutrition and Foods courses. (2H,2C).

4575,4576: ADMIN. AND CURR DEVELOPMENT OF COOPERATIVE TRAINING PROGRAMS IN VIHOE
This course prepares coordinators of cooperative training programs and covers general aspects of vocational industrial/health occupations educations, the world of work, and the organization and administration of cooperative training programs. Also included are the duties of the coordinator, instructional development, sources of instructional materials, relationship of co-curricular activities to instruction, and the development of independent study guides and programmed guides for VIHOE students. (3H,3C).

4604: FUNDAMENTALS OF TRAINING AND DEVELOPMENT
Overview of training and development in an organizational setting. Students learn the relationship of training and development to human resource development and selected skills necessary to successfully become a training specialist. Particular attention is given to the design and implementation of training and development programs. X-grade allowed. (3H,3C).

4614: INSTRUCTIONAL APPLICATIONS IN TRAINING AND DEVELOPMENT
Develop the ability to plan, organize and apply a variety of group and individual instructional methods in an organizational setting. Emphasis is placed on methods and procedures used by successful training specialists. X-grade allowed. (3H,3C).

GRADUATE COURSES (EDHL)

5304 (HNFE 5674): PRINCIPLES OF COMMUNITY HEALTH EDUCATION
Public health issues and concepts are analyzed and evaluated in relationship to existing principles of health education. (3H,3C).

5314 (HNFE 5694): PUBLIC HEALTH ADMINISTRATION
This course will focus on relevant and timely public health administration concepts. The major topics covered include: health policy, health care planning, health care economics, health law, and managerial functions as they relate to health care and public health settings. (3H,3C).

5604 (HNFE 5684): PROGRAM DEVELOPMENT IN HEALTH EDUCATION
Theory, trends, and design of community health education programs implemented in communities, health agencies, hospitals, and industry. Pre: 5304 or HNFE 5674. (3H,3C).

5704: HEALTH OF THE ELDERLY
The health needs and problems of the elderly, the implications for those working with the elderly, and possible health care delivery systems. (3H,3C).

5734: HEALTH BEHAVIOR AND HEALTH EDUCATION
This course has two main purposes: (1) to familiarize students with historical, theoretical and methodological aspects of health psychology; and (2) to acquaint health education students with the social, psychological, and cultural determinants of health behaviors which form the underpinnings of health education practice. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C)

5904: PROJECT AND REPORT
Variable credit course.

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

GRADUATE COURSES (EDPE)

5104: ANALYSIS & SUPERVISION FOR TEACHING PHYSICAL EDUCATION
Techniques for the analysis of teaching physical education with particular application to instructional supervision. Introduction to research on teaching physical education with emphasis on teaching process observation for teacher skill development. X-grade allowed. (3H,3C).

5134: CURRICULUM DEVELOPMENT IN PHYSICAL EDUCATION
This couse has two main purposes: To familiarize students with curricular models for grades K-12 and to anaylze practical approaches to curriculum development. The curricular models include: physical fitness, team sports, low organized games, sports skills, lifetime sports, movement education, and outdoor education. X-grade allowed. (3H,3C).

5184: ADMINISTRATION OF ATHLETICS
Factors relating to interscholastic athletics on secondary and college levels and relationship to general education. Pre: 4114. (3H,3C).

5194: MOTOR SKILL LEARNING
The purpose of the course is to present the current motor behavior literature with particular emphasis on theories and applications to instruction found in motor learning and motor development research. The ocncept of the learner as an information processor serves as the foundation for the course. (3H,3C).

5254: BEHAVORIAL ASPECTS OF EXERCISE & SPORT
The theory-based research in motivation, arousal, aggression, personality, and leaderships, particularly as applied to physical activity settings, will be examined. Implications for learning and performing sports skills and conducting exercise and fitness programs will be discussed. (3H,3C).

5304: SPORT MARKETING
The study of marketing theories, principles and case studies as they apply to the various aspects of sport including, but not limited to, recreational activities, private fitness, athletics, and corporate fitness. (3H,3C).

5404: DESIGNING SYSTEMS FOR DIRECT OBSERVATIONS
Theoretical and practical aspects of quantifiable behavioral measurement for analysis and research in education. Introduction to quantifiable naturalistic measurement
techniques for education. Issues in data collection, analyses, and reporting. A comprehensive project designing a system for application in a setting chosen by the student. Pre: EDRE 5404. (3H,3C).

5454: MANAGEMENT OF SPORTS AND RECREATIONAL FACILITIES
Analysis of terminlolgy, principles, and standards of planning, design, use and maintenance of areas and facilities used for sports and recreational purposes. Specific attention will be given to revenue producing facilities. (3H,3C).

5504: PHYSICAL AND SENSORY ASPECTS OF DISABLING CONDITIONS
A study of the physical, sensory, neurological, emotional, and health problems which affect function and development of children and youth. Pre: 4134. (3H,3C).

5514: PSYCHOMOTOR ASSESSMENT & PROGRAMMING TECHNIQUES FOR ADAPTED PHYSICAL EDUCATION
Describes and critically evaluates assessment instruments and procedures utilized in adapted physical education. Development of appropriate programming techniques based on assessment information. (2H,3L,3C).

5754: INTERNSHIP IN PHYSICAL EDUCATION
Student participation in a planned clinical experience under supervision of a university staff member in an appropriate work center. Maximum 12C. Consent required. Pass/Fail only. Variable credit course..

5774: PROBLEMS IN PHYSICAL EDUCATION
Study of problems in physical, sport, and exercise science. Maximum 6C per course. Variable credit course.

5784: GRADUATE SEMINAR IN PHYSICAL EDUCATION
Selected topics in physical education, sport, and exercise science. Maximum 6C per course. Variable credit course. X-grade allowed.

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Independent research relating to student's area of concentration, undertaken in lieu of a thesis; demonstration of ability to identify problem area, collect and organize relevant information, and present conclusions and recommendations in a logical, well-written report. Variable credit course.

5964: FIELD STUDIES IN PHYSICAL EDUCATION
Applied research and/or evaluation in one or more institutions. Student is graded on basis of design of the study and ability to conduct the study and report the results. Maximum 12C. Consent required. Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

5994: RESEARCH & THESIS
Variable credit course.

6004: ADVANCED TOPICS IN MOTOR DEVELOPMENT
The purpose of this course is to provide indepth study of selected topics in motor skill development. While the focus of the material will be the early years, a life span approach is utilized. (3H,3C).

6014: RESEARCH IMPLICATIONS FOR TEACHING PHYSICAL EDUCATION
The purpose of the course is to review the recent research literature from several related disciplines and then to apply the research to teaching physical education to children and youth. Areas of research that will be reviewed include: motor development, sport psychology, motor learning, sport sociology, biomechanics, and exercise physiology. (3H,3C).

6034: MODELS OF TEACHER EDUCATION IN PHYSICAL EDUCATION
Examination of the major models for training preservice and inservice physical education teachers in colleges and universities. Emphasis will be placed on evaluation of existing models, and the institutional and professional influences impacting on teacher training for physical education. Alternative, experimental models for teacher training will be covered. Pre: 5104. (3H,3C).

6044: INSTRUCTIONAL DESIGN FOR PHYSICAL EDUCATION
Instructional design-based teaching and learning models for motor play skills. Extension of generic instructional design principles into physical education settings. Focus on evaluation and implementation of teaching/learning models relevant to physical education. Pre: EDCI 5164. (3H,3C).

6944: PROFESSIONAL SEMINAR
Critical review of current literature, research, grant funding, and national meeting reports in selected areas of physical education. Maximum 3C. Pass/Fail only. (1H,1C).

ADVANCED UNDERGRADUATE COURSE (EDPE)

The following 4000-level course has been approved for graduate credit:

4734: CURRICULUM AND INSTRUCTION FOR SECONDARY PHYSICAL EDUCATION
Integration and analysis of curriculum and teaching models for secondary physical education. Emphasis on appropriate selection of curriculum content and transition to teaching/learning models. Unit and lesson planning and evaluation. Pre: 3714. (2H,3L,3C).

GRADUATE COURSES (EDTE)

5414: CONTEMPORARY PROBLEMS & ISSUES IN TECHNOLOGY EDUCATION
Discussion and assessment of current problems and issues in technology education. A research discussion and seminar format will be followed. (3H,3C).

5424: PROFESSIONAL SEMINAR IN TECHNOLOGY EDUCATION
A seminar forum for review of research proposals, student and faculty research projects, and timely topics impacting the Technology Education profession. May be repeated for up to a maximum of three semester hours credit. Pass/Fail only. (1H,1C).

5434: CURRICULUM DEVELOPMENT IN TECHNOLOGY EDUCATION
Concepts and principles involved in Curriculum Development in Technology Education. The course will include a review of the historical development of Technology Education, a study of the processes of curriculum development and the application of these processes to Technology Education. (3H,3C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

ADVANCED UNDERGRADUATE COURSES (EDTE)

The following 4000-level courses have been approved for graduate credit:

4414: TECHNOLOGY EDUCATION PRACTICUM
The application and evaluation of the group and unit approach to the teaching of modern industry and exploring technology in technology education. (3H,3C).

4444: COMMUNICATION TECHNOLOGY
This course provides a synthesis of the broad spectrum of communications technologies, including printing, computer-aided drafting, photographic, video, design, and electronic communications technology. (2H,3L,3C).

4445-4446: TECHNOLOGY EDUCATION ELECTRONICS
Study of electronics in terms of functions. 4445 stresses DC, AC, power supplies, amplifiers, and oscillators. 4446 deals with transmitters, receivers, communication systems, and digital electronics. (2H,3L,3C).

THEATRE ARTS

Patricia Raun, Chair

Professors: A.G. Kilkelly; R.W. Ward
Associate Professors: W.S. Barksdale; D.W. Johnson; G.W. Justice; P.S. Lavender; R.H. Leonard; J.M. McCann; P.A. Raun
Assistant Professor: J. Ambrosone; L. Liebetrau; S.C. Rinehart; M. Zobel
Adjunct Professors: J. Liebetrau
Career Advisors: G.W. Justice; R.W. Ward; P. Raun (231-5335)

E-mail: theatre@vt.edu
Web: www.theatre.vt.edu

The Department of Theatre Arts provides graduate programs leading to the M.F.A. in arts administration, costume design, costume technology, scenography, stage management, technical direction, and properties management.

Special Degree Requirements

Each three-year program of study leading to the M.F.A. is tailored to the individual student. During the three years, the student works closely with a master teacher in studios/ tutorials and a program of study is developed by the master teacher to meet the student's specific career goals. The purpose of the program is to prepare students for positions of leadership in the profession. The degree program consists of a combination of studio assignments, practical experience on and off campus, and course work supportive of the specific area of study. All students are expected to participate in departmental productions and major assignments are provided during all three years. Assistantship assignments are in support of the production process in the costume shop, scene shop, management office, or academic program. Additionally, a professional internship and summer employment are required. In order to successfully complete the program, students must meet professional standards and competencies as defined by the master teacher and the student's advisory committee.

Graduate Courses (TA)

5004: HIGH CONCEPT LOW TECH THEATRE, I
Exploration of techniques and approaches to working with literature in theatrical modes of presentation that require minimum technical production expertise. (3H,3C).

5014: HIGH CONCEPT LOW TECH THEATRE, II
Exploration of advanced skills in developing writing for performance, directing, and conceptualizing of public performance. Pre: 5004. (3H,3C).

5015,5016: GRADUATE SEMINAR
Special topics in the theory and practice of theatre, current trends, and recent developments. (3H,3C).

5415,5416: PRODUCTION STUDIO I
Topic-oriented investigation of various fundamental production problems involving research, collaborative work, and individual projects. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5425,5426: PRODUCTION STUDIO II
Topic-oriented investigation and experimentation with various advanced production problems involving research, collaborative work, and individual projects. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5435,5436: PRODUCTION STUDIO III
Topic/project-oriented investigation of specific production problems requiring the application of professional competencies. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5615,5616: ARTS MANAGEMENT STUDIO I
Topic-oriented investigation of various fundamental arts management problems involving research, collaborative work, and individual projects. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5625,5626: ARTS MANAGEMENT STUDIO II
Topic-oriented investigation and experimentation with various advanced arts management problems involving research, collaborative work, and individual projects. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5635,5636: ARTS MANAGEMENT STUDIO III
Topic/project-oriented investigation of specific arts management problems requiring the application of professional competencies. (2H, 2C minimum; 6H, 6C maximum) each. Variable credit course.

5704: GRADUATE THEATRE INTERNSHIP
Internship of one semester in production (technical theatre, design, or directing), child drama (theatre for youth or creative drama), or arts management (including stage management) with a professional theatre company or similar off-campus professional situation. Pass/ Fail only. X-grade allowed. (27L,9C)

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

Advanced Undergraduate Course (TA)

The following 4000-level course has been approved for graduate credit:

4315-4316: DIRECTING
Script analysis, theories, techniques, and practical applications of theatrical direction. 4315: Theories and aesthetics of directing, functions of the director, script analysis, basic principles and techniques of staging. 4316: Rehearsal techniques, style determination realism, and non-realism. Senior standing required. (3H,3C)

URBAN AFFAIRS & PLANNING

UNIVERSITY EXEMPLARY DEPARTMENT *

Max Stephenson, Chair

University Distinguished Professor: P. L. Knox
Professors: J.R. Bohland; J.O. Browder; C.T. Koebel; A.C. Nelson; J. Randolph; J.L. Scarpaci
Associate Professors: R.E. Lang; T.W. Sanchez; M.O. Stephenson, Jr.; D. Zahm
Assistant Professors: C.J. Dawkins; A. Ebrahim; B. Goldstein; H. Mayer; J. Richardson
Adjunct Professors: E.L. Blythe; A.H. Moore; A. Pheley M.E. Ridenour; A.W. Steiss

E-mail: uapvt@vt.edu
Web: www.uap.vt.edu

Urban Affairs and Planning (UAP) is a program in the School of Public and International Affairs in the College of Architecture and Urban Studies (CAUS). UAP offers the accredited master of urban and regional planning (MURP) and the planning stream of the Ph.D. in the CAUS EDP program (see Environmental Design and Planning). In addition, UAP faculty support the master of public and international affairs (MPIA) and PIA stream of EDP Administered by SPIA's GIA program (see Government and International Affairs). All UAP graduate degrees are offered in both Blacksburg and Alexandria.

URBAN AND REGIONAL PLANNING

The mission of the program is to develop in students:

- an understanding of the social and environmental context of planning;
- an understanding of the use of professional planning concepts, skills and theory;
- an understanding of the history and tradition of the planning profession;
- competence in an area of specialization;
- competence in quantitative and qualitative analysis; and
- competence in the written and oral communication skills necessary to function as a planning professional.

The urban and regional planning program is a two-year interdisciplinary professional accredited degree (48 hours) open to students from a wide variety of undergraduate fields. Areas of specialization include: environmental planning and policy, physical development planning, economic/community development planning, social policy, and international development planning. Graduates typically assume professional responsibilities in a wide variety of positions in public service or in the private sector. The program is accredited by the Planning Accreditation Board.

MURP CURRICULUM REQUIREMENTS

Total Credit Hours Required: 48

FOUNDATIONS OF PLANNING (9 CREDIT HOURS)

UAP 5174: Theory and Practice of Planning (3)
UAP 5234: Urban Economy and Public Policy (3)
UAP 4754: Legal Foundations of Planning (3)

ANALYTICAL METHODS (7 CREDIT HOURS)

UAP 5224: Research Methods in Planning and Policy (4)
choose one:
UAP 5484: Advanced Research Methodology (3)
or UAP 5494: Advanced Quantitative Techniques (3)
or GEOG 5034: Spatial Analysis (3)

PLANNING APPLICATIONS (6 CREDIT HOURS)

UAP 5124: Urban and Regional Planning Studio (3)
choose one:
UAP 5434: Urban Development Project Studio (3)
or UAP 5764: International Development Studio (3)
or UAP 5774: Economic Development Studio (3)
or UAP 5794: Environmental Planning Studio (3)

CHOOSE ONE OPTION (26 CREDIT HOURS)

A. Thesis option
UAP 5994: Research and thesis (6)
Electives (20)
B. Major paper option
UAP 5904: Project and Report (3)
Electives (23)
C. Practicum option
UAP 5804: Practicum Problem (2)
Electives (24)

AREAS OF CONCENTRATION (ELECTIVES ARE SELECTED IN THE FOLLOWING AREAS)

Environmental Planning
Land Use and Physical Planning
International Development
Community and Economic Development
Social Policy and Planning

GRADUATE COURSES (UAP)

5104: URBAN & REGIONAL DEVELOPMENT THEORY
An examination and critique of theories relating to socio-economic development and change at three major scales (international, national/regional, and intra-urban) and of theories relating to the linkages between the dominant processes operating at these major scales. Particular emphasis is given to the role of the state in urban and regional development. (3H,3C).

5114: COMPUTER APPLICATIONS IN URBAN PLANNING & MANAGEMENT
An examination of a wide range of computer-based techniques that are of value in analyzing urban and regional planning and management problems. Techniques include linear programming, goal programming; modeling of complex systems; and decision modeling. Pre: 5224. (3H,3C).

5124: URBAN & REGIONAL PLANNING STUDIO
Application of planning strategies to solve urban problems encountered in professional practice. Includes methods and techniques for securing and analyzing relevant data; identifying goals and objectives; formulating proposals; formulating strategies to implement proposals; presentation of findings. (3H,3C).

* University Exemplary Department Awards recognize the work of departments that maintain, through collaborative efforts of dedicated colleagues, exemplary teaching and learning environments for students and faculty.

5134: THEORY AND PRACTICE OF POLICY DEVELOPMENT
Analysis of issues, processes, and institutions central to public sector urban policy. Emphasis on the concept of the public interest and the utility of decision models as means for explaining the manner in which the public interest becomes translated into public policy by various public institutions at federal and local levels. (3H,3C).

5144: URBAN POLICY ANALYSIS & IMPLEMENTATION
Methodological approaches to urban policy and analysis; examination of process and techniques that facilitate policy implementation; application of analytic methods resulting in policy implementation. Pre: 5134. (3H,3C).

5154: URBAN MANAGEMENT
Focuses on the basic management functions of planning, organizing, staffing, directing, coordinating, budgeting and evaluation, from a general perspective, as these affect urban organizations. Includes both theoretical and applied aspects of urban management from normative and empirical research, and introduces basic public management techniques. (3H,3C)

5164: COLLABORATIVE GOVERNANCE & CIVIL SOCIETY
Theoretical foundations of collaborative policy and governance approaches are examined. Strategies and methods for forming and sustaining collaborative coalitions are discussed. Case studies are used to illustrate the effectiveness of collaborative approaches in different policy domains. (3H,3C).

5174: THEORY & PRACTICE OF URBAN & REGIONAL PLANNING
Theoretical foundations of urban and regional planning. Methods and procedures employed in the professional practice of planning. Examination of the interdependence of planning theory and planning practice. (3H,3C).

5184: LOCAL PLANNING ADMINISTRATION
Role of local legislative bodies, planning commissions, administrators, and the public in local planning activities. Responsibilities of professional planners in local planning activities. Emphasis is placed on methods of implementing local planning programs. (3H,3C).

5194: URBAN GROWTH MANAGEMENT
Examines regulatory and financial techniques for controlling and guiding urban development. Evaluates their advantages and disadvantages with respect to development circumstances. Focus is primarily on the practice of local and state governments in the U.S. Pre: 4754. (3H,3C).

5204 (GEOG 5204) (SOC 5644): THE GEOGRAPHY OF THIRD WORLD DEVELOPMENT
Geographical, historical, and ecological perspectives on Third World development. Applicability of development theory to particular case studies. Problems in planning and constraints on economic development.

5224: QUANTITATIVE TECHNIQUES IN PLANNING
A presentation of research techniques used in urban and regional planning with an emphasis on predictive techniques and the use of the computer. (3H,3L,4C).

5234: URBAN ECONOMY & PUBLIC POLICY
This course applies principles of urban economics and microeconomics to the analysis of a range of urban problems, including: housing, employment, environmental quality, poverty, and the provision of urban services. (3H,3C).

5244: MULTICULTURAL
Examines the growing ethnic and demographic diversity of urban United States. Stresses theories and techniques that can be used to bring about more inclusive planning and public policies at all levels of government. (3H,3C).

5264 (GEOG 5264): GLOBAL CHANGE & LOCAL IMPACTS
All jurisdictions–national, regional, or local–function in an interconnected global market. Understanding the structure and interactions within that global market and the impacts therein is the focus of this course. Thematic topics include a review of welfare state functions, privatization, decentralization, and nonprofit organizations and their relation to global market dynamics. Upon completion of the courses, students will have an understanding of how global forces influence local areas and how local leaders have developed strategies to cope with their position in an increasingly global market. (3H,3C).

5304: LAND USE PLANNING
Procedures for: (1) identifying the type, magnitude, and locational characteristics of urban land uses; (2) making projections of future land use; and (3) preparation of land use plans. (3H,3C).

5314: SOCIAL ANALYSIS OF LAND USE PLANNING
Examines the underlying social and cultural values which shape U.S. land use and zoning policies. Analyzes zoning ordinances, historic preservation, environmental planning, housing, and urban design policies for their explicit and cultural meanings. Pre: 4754. (3H,3C).

5364: NON-GOVERNMENTAL ORGANIZATIONS IN INTERNATIONAL DEVELOPMENT
Explores theory and cases of non-governmental organizations in international development. Analyzes various role of NGOs, and their interactions with local communities, government agencies, international organizations, and private businesses. Examines tensions and collaborations between NGOs and other development actors, drawing from cases in environmental, health, and policy domains. (3H,3C).

5374: PLAN IMPLEMENTATION IN DEVELOPING COUNTRIES
Examines the instruments available for the implementation of development policies in Third World countries. Analyzes cases of planning and decision making to identify practical issues and available tools for implementation. The course focuses on policies which affect the spatial arrangements and physical development of cities and urban regions in developing countries. Pre: 4764. (3H,3C).

5384: HOUSING & INFRASTRUCTURE PLANNING IN THE THIRD WORLD
An introduction to housing problems in developing countries and alternative policy approaches to them. The course examines the formal and informal housing sectors and asks why the housing sector is important for both national governments and international organizations. It traces changes in the way housing problems have been identified and in the solutions proposed to them. Pre: 4764. (3H,3C).

5394: NATURE, SOCIETY & THE GLOBAL ECONOMY: INTERDISCIPLINARY PERSPECTIVES
Graduate seminar examines social theories of environmental change (e.g. social ecology, ecofeminism, political economy, environmental history, neo-classical and neo-malthusian perspectives). Environmental degradation is situated in the context of global economic development, providing a framework for critical analysis of alternative conceptions of society-nature relationships. Book reviews, term paper, student presentations required. Second-year grad standing and permission of instructor required. (3H,3C).

5404: STRATEGIES FOR URBAN DEVELOPMENT IN THE THIRD WORLD
Analysis of the reciprocal relationships between development and urbanization as they occur within a Third World context. The nature of those relationships at different scales–international, regional, and urban–are considered from the standpoint of different strategies of development. (3H,3C).

5414: NATURAL RESOURCE PLANNING
The natural resource planning process as implemented by federal public lands and water resources agencies in the U.S. Public participation, environmental impact assessment, and resource evaluation methods used in planning and decision-making. Applications to resources planning in developing countries. (3H,3C).

5434: URBAN DEVELOPMENT PROJECT REVIEW STUDIO
A studio focusing on the theory, methods, and techniques of evaluating physical development projects. Emphasis on evaluation criteria implied in public policy, as expressed in comprehensive plans and implementing regulatory ordinances (zoning, land subdivision regulations, building codes, environmental regulations). (3H,3C).

5444: STRATEGIC PLANNING & MANAGEMENT
An examination of different processes and procedures for generic planning and management of a strategic nature. Particular emphasis on analytical techniques, especially Artificial Intelligence, that are used in the process. Pre: 5244. (3H,3C).

5474: PROGRAM EVALUATION
Conceptual approaches and methodological techniques for evaluating national, regional, and local human services programs. Examination of issues relevant to the function of evaluation research and the role of evaluators. (3H,3C).

5484: ADVANCED URBAN RESEARCH METHODOLOGY
The various methodological approaches used in the fields of urban planning and in public policy to analyze causes of problems and thus suggest policy recommendations. Emphasis is on defining the research problem, developing an appropriate research design, data collection, and fundamental techniques of data analysis. (3H,3C).

5494: ADVANCED QUANTITATIVE TECHNIQUES FOR URBAN RESEARCH
Advanced quantitative techniques used in urban analysis. Application of the methods to situations encountered in urban planning, urban policy analysis, and urban management are stressed. Pre: 5484. (3H,3C).

5514: PUBLIC BUDGETING & MANAGEMENT
Examines public budgeting and management theories, concepts, policies, processes, and practices, and their effects on federal, state, and local governments. Theoretical aspects of budgeting and management control are related to practical budgeting issues and exercises. Attention is also given to the internal management of the budgeting function. (3H,3C).

5524 (SOC 5524): INTERNATIONAL DEVELOPMENT
Social and cultural factors in the development of societies, including the role of women in development. Contemporary developing countries, and historical material from developed countries; policy issues facing governments of developing countries and those interested in assisting their development. (3H,3C).

5544: PUBLIC & NON-PROFIT FINANCIAL MANAGEMENT
Examines concepts central to effective financial management of public and non-profit organizations. Affords students an opportunity to further their understanding of the relationship between financial accounting and reporting systems and effective organization management. Pre: 5514. (3H,3C).

5554: LAND USE LAW
State enabling legislation; police power of the state; nuisance; land use regulation; subdivision regulation; exclusionary zoning; growth management; environmental controls. Pre: 4754. (3H,3C).

5564: INFORMATION TECHNOLOGY, SOCIETY, & PUBLIC POLICY
Social impacts of new and emerging information technologies from a public policy perspective. Technical nature of IT and influences of IT on four core dimensions of society: politcal, economic, cultural, and spatial. Course intergrates theoretical and philosophical literature on IT with applied policy and planning issues. (3H,3C)

5604: HOUSING POLICY
An examination of national and local housing markets with emphasis on the impact of various public housing policies on the demand for and supply of housing within these markets. The relationships between public and private delivery systems. Pre: 5234. (3H,3C).

5624 (ARCH 5624) (LAR 5624): URBAN DESIGN SEMINAR
Current topics in urban design. Topics may include: theoretical, conceptual and practical concerns in the generation of urban spatial form; the roles of public and private interests in shaping urban form; the effects of urban intensification on the quality of public spaces; environmental issues in urban design; the role of public policy and regulatory mechanisms; the genesis and development of urban typologies. (3H,3C).

5634 (ARCH 5634): URBAN DESIGN STUDIO
Urban design studio projects involving the translation of design and planning theory and methodology to actual form-giving proposals for the urban context. Emphasis will be on the development of urban tectonic form in response to functional and behavioral planning, symbolic and aesthetic factors. May be repeated for a maximum of 12 credit hours. Variable credit course. Pre: ARCH 4715.

5644 (CEE 5644): TRANSPORTATION SYSTEMS PLANNING
Advanced consideration of problems dealing with transportation systems as they affect the socio-economic development of cities, regions, and nations; the travel behavior of a populace; the location of economic activity; the use of land; and the allocation of resources. Pre: CEE 3604. (3H,3C).

5664 (CEE 5664): INTERCITY TRANSPORTATION
Intercity transportation, including trucking, railroads, and aviation industries, as a vital part of the economy. Operation and logistic rules that govern the flow of shipments and dictate costs and freight rates under various regulatory policies and market environments. Pre: CEE 3604. (3H,3C).

5684: HEALTH PLANNING
Examines the practice of planning within the different health system environments. Reviews the philosophies and methods of health planning as applied to the U.S. experience and other national settings. Projects are employed to give students direct, practical experience in health planning. Pre: 4614. (3H,3C).

5754: PROFESSIONAL DEVELOPMENT COLLOQUIUM
An examination of new emerging concepts, issues, techniques, and skills relevant to the professional development of those involved in planning, designing, and managing the urban environment. (1H,1C).

5764: INTERNATIONAL DEVELOPMENT STUDIO
International development project initiation and institutional framework; project design processes, criteria, and methods; implementation and evaluation design processes, criteria, and methods. Examination of case projects by public and private donor agencies as a basis for project design. Pre: 4764. (3H,3C).

5774: ECONOMIC DEVELOPMENT STUDIO
Principles, concepts, and techniques related to economic development at either the local and regional scale are brought to bear in solving a development problem. Emphasis is on problems which are encountered in planning or implementing economic development. Pre: 5234 or 5104. (3H,3C).

5784: LOCAL ECONOMIC DEVELOPMENT PLANNING
An introduction to local economic development programs. Covers intergovernmental relations, financing techniques, federal and local subsidies, advertising, marketing, public relations, labor market issues, tax considerations, fiscal impact analysis, and land use planning issues. (3H,3C).

5794: ENVIRONMENTAL PLANNING STUDIO
Application of environmental planning techniques involving either land use or residuals management in a specific project. (3H,3C).

5804: PRACTICUM PROBLEM
The practicum is one option (together with the major paper and thesis) which MUA and MURP Degree candidates may elect to complete their degree requirements. It is intended to provide the candidate with an opportunity to demonstrate: (1) a required degree of comprehension of the concepts, principles and techniques relevant to these fields, and (2) the ability to apply this understanding in a professional manner in a situation which simulates professional practice. Pre: 5124 or 5144. (2H,2C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5904: PROJECT & REPORT
Variable credit course.

5924: PEACE CORPS ENROLLMENT
(OC)

5964: FIELD STUDY
Pass/Fail only. Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course. I.

ADVANCED UNDERGRADUATE COURSES (UAP)

The following 4000-level courses have been approved for graduate credit:

4184: COMMUNITY INVOLVEMENT
Issues, concepts, and techniques of citizen participation in community development. Institutional frameworks and their historical precedents. Exercises developing group communications skills, public meeting facilitation, and design of community involvement programs. (3H,3C).

4214: WOMEN, ENVIRONMENT AND DEVELOPMENT IN A GLOBAL PERSPECTIVE
Explores intersecting roles of gender, culture, and socio-economic status in people's use of nature, management of environmental resources, and experiences of environmental change. Examines debates on environmental and development initiatives, environmental ethics, and environmental social movements from feminist perspectives. Pre: 3344 or 3354. (3H,3C).

4244: NON-PROFIT ORGANIZATION AND MANAGEMENT
Examines the role of the non-profit sector in American society. Also analyzes the role of important sub-sectors within the nation's third sector and explores key management challenges confronting non-profit organization leaders within them. Junior standing required. (3H,3C).

4264: ENVIRONMENTAL ETHICS AND POLICY
Issues in applied environmental ethics. Contributions of diverse religious and philosophical traditions to contemporary perspectives on the human-nature relationship. Examination of environmental policies from utilitarian economic, deep ecology, and ecofeminist perspectives. Junior, senior or graduate standing required. Pre: 3344 or 3354. (3H,3C).

4284: ENVIRONMENT, POLITICS & PLANNING: COMPARATIVE APPLIED POLITICAL ECOLOGY
Uses political ecology concepts, linking environmental change and social difference, to address practical problems where social justice and environmental management intersect at multiple spatial scales and institutional levels. Junior or senior standing required. Pre: 3354. (3H,3C).

4304: NON-PROFIT ORGANIZATION LEADERSHIP AND GOVERNANCE
This course explores the major conceptual issues related to developing an understanding of the foundations and roles of leadership and governance of third sector and nongovernmental organizations. The course focus is explicitly comparative and contextual and is designed to equip students with the capacities to assess and improve governing board effectiveness as well as to devise and implement leadership strategies in the complex structural, social and political contexts in which nonprofit organizations are typically enmieshed both in the United States and other industrialized democracies and in developing nations. Pre: 4244. (3H,3C).

4344: LAW OF CRITICAL ENVIRONMENTAL AREAS
This course examines the legal principles and policy debates involved in the regulation and protection of critical environmental resources. Specific topics vary but will likely include wetlands law and policy, endangered species habitat, open space, forestland and farmland protection, costal zone management, and floodplain regulation and policy. Pre: 4754, AAEC 3314. (3H,3C).

4374: LAND USE AND ENVIRONMENT: PLANNING AND POLICY
Environmental factors involved in land use planning and development, including topography, soils, geologic hazards, flooding and stormwater management, ecological features, and visual quality. Techniques used in conducting environmental land inventories and land suitability analyses. Policies and programs to protect environmental quality in land use planning and development. Pre: 3354. (3H,3C).

4384: POLLUTION CONTROL PLANNING AND POLICY
Planning and policy aspects of managing residuals and environmental contaminants and their effects on human health and environmental quality. Technical and economic factors involved in management of water quality, air quality, solid and hazardous wastes, toxic substances, and noise. Implementation of pollution control legislation, policies, and programs at federal, state, and local levels. (3H,3C).

4394: COMMUNITY RENEWABLE ENERGY SYSTEMS
Practical design fundamentals for small scale renewable energy systems: solar building heating and cooling; solar domestic hot water; wind, photovoltaic, and hydroelectric systems; alcohol, methane and other biomass conversion systems. Developing plans, programs, and policies to stimulate development of renewable systems. Pre: MATH 1016 or ECON 2116. (3H,3C).

4404 (ALS 4404) (NR 4404): APPROACHES TO INTERNATIONAL DEVELOPMENT
An introduction to issues relating to international development. The course will focus on areas to help students better understand the interdependencies between countries and how institutions and organizations can foster effective working relationships on global projects of mutual interest between countries. (1H,1C).

4604: SOCIAL POLICY AND PLANNING
A survey of the history of social policy in the United States of existing federal, state, and local statutes that define the character of contemporary social policy and planning and of issues that are likely to affect the direction of future social policy developments. Policy areas considered include income maintenance, health, housing, and labor force development. Pre: 3014. (3H,3C)

4714 (ECON 4714): ECONOMICS AND FINANCING OF STATE AND LOCAL GOVERNMENTS
Examines the provision and financing of public goods and services in local governments. Analyzes associated policy issues. Reviews experience in Western Europe and developing countries, as well as in the United States. Pre: ECON 2006. (3H,3C).

4724: CAPITAL BUDGETING AND STRATEGIC FACILITIES PLANNING
Examines the principles and practice of capital budgeting as a primary instrument for the effectuation of long-range public policy objectives. Capital budgeting forms a critical bridge between strategic planning and the delivery of vital public services. Strategic facilities are public improvements that have a relatively long life, involve substantial investment of public resources, and yield fixed assets for the community or organization. (3H,3C).

4744: PRINCIPLES OF REAL ESTATE
Examines the relationship between the real estate market and urban development. Focuses on the private sector real estate market and how it responds to and shapes urban policy and urban planning practices. Pre: UAP 3014. (4H,4C).

4754: LEGAL FOUNDATIONS OF PLANNING
Examination of the legal context in which urban planning and public policy operate. Legal structure, role of law, powers of sovereign governments, constitutional limitations on government activities, and public-private conflict and their influence on planning and public policy are examined. (3H,3C).

4764 (GEOG 4764) (SOC 4764): INTERNATIONAL DEVELOPMENT POLICY AND PLANNING
Examination of major development theories and contemporary issues and characteristics of low-income societies (industrialization, urbanization, migration, rural poverty, hunger, foreign trade, and debt) that establish contexts for development planning and policy-making. Junior standing required. (3H,3C).

4854: PLANNING OF THE URBAN INFRASTRUCTURE
Course examines the interdependences among the elements of the built environment of the city and those between the elements of the built environment and the policy/planning structure of the city. Considered are those elements associated with the primary urban activities (residential, commercial, industrial) as well as the urban form-giving infrastructure facilities that support those land uses (water supply, sewerage, solid waste disposal, transportation, education, recreation, health, and safety). Pre: 3014. (3H,3C).

VETERINARY MEDICAL SCIENCES

John C. Lee, Interim Associate Dean for Research and Graduate Studies

Professors: S.A. Ahmed; R.J. Avery; D.L. Barber; S.M. Boyle; R.V. Broadstone; C.B. Carrig; M.V. Crisman; M.F. Ehrich; P.Eyre; S.D. Holladay; K.D. Inzana; T.J. Inzana; B.S. Jortner; M.M. Larson; J.C. Lee; M.S. Leib; D.S. Lindsay; R.A. Martin; J.B. Meldrum; W.E. Monroe; D.L. Panciera; J.P. Pickett; B.J. Purswell; R.L. Pyle; J.L. Robertson; G.G. Schurig; P.K. Shires; S.A. Smith; D.P. Sponenberg; N. Sriranganathan; C.D. Thatcher; T.E. Toth; G.C. Troy; G.H. Turnwald; D.R. Waldron; N.A. White II; W.D. Whittier; J.R. Wilcke
Associate Professors: J. Abbott; D.J. Blodgett; T. Caceci; S. Craig; J.J. Dascanio; R.J. Duncan; F. Elvinger; L.A. Eng; L.E. Freeman; M.O. Furr; W.R. Huckle; J.C. Jones; B.G. Klein; O.I. Lanz; V.A. Buechner-Maxwell; X.J. Meng; D.M. Moore; K.D. Pelzer; F.W. Pierson; R.S. Pleasant; K.C. Roberts; K.E. Saker; G.K. Saunders; W.K. Scarratt; B.J. Smith; K.E. Sullins; H.M. Suthers-McCabe; Y. Suzuki; W.S. Swecker, Jr.; A.M. Zajac
Research Associate Professor: W. Eyestone
Assistant Professors: F.S. Almy; D. Berry; S.H. Berry; L. Dahlgren; L.L. Donaldson; C. Hatfield; I.P. Herring; R. Kasimanickam; T. Kaur; Y.W. Lee; J. Rossmeisl; S. Witonsky; K. Zimmerman
Clinical Associate Professor: J.F. Currin
Clinical Instructors: D.C. Grant; C. Keoughan; T.O. Manning; W.L. Palmer; Z. Ristic; R. Torres-Diaz
Adjunct Faculty: P. Arambulo: S.B. Barker; M.J. Bowen; D.L. Boyd; T.P. Caruso; N. Castagnoli, Jr.; B.M. Dunham; J.M. Erwin; M.R. Finkler; J.M. Gregg; A.W. Hayes; K.P. High; S.R. Jenkins; V. Kok; L.J. Kyle; G.G. Meza; K.N. Opengart; J.B. Palmieri; S. Pederson; S.L. Porter; S. Samal; J. Sleeman; S.J. Stahl; E. Stephenson; E. M.L. Tilghman; L. Tobias; M.E. Torrence; C.A. Williams; J.H. Williams; D. Wolf

The Virginia-Maryland Regional College of Veterinary Medicine offers the M.S. and Ph.D. in veterinary medical sciences.

The primary objective of the graduate program in Veterinary Medical Sciences (VMS) is to prepare graduate students as scholars and researchers who will expand the base of new veterinary and biomedical knowledge. The program of training prepares graduate students to conduct scientific research.

The VMS graduate program includes the Departments of Biomedical Sciences and Pathobiology, Large Animal Clinical Sciences, and Small Animal Clinical Sciences. Opportunities for specialization are available in areas such as anatomy, physiology, molecular biology, pharmacology, toxicology, microbiology, pathology, immunology, epidemiology, clinical nutrition, veterinary informatics, and experimental medicine and surgery.

The graduate students plan their academic programs with a major professor as an advisor, developing a comprehensive program that meets the degree requirements and research goals.

Specific details for each graduate student's plan of study will be the responsibility of the student's advisory committee. Courses, laboratory and field research, clinical exposure, and teaching experiences will be tailored to meet individual needs with regard to the background of the individual and his or her career objectives.

This program will prepare graduates for careers in public health service, agricultural research, biomedical research, industry and government, education, or other areas requiring knowledge of animals and zoonotic diseases.

SPECIAL DEGREE REQUIREMENTS

The MS/Residency is a three-year combined degree and clinical residency tract. Resident/graduate students are required to register for 6 hours of regular courses plus VMS 6014, Veterinary Clinical Sciences Residency (1-6 hours, variable credit).

GRADUATE COURSES (VMS)

5004 (VM 9084): EMERGING INFECTIOUS DISEASES
The course will define and discriminate between emerging and other diseases, define spatial and temporal determinants, host and agent characteristics and risk factors, analyze social, economical and international trade changes, improper use of antibiotics, and multi-drug resistant infectious agents such as factors of emerging diseases. Selected emerging food-borne, bacterial, viral, zoonotic diseases of animals and humans will be described and analyzed. Pre: third-year standing in the DVM curriculum. Pass/Fail only. (1H,1C)

5005 (VM 9085, 9086): EMERGING INFECTIOUS DISEASES
Stand-alone, fully on-line, asynchronous distance and distributed learning course, accessible as streaming videos on the internet or on CDs. 5005: The course defines and discriminates amongst numerous factors influencing the emergence of infectious diseases. Selected emerging food-borne, bacterial, viral, zoonotic diseases of animals and humans are described and analyzed. 5006: The course expands the pathology of emerging infectious diseases. Additional viral, parasitic and zoonotic diseases of animals and humans are described and analyzed. Xenotransplantation is also discussed from the perspective of zoonotic diseases. Third year standing in the DVM curriculum, or good standing in a graduate studies program is required. Pass/Fail only. (1H,1C)

5014: ANIMAL PATHOLOGY RESIDENCY
Training in diagnostic pathology through weekly rotations in the necropsy and surgical biopsy service of the teaching hospital. Students will perform necropsies and histopathologic examinations of necropsies and surgical biopsies and write diagnostic reports. The course is taken in weekly intervals of necropsy and/or surgical biopsy, with a credit hour given for each 2-week interval. Variable credit. May be repeated with a maximum of 5 hours. DVM degree required. Variable credit course.

5024: SELECTED TOPICS IN VERTERINARY PATHOGENIC BACTERIOLOGY
Lecture and discussion course emphasizing the latest developments in the knowledge of the major bacterial pathogens affecting animals. Particular emphasis will be placed on mechanisms of pathogenesis and host-parasite relationships. Pre: BIOL 4674. (3H,3C).

5034: ENVIRONMENTAL-GENETIC INTERACTIONS ON DISEASE RESISTANCE
Students will explore various factors which determine the animal's response to low to moderate doses of infectious agents and toxins. Among the topics for discussion are genetic makeup, environmental stressors, steroids and disease defense components. Pre: 4024. (2H,2C).

5044 (VM 8064): VETERINARY IMMUNOLOGY
Study of immunological mechanisms effective in protecting animals from infectious and foreign agents. Includes the use of immunological reactions for diagnostic purposes and the role of immune mechanisms in the induction of diseases. (2H,2C).

5054 (VM 8124): VETERINARY VIROLOGY
Study of general virology, e.g. classification, physico-chemical characteristics, replication, recognition of and immune response to members of different virus families. Study of clinical signs, pathology, histopathology, prevention and diagnosis of animal virus diseases by species of animals. Pre: 5044. (2H,2C).

5064 (VM 9154): CLINICAL IMMUNOLOGY
Study of immunodeficiencies (including AIDS), autoimmunities, allergies and other immunologically mediated diseases, principles of immunization, tumor immunology, immunohematology, transplantation immunology, selection of immunologically optimal breeding animals and a review of relevant laboratory tests. The course covers both animal and human diseases.
Pre: VM 8064 or BIOL 4704. (2H,2C).

5074: MOLECULAR BASIS OF INHERITED DISEASES
An introduction to genetics and biochemistry of variant human and animal phenotypes. Analysis and diagnosis of inherited diseases by recombinant DNA methods. HLA complex: genetic polymorphism and disease susceptibility; oncogenes and genetic markers in medicine. Metabolic basis of inherited diseases including dysfunction of carbohydrates, amino acids, organic acids, purines and pyrimidines, lipids, metals, porphyrins, hormones, membrane transport system, immune system and connective tissue. Pre: BCHM 5124. (3H,3C).

5104: CONSERVATION MEDICINE
Facilitates learning and comprehension of complex biological systems in the context of relevant environmental conditions. The Public Health Triad with its three key dimensions: animal health, human health and environmental health, is used as an organizing principle to illustrate their dynamic interrelationships. Information Technology is used to bridge the gaps between the Triad and hands-on experiences with Global Positioning Systems (GPS), Geographic Information Systems (GIS), and Bush-to-Base Bio-Informatics (B2B) as research tools for multidisciplinary data management. Through the process of writing and reviewing mock grant proposals, multi-disciplinary research proposals are designed, written and reviewed. (1H,2L,2C).

5124 (VM 8474): REPRODUCTIVE PATHOLOGY
Study of lesions of the reproductive system of domesticated animals. Relationship of these lesions to infertility and examination of the pathogenesis of the lesions and infertility. Pre: ALS 4304. (1H,1C).

5134: MECHANISMS OF DISEASE
This course is a sequel to VMS 5124 General Pathology. Whereas course VMS 5124 deals with general reaction of tissues to injury, Mechanisms of Disease focuses on the types of host reaction induced by agents of disease in tissues and thereby, the means of diagnosing them. Emphasis is given to the lesions produced. The course has a lecture-tutorial theme. Pre: 5124. (3H,3C).

5144: ONCOLOGY PATHOLOGY
This course presents the pathology of neoplasms of all organ systems by using assigned reading, tutorials, tissue sections and discussion. Emphasis is on the clinical presentation, histologic diagnosis, and prognosis of each neoplasm. Formal lectures are not given. Independent study and twice weekly discussion sessions. DVM degree required. Pre: 5134. (2H,2C).

5154: TOPICS IN VETERINARY CLINICAL PATHOLOGY
Readings and discussion in selected areas of veterinary clinical pathology. Topics will vary and course may be taken for credit more than once. DVM degree required. (1H,1C).

5164: VETERINARY CLINICAL HEMATOLOGY
Advanced course in veterinary clinical hematology. Selected topics dealing with the production, function and cytology of circulating blood cells in normal and diseased states with emphasis on veterinary clinical application. DVM degree required. (3H,3L,4C).

5184 ( ): VETERINARY PATHOLOGY I
Mechanisms of cellular reaction to injury, inflammation, circulatory disturbances, and neoplasia. Emphasizes mechanisms of disease at the level of cells and tissues. (2H,2L,3C).

5194: CLINICAL MICROPATHOLOGY
This course presents practical topics in diagnostic pathology. It covers the entire spectrum of disease processes, including the background of clinical, gross anatomic physiologic information required for integration with the microscopic changes observed to arrive at a correct diagnosis. DVM degree required. (1H,1C).

5204: ADVANCED VETERINARY CYTOLOGY
Advanced course in veterinary cytologic interpretation. Selected cytologic specimens of normal and diseased tissues are examined microscopically, described and interpreted. Course may be taken more than once. (Maximum 4 credits). DVM degree and permission of instructor required. (1H,1C).

5214: PHARMCOLOGY AND TOXICOLOGY TESTING
Procedures and methods used to approve new drugs and chemicals for marketing. Experimental design, practical considerations, legal requirements, evaluation of general and specific toxicology testing methods, risk assessment, and prospects for changes in current testing methods will be covered. Pre: BCHM 4204. (3H,3C).

5224: DISPOSITION OF XENOBIOTICS IN DOMESTIC ANIMALS
General mechanisms involved in the absorption, distribution, metabolism, and excretion of xenobiotics will be presented and discussed. The basic concepts and calculations used in pharmacokinetic modeling will be introduced. Sampling techniques, kinetic based interactions, and standard research techniques in pharmacokinetics will be investigated. (3H,3C).

5234: VETERINARY CLINICAL PHARMACOLOGY AND THERAPEUTICS
Application of the basic pharmacology of modern therapeutic agents to the treatment of animal diseases with emphasis on the effects of the disease being treated, co-existing pathopysiologic abnormalities and species peculiarities on the anticipated response to the agent. DVM degree required. (3H,3C).

5244: VETERINARY PHARMACOLOGY
Principles of pharmacodynamics and pharmacokinetics, including interaction of drugs with receptors; their absorption, distribution and clearance; drug metabolism and drug interactions. Study of drugs by pharmacological classes, their general mechanisms of action, usefulness and side effects. Also, pharmaceutical calculations and prescription writing. (4H,3L,5C).

5254 (VM 8424): VETERINARY TOXICOLOGY
Study of toxic agents, mechanisms and action, toxicoses, and treatments, especially as related to domestic and wild animals. Principles of toxicity testing and clinical diagnosis. Second-year standing in the DVM curriculum is required. Pre: ALS 5304. (2H,2C).

5264 (BCHM 5264): ADVANCED MEDICAL BIOCHEMISTRY
Application of basic principles of biochemical events at the cellular level to study the physiological processes occurring in the whole organism. Examples of deviant biochemical processes in human and animal diseases. Emphasis on physiological regulation, lack of control manifested in patients (diagnosis), and current knowledge in regaining control (therapy). Pre: BCHM 4116 or BCHM 5116. (2H,2C).

5274: SYSTEMS PATHOLOGY
This lecture-only course covers the pathology and pathogenesis of specific lesions and diseases of each organ system at the gross and microscopic level. Emphasis is on diagnostic characteristics and interpretation of diseases. DVM degree required. (3H,3C).

5284: CELLULAR PATHOLOGY
This course presents the mechanisms involved in cellular reaction to injury, inflammation, tissue repair and regeneration, circulatory disturbances (thrombosis, embolism, infarction, hemorrhage, edema, congestion, shock) and neoplasia and other alterations of cell growth. Emphasis will be placed upon disease processes at the cellular and tissue levels. (3H,3C).

5294 (VM 8314): FUNDAMENTALS OF VETERINARY PHARMACOLOGY
General principles of drug action, including dose response, contribution of chemical properties to pharmacokinetics, species differences in response, clinical effects of agonists and antagonists, adverse responses, and comparisons of pharmacodynamics and pharmacokinetics among subtypes of important drug classes. Pre: second-year standing in the DVM curriculum. (3H,3C).

5305,5306 (VM 9095, 9096): VETERINARY ONCOLOGY
These companion courses are designed to provide intensive study of the biology of neoplasms, their diagnosis, clinical presentation and treatment. 5305: Introductory/review lectures: factors in protooncogene mutation, methods of diagnosis, and cancer epidemiology. A second portion of this course discusses important neoplasms of various animal species and body systems, and classical methods of treatment. 5306: In-depth discussion of cancer chemotherapy, immunotherapy, and new advances in therapy such as gene replacement/modification. Pre: third-year standing in the DVM curriculum. 5305: (2H,2C) 5306: (1H,1C).

5314: MEMBRANE PHYSIOLOGY
General topics of membrane physiology. Emphasis on mechanisms involved in the transduction of extracellular signals into physiological changes within the cell. Specific topics include: receptor-agonist interactions, phos-phatidylinositol turnover, changes in the concentrations of intracellular free calcium and/or cyclic AMP, protein kinase C, and prostaglandins. (2H,2C).

5324: GENERAL NEUROCHEMISTRY
Biochemical mechanisms involved in normal and abnormal nervous system function including discussions of experimental techniques, structural components, neurotransmitters, cerebral blood flow and metabolism, sensory systems, learning, mental disorders, and neuropharmacological agents. Pre: BCHM 4116 or BCHM 5124. (3H,3C).

5334: GASTROINTESTINAL PATHOPHYSIOLOGY
Lecture will present in-depth analyses of selected key digestive tract diseases of multiple species. Disesase will be selected to reflect clinical importance, discuss region of digestive tract, and importance of underlying pathophysiologic principles. A multidisciplinary approach will be taken, including physiology, morphology, epidemiology, microbiology, etc. Completion of 1st & 2nd year DVM or completion of a comprehensive physiology course required. (2H,2C).

5344: ADVANCED METHODS IN MACROSCOPIC MORPHOLOGY
A course designed to familiarize graduate students with advanced methodology in the preparation, examination, and quantitative/ qualitative evaluation of research specimens at the gross anatomical level. A “tool kit” for developing solutions to methodologial problems commonly encountered in anatomic research work. Will emphasize actual manipulation and preparation, and requires preparation of a semester project by the student. Pre: ALS 5304 or BIOL 2405. (1H,3L,2C).

5355-5356: REPRODUCTIVE DISEASES AND ENDOCRINE DYSFUNCTION IN DOMESTIC ANIMALS
This course provides advanced graduate level study in the endocrine and reproductive functions and disease processes of domestic animals, utilizing a discussion format of pre-assigned topics from current research and clinical scientific periodicals. Emphasis is on production disease management, clinical diagnosis and therapy. Senior courses in reproduction and endocrinology required. (2H,2C).

5364: ULTRASTRUCTURE METHODOLOGY IN BIOLOGICAL SCIENCES
An introduction to the methodology of transmission electron microscopy as it applies to the life sciences. The goal of the course is to provide students who expect to use ultrastructure as a research tool with the fundamental principles behind the techniques, and hands-on experience in preparing and examining them in the electron microscope. Students prepare tissues and will generate a final project in the form of a journal article. Because of the intensive nature of the laboratory portion, course enrollment is limited to 15 students, and permission of the instructor is required. Pre: BIOL 4504. (2H,3L,3C).

5374: ADVANCED NERVOUS CONTROL OF CARDIOVASCULAR SYSTEM
Advanced course in nervous control of cardiovascular system. Selected topics dealing with autonomic innervation, receptor mechanisms, central and peripheral nervous systems involved in cardiovascular reflexes and in circulatory regulation both normal and pathological states will be considered. Pre: ALS 2304. (3H,3C).

5384: PRINCIPLES AND METHODS IN CARDIOVASCULAR RESEARCH
This course will review theories and techniques that relate to cardiovascular research. Emphasis is placed on classic as well as state-of-the-art laboratory techniques and methodologies. (3H,3C).

5394: EXPERIMENTAL TECHNIQUES AND MANAGEMENT FOR EXPERIMENTAL ANIMAL SURGERY
Graduate level course in the preoperative, operative, and postoperative medical and surgical management of experimental animals used in research. The fundamentals of humane treatment of animals, aseptic technique, anesthesia, surgical instrumentation, draping, suturing, suture materials and patterns, tissue handling, wound healing and specific surgical procedures will be emphasized. Available to non-DVM students only. (3H,4L,4C).

5404: PROSTAGLANDINS IN CARDIOVASCULAR PATHOPHYSIOLOGY
Advanced course in cardiovascular pathophysiology. Selected topics will deal with pathophysiology of arteriosclerosis, thrombosis, myocardial ischemia, abnormal vascular reactivity, and interactions of the eicosanoids with the preceding pathophysiologic conditions will be discussed. Pre: ALS 2304. (3H,3C).

5414: REPRODUCTIVE CELL BIOLOGY
Detailed study of the processes of gamete production, gamete maturation, fertilization, and early embryo pre-implantation development, by analysis of the known molecular changes which gametes and embryos undergo. Emphasis will be on oocyte maturation, sperm capacitation, and embryo development through blastocyst. Extensive use of current literature. Pre: ALS 5314, BCHM 5124. (3H,3C).

5424: MARINE MAMMAL BIOMEDICINE
Survey of the principal adaptive physiologic and morphologic specializations of cetaceans and pinnipeds, principal diseases, and toxicologic and parasitologic responses. An overview of types of marine mammals, evolutionary development and historical biomedical literature will be presented. Echolocation and vocalization, stranding, reproductive biology, diving, macroscopic and microscopic anatomy will be treated. (2H,2C).

5434 (VM 8014): VETERINARY ANATOMY I
Study of the basic structural and functional anatomy of carnivore (dog, cat), horse, and ruminants. Gross morphology is applied to clinical diagnosis, interpretation, surgical and medical treatment. (2H,6L,4C).

5444 (VM 8114): VETERINARY ANATOMY II
Study of the structural and functional anatomy of carnivores (dog, cat), horses, and ruminants. Gross, developmental and radiographic morphology with applications for clinical diagnosis, interpretation, and surgical and medical treatment. Pre: VM 8014 or VMS 5434. (2H,4L,4C).

5454 (VM 8034): VETERINARY PHYSIOLOGY I
Study of physiological functions in companion, food, fiber, laboratory, zoo, and wildlife animal species. Emphasizes fundamentals and the overview of cellular, organ, and regulatory integration. Topics include cells, muscles, blood, respiration, circulation, environmental and regulatory physiology. (2H,2L,3C).

5464 (VM 8134): VETERINARY PHYSIOLOGY II
Study of how living animals function. The central themes include close relationship between structure and function, process of adaptation, and the concepts of homeostasis and feedback control systems. The course focuses on the function of the tissues, organs, and organ systems of multicellular organisms. (4H,4C).

5474 (VM 8104): VETERINARY NEUROBIOLOGY
Normal structure and function of the mammalian nervous system. Basic neuroanatomy, neurophysiology, neurochemistry, and neurohistology of sensory, motor, integrative, and regulatory systems will be discussed, as well as metabolic support systems. (4H,2L,2C).

5485,5486: PATHOPHYSIOLOGY OF LARGE ANIMAL MEDICINE AND SURGERY
The pathophysiology of medical and surgical diseases of large animals will cover alterations in normal physiology during disease. Coverage will include basic physiology, pharmacology, response to injury, response to inflammation and healing of the following systems; 5485: 1) GI system 2) Urogenital system, 3) Cardiopulmonary system including anesthesia, 4) Hemopoietic system; 5486: 1) Musculoskeletal, 2) Nervous, 3) Integumentary. DVM degree required. (2H,2C).

5504: ADVANCED GENERAL SURGERY TOPICS
Advanced course in general veterinary surgery. Consideration of surgical pathology affecting the gastrointestinal, respiratory, urogenital and cardiovascular systems. Emphasis is placed on surgical biology and alterations to normal homeostasis caused by surgical pathology and surgical intervention. DVM degree required. (3H,3C).

5514: MUSCULO-SKELETAL SURGICAL ADVANCED
Myology, arthrology, osteology and biomaterials will be reviewed to provide state of the art information to graduate veterinarians. Research directions and trends will be stressed. Laboratory experience with selected problems. (2H,4L,3C).

5524: VETERINARY CLINICAL NUTRITION CONSULTATION
The Veterinary Clinical Nutrition Consultation course provides graduate students with clinical experience in clinical nutrition of small and large animal species. Students will be assigned clinical consults in nutrition from cases presented to the small and large animal hospital and from field services (AHS and PMM) at the VMTH. The student will be responsible for documenting the consult for the medical records. The student will participate in clinical rounds in the different service areas at the VMTH on a rotational basis. Repeatable with maximum of 6 credits. DVM degree required. (2H,2C).

5534: TOPICS IN ADVANCED SMALL ANIMAL GASTROENTEROLOGY
In-depth study of small animal gastrointestinal medicine. The student will be exposed to both common and uncommon disorders of the gastrointestinal system. Gastrointestinal controversies will be explored. DVM degree required. (3H,3C).

5544 (ALS 5144) (HNFE 5144): MOLECULAR ASPECTS OF NUTRITION AND DISEASE
The role of specific nutrients in human and animal health at a physiologic and molecular level. Emphasis is placed on the influence of nutrients on gene expression especially with regard to pathophysiology of diseases. Physiological and molecular aspects of nutrition and immune function will also be discussed. Pre: BCHM 5124, (ALS 5104 or HNFE 5104). (3H,3C).

5554: ADVANCED SURGERY OF THE SPECIAL SENSES AND SKIN
Conceptual and practical development of surgical principles and progress that have occurred in recent years within these fields. Neurology, ophthalmology, audiology, and dermatology will be considered from a surgical perspective. Current problems and research areas will be reviewed. Laboratory manipulations are used to increase skill levels in these areas. DVM degree required. (2H,3L,3C).

5564 (VM 8534): INTRODUCTION TO CLINICAL RESEARCH
Design of studies in veterinary-related clinical research, planning and implementation of experimental and survey data collection, management and analysis of data, evaluation of analysis and critical evaluation of published information. Instructor approval required. (2H,2C).

5574: ADVANCED POULTRY DISEASES
An advanced course covering diagnosis, etiology, and treatment of poultry diseases. Diseases will be grouped by system affected, their common features detailed, and then unique characteristics of these diseases described. (3H,3C).

5584: CURRENT TOPICS IN CT/MRI
Course is designed for graduate students who need an understanding of computed tomographic and magnetic resonance imaging physics, artifacts, and applications. The course will emphasize critical discussions of relevant veterinary and medical literature. Image reading sessions will be used to illustrate principles learned from lectures and literature discussions. Students registering for this course should have a basic knowledge of radiographic principles, comparative anatomy, and human/animal disease processes. Instructor consent required. Taught even years. (2H,2C).

5594: POULTRY DISEASE: FIELD INVESTIGATION AND DIAGNOSIS
Students and professors will visit commercial poultry flocks experiencing disease problems. Flock history will be recorded, signs and symptoms will be noted, samples taken and processed, information will be analyzed and diagnosis rendered. When appropriate, research needed to solve problems will be conducted. DVM degree required. Variable credit course.

5604: PRINCIPLES AND METHODS IN EQUINE SURGERY
Graduate level course in advanced techniques in equine surgery. Activities include elucidation of pathophysiology, diagnosis, and surgical approach to complex equine conditions including nonroutine cases as they are presented. DVM degree required. Maximum 3 credits. Variable credit course.

5614: PRINCIPLES AND METHODS IN EQUINE INTERNAL MEDICINE
Graduate level course in the application of advanced techniques in equine internal medicine. Activities will include elucidation of pathophysiology, performance of diagnostic methodology, and therapeutic management of complex medical disorders affecting the equine species. Course will be offered at the Marion duPont Scott Equine Medical Center. DVM Degree required. (1H,6L,3C).

5624: CLERKSHIP IN VETERINARY MEDICAL INFORMATICS
Advanced course in informatics where students apply principles of veterinary informatics to a problem area in one of the hospital or service units of the college. A DVM degree required and graduate standing. Variable credit course. Pre: 5774.

5634 (VM 8414): CLIN PATH SM ANIMALS
A case-based course relating abnormal clinical laboratory data to specific organ dysfunctions with emphasis on data interpretation and pathophysiologic mechanisms. Understanding the diagnostic and prognostic value of pertinent laboratory tests as aids in the medical management of clinical cases. Alterations in the hematology, clinical chemistry, urinalysis, and cytology of the small domestic species will be studied. (1H,1C).

5644 (VM 8194): CLIN PATH LG ANIMALS
A case-based course relating abnormal clinical laboratory data to specific organ dysfunctions with emphasis on data interpretation and pathophysiologic mechanisms. Understanding the diagnostic and prognostic value of pertinent laboratory tests as aids in the medical management of clinical cases. Alterations in the hematology, clinical chemistry, urinalysis, and cytology of the major large animal domestic species will be studied. (1H,1C).

5654 (VM 8454): VETERINARY CLINICAL NUTRITION
This course considers the nutritional needs of species of veterinary importance throughout life and for various work-loads and purposes. Nutritional management of diseased or compromised patients is considered. Pre: second-year standing in the DVM curriculum or completion/test-out of VM 8234 or equivalent course. (1H,1C).

5714: BIOMEDICAL LITERATURE
This course deals with searching the literature in Biomedicine, both in printed form as well as computerized bibliographic databases. It also covers the topic of managing personal collection of published materials for effective retrieval. This course is for graduate students enrolled in biomedical research programs. Pass/Fail only. (1H,1C).

5724: AVIAN HISTOPATHOLOGY
The course consists of supervised light microscopic examination of avian tissues by system. After initial description of the basic responses of organ systems to injury, students will be expected to examine additional tissues and correlate lesions with possible etiologies. Histology. Pre: BIOL 4504. (3H,3C).

5734 (VM 8414): CLINICAL PATHOLOGY
The study of relating abnormal clinical laboratory data to specific organ dysfunctions or lesions with emphasis on data interpretation and on understanding the pathophysiologic mechanisms leading to abnormal data. Additional emphasis will be placed on understanding the diagnostic and prognostic value of thoughtfully selecting pertinent laboratory tests to aid in the medical management of clinical cases. Alterations in the hematology, clinical chemistry, urinalysis, and cytology of the major domestic species will be studied. (3H,3C).

5744 (VM 8324): VETERINARY PARASITOLOGY
Study of the morphology and biology of parasites of veterinary importance. Considers pathogenesis, diagnosis, signs, and treatment of parasitic diseases of animals. Study of the immunologic and pathophysiologic aspects of host/parasite relationships and the importance of zoonotic parasitic infections. (2H,2L,3C).

5754 (VM 8334): VETERINARY BACTERIOLOGY AND MYCOLOGY
Study of important bacterial and mycotic agents that cause disease of economic and public health significance in food and fiber, companion, laboratory and zoo/wildlife animal species. Special emphasis is on: habitat, microbial characteristics, virulence attributes, pathogenesis, immunity, approaches to prevention, antimicrobial susceptibility and diagnosis. (3H,3L,4C).

5764 (VM 8494): AQUATIC MEDICINE AND FISH HEALTH
The etiology, diagnosis, pathology, pathogenesis, chemotherapy, control and management of infectious and non-infectious diseases of aquatic organisms, especially pertaining to cultured food and tropical fish. Hands on experience with water quality evaluation, diagnostic techniques and the identification of common pathogenic organisms. Pre: VM 8364 or FIW 4514. (2H,2C).

5774: INTRODUCTION TO VETERINARY MEDICAL INFORMATICS
Introduction to the discipline of veterinary medical informatics. Current themes and medical computing applications applied to veterinary medicine are covered. A DVM degree and graduate standing required. (3H,3C).

5784: VETERINARY MEDICAL DATABASE MANAGEMENT
This course defines the goals, rationale, and components of the medical record database. In so doing, it describes the informatics tools used in modern veterinary medical records management. Special emphasis is on Problem Knowledge Couplers and the computerized Problem Oriented Record. DVM degree and graduate standing required. (3H,3C).

5794: CLINICAL NEUROPATHOLOGY
This course uses necropsy tissues of clinical cases to present the mechanisms involved in neurologic disease of animals. Gross, microscopic, and radiologic approaches will be employed. Emphasis will be placed upon the correlation of clinical and pathological findings. May be repeated. Pre: Instructor's approval required. (1H,1C).

5814 (VM 8254): FUNCTIONAL MORPHOLOGY AND NATURAL HISTORY OF REPTILES AND BIRDS
Anatomical features will be described that are unique to, or are characteristic of each major group covered. Features to be discussed will largely be those that adapt the animal group to its habitat and permit successful exploitation of that habitat; the discussion will extend to how anatomical features and functions are utilized in the life of members of the group. On completion of discussion of pertinent anatomical features, selected attributes of the group's natural history will be covered, as well as a brief survey of members of the group common to the local and extended area. Pre: first-year standing in the DVM curriculum. (1H,1C).

5824 (VM 8264): SMALL ANIMAL NUTRITION
Practical feeding guidelines for companion animals. Special consideration also given to the relationship of diet to nutrient excesses and deficiencies that result in clinical disorders. Diagnosis, treatment, and prevention of metabolic disorders of companion animals will be discussed. (1H,1C).

5834 (VM 8384): FOOD ANIMAL NUTRITION
Practical feeding guidelines for food animals. Special consideration also given to the relationship of diet to nutrient excesses and deficiencies that result in clinical disorders. Diagnosis, treatment, and prevention of metabolic disorders of food animals will be discussed. Pre: VM 8454. (2H,2C).

5844 (VM 8394): EQUINE NUTRITION
The course is designed to provide practical feeding guidelines for different classes of horses. The relationship between nutrition and clinical disorders of the horse is explored including their nutritional management. Students will be expected to complete a problem-solving nutrition project during the course. Pre: VM 8454. (1H,1C).

5854 (VM 8564): DATA MANAGEMENT FOR VETERINARY EPIDEMIOLOGY
Use of computer software in veterinary surveys, outbreak investigations and epidemiological studies for field data collection, compilation, analysis, and graphical representation of results, including geographic information systems. Basic computer literacy beneficial, but not required. Course will utilize the CDC/WHO programs Epi Info and Epi Map. Pre: second-year standing in the DVM curriculum. (1H,1C).

5864 (VM 8754): VETERINARY CARDIORESPIRATORY SYSTEM
This course concentrates on respiratory and cardiovascular diseases of the common domestic species. Emphasis is given on teaching students how to develop a data base for these two body systems using effective communications and modern diagnostic tools. The course focuses on the common diseases of these systems and how these diseases are managed and treated. Pre: second-year standing in the DVM curriculum. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5944: SEMINAR IN VETERINARY MEDICAL SCIENCES
Presentations by graduate students on current topics in Veterinary Medical Science. Topics and responsibility for seminars is rotated among the professional departments of the college. Maximum 4 credits. Pass/Fail only. (1H,1C).

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course. X-grade allowed.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH AND THESIS
Variable credit course.

6014: VETERINARY CLINICAL SCIENCES RESIDENCY
Advanced course with training and instruction in veterinary patient management. Supervised practicum in veterinary diagnosis and therapy in a veterinary teaching hospital. Material will include development of knowledge and skills for problem solving, performance of techniques, and effective communication. Regularly scheduled rounds and conferences will supplement daily activities. 0 credit. DVM degree required. (0C).

6044: ADVANCED MEDICINE LABORATORY
Advanced course in specialized medical diagnostic, therapeutic and monitoring techniques. Selected procedures utilizing specialized equipment and modalities necessary for specialty private or academic clinical practice of internal medicine, anesthesia and certain surgical specialities will be taught. DVM degree required. (1H,3L,2C).

6054: SPECIAL STUDIES IN RADIOLOGY
Course will review selected cases dealing with radiology of the thorax, abdomen, and musculoskeletal system. Special procedures, contrast media, and alternate imaging will be included. DVM degree required. (1H,1C).

6504: GRADUATE RESIDENCY IN THERIOGENOLOGY
Student participation in a planned clinical experience in veterinary medicine under the supervision of a university staff member. Students will be assigned clinical case management in the area of study and will maintain case medical records, clinical disease problem identification and appropriate treatments under the direction and supervision of the on-site course director. The student will participate in and be responsible for delivery of clinical case discussions. (Maximum 12C; 6C per semesters I and II). DVM degree required. (18L,6C).

6514 (VM 8514): EQUINE THERIOGENOLOGY
An advanced study in the breeding management, estrous cycle manipulation, embryo transfer, reproductive disease diagnosis and treatment of the mare and stallion. The didactic work of this course will emphasize the practical application of the latest research covered in this species. Pre: Second-year standing in the DVM curriculum. Pre: (VM 8634) or (ALS 4304. (1H,1C).

6524 (VM 8734): POPULATION MEDICINE
General Principles of herd health/preventive medicine for the major agricultural and pet industries of the United States. Epidemiologic and biometeric principles with emphasis on the development and institution of health programs. Record keeping systems to monitor disease and health in domestic and foreign animal populations will be stressed. Basic skills necessary for diagnosis of diseases in populations of animals with emphasis on establishment of medical records and the mechanics of the physical exam of individuals, populations and the environment. (3H,3L,4C).

6534: MECHANISMS OF DISEASE IN VETERINARY MEDICINE
Advanced study of topics concerning the pathophysiology, diagnosis, and current therapy of diseases in Veterinary Medicine. Pre: DVM or equivalent, or consent of instructor. May be repeated to a maximum of 18 credits. (3H,3C).

6544: ADVANCED SEMINAR IN CLINICAL STUDIES
Presentations by graduate students/residents on current clinical topics in Medicine, Surgery, Theriogenology, Nutrition, Epidemiology, Production Medicine and Pathology. Responsibility for presentations is rotated equally among graduate students/residents in the Virginia-Maryland Regional College of Veterinary Medicine. Pass/Fail only. (1H,1C).

6554 (VM 8684): ADVANCED EPIDEMIOLOGY
This course is intended for students interested in applying analytical epidemiological methods in assessing the health and disease status of populations (animal and/or human) and the factors affecting that status. It will include lecture/discussion sessions and exercises on the design, analysis, and interpretation of clinical trials and cross-sectional, case-control, and longitudinal studies. Risk assessment and techniques for assessing and enhancing the validity of epidemiological studies will also be covered. Pre: third-year standing in the DVM curriculum. (2H,2C).

6564 (VM 9094): ADVANCED VETERINARY PUBLIC HEALTH
Consideration of the organization and delivery of Veterinary Public Services at the local, state, national and international levels including zoonoses surveillance, investigation and response to disease outbreaks, biological warfare and terrorism, response to natural emergencies and disasters, and public health policy formulation. Pre: third-year standing in the DVM curriculum. (1H,1C).

6574 (VM 9214): ANIMALS AND PUBLIC POLICY
Course will examine society's changing attitudes toward the care and use of animals and examine the philosophical spectrum between animal welfare and animal rights. Will explain the role of the major regulatory and accrediting organizations in setting standards of care for animals used in research, exhibition, transportation, and production. Will describe the regulatory process for making policies and regulations to support federal legislation. Will provide information on the currently acceptable standards for the care and use of animals for regulated purposes. Pre: third-year standing in the DVM curriculum. (1H,1C).

6584 (VM 9234): VETERINARY PUBLIC POLICY
Overview of the formulation and implementation of public policy at the local, state, and national level through legislation, regulation, and operational strategy. Understanding of the concepts of legal authority and public mandate. Training in risk communication and media relations. Review of current public policy issues related to veterinary medicine, animal and human health such as food safety, animal disease control, animal welfare, business practices. National leaders will interact with the class to discuss current issues. Pre: third-year standing in the DVM curriculum. (2H,2C).

6594 (VM 9244): INTERNATIONAL VETERINARY MEDICINE
Overview of international veterinary activities. Understanding of the role of governmental agencies, inter-governmental and non-governmental organizations in international relations, development, relief work, conservation, disease control and prevention, and trade. Understanding of the legal authority of binational agreements and international treaties. Training in intercultural communications, negotiation and conflict resolution. Review of current global issues. Pre: third-year standing in the DVM curriculum. (2H,2C).

6704 (BIOL 6704): TOPICS IN IMMUNOLOGY
Readings and discussion in a specific area of immunology. Topic will vary and course may be taken for credit more than once. (3H,3C).

7994: RESEARCH AND DISSERTATION
Variable credit course.

ADVANCED UNDERGRADUATE COURSES (VMS)

The following 4000-level courses have been approved for graduate credit:

4014: ANIMAL DOMESTICATION AND GENETIC RESOURCES
Considers the process, history, sociology and geography of animal domestication. Includes behavioral, physiologic and morphological changes incurred by domesticated stocks. Examines genetic variability of domestic species, considers breed groups and uniquely adapted breeds. Considers reasons for erosion of genetic variability and mechanisms to counteract such erosion. International in scope. Pre: senior status or enrollment in veterinary professional curriculum. (1H,1C).

4024: DISEASES OF POULTRY
Biology control and prevention of poultry diseases. Taught alternate years. (2H,2C).

4034 (BCHM 4034): ENVIRONMENTAL HEALTH TOXICOLOGY
Health effects associated with the exposure to chemicals, identifying and managing problems of chemical exposure in the work places and the environment, fundamental principles of biopharmaceutics and toxicokinetics, and risk assessment. Emphasis on conceptual understanding of chemical entry into the body, biotransformation, or degradation multiple chemical sensitivity, and chemically induced diseases. Indentification of nutrient interactions with environmentally induced disorders and to understand the mechanisms of such interactions and their influence on human health and welfare. Pre: BIOL 2104 or BIOL 3124, ALS 2304 or BIOL 2406 or BCHM 3114. (3H,3C).

4054: LABORATORY ANIMAL MANAGEMENT
This course involves a study of the principles of laboratory animal science, providing the student with a basic understanding of the laws and regulations governing the care and use of animals, husbandry and surgery of a variety of lab animal species, and variables which can adversely affect animal research. Through formal lectures, discussions, and laboratory sessions, the course is designed to complement graduate studies in biological, biomedical, and life sciences which involve the use of animals in research. (2H,3L,3C).

4074: PHARMACOLOGY
A basic course in the science of pharmacology, intended to provide an understanding of the mechanisms of action and physiological systemic effects of major classes of drugs of biological, agricultural, social, and medical importance. Must have prerequisites or equivalent. Pre: CHEM 2514 or CHEM 2535 or ALS 2304 or BIOL 2406. (3H,3C)

4084 (VM 9204): MEDICAL TOXICOLOGY
Adverse health effects of exposure to drugs or substances of abuse. Covers principles of toxicodynamics, toxicokinetics, biotransformation, diagnosis and treatment.Emphasis will be placed on mechanism(s) of action of the various drug classes, body system(s) affected, clinical manifestations of problems and the resulting adverse effects on human health and society.Methods of treatment and client education will also be addressed.Laws controlling and governing the use of these drugs/substances and the agencies responsible for them will also be covered. Pre: third year standing in DVM curriculum. Pre: (CHEM 2514 or CHEM 2535), (BIOL 2406 or ALS 2304), (MATH 1015). (2H,2C).

4974: INDEPENDENT STUDY
Variable credit course.

4984: SPECIAL STUDY
Variable credit course.

4994: UNDERGRADUATE RESEARCH
Variable credit course.

WOMEN'S STUDIES

Bernice Hausman, Director

Professors: K. Allen (Human Development); R. Blieszner (Human Development); C. Burch-Brown (Art); T. Calasanti (Sociology); K. DePauw (Graduate School); G. Downey (Science and Technology Studies); E. Fine (IDST); V. Fowler (English); A. G. Kilkelly (IDST and Theater Arts); J. Rothschild (SPIA)
Associate Professors: C. Burger (IDST); E. Creamer (ELPS); W. Dunaway (SPIA); E. T. Ewing (History); S. Fowler (Graduate Education Development Institute); L. Gillman (IDST); B. Hausman (English); S. Johnson (Foreign Languages & Literatures); K. Jones (History); N. King (IDST); S. Knapp (English); R. Shingles (Political Science); J. Watson (Foreign Languages & Literatures)
Assistant Professors: N. Alexander-Floyd (IDST); A. Baxley (Philosophy); S. Carter-Tod (English); C. Dannenberg (English); S. Halfon (Science and Technology Studies); G. Kao (IDST); M. Mollin (History); E. Plummer (Women's Center Director)

E-mail: ws@vt.edu
Web: www.idst.vt.edu/ws

The Women's Studies Program is housed in the Department of Interdisciplinary Studies but includes faculty from across the entire campus.
The Women's Studies Program offers courses for graduate students pursuing degrees in other disciplines. Graduate Students may take WS courses individually or as part of the WS Graduate Certificate Program. Students enrolled in the program may be either degree-seeking students or non-degree seeking students.

WOMEN'S STUDIES GRADUATE CERTIFICATE PROGRAM

The Graduate Certificate Program in Women's Studies includes a nine-credit sequence of courses and a final project (thesis, dissertation, or other project) focusing on gender, inequality, or feminist perspectives. Women's Studies graduate courses focus on gender, sexuality, race, class, and inequality as categories of analysis and the basis for feminist research in all fields. The curriculum includes courses in theory (Feminist Theory), methodology (Feminist Research Practicum), and pedagogy and academic issues (Feminist Perspectives on Pedagogy and Academe). Those wishing to pursue the Graduate Certificate in Women's Studies should check the Women's Studies website for details and send a letter of interest to the Program Director.

GRADUATE COURSES (WS)

5914: FEMINIST THEORY
This graduate seminar covers the interdisciplinary scholarship aimed at explaining sex-based inequality and examines the gender ideologies that rationalize sex-based inequality. The seminar covers important "classic" texts in feminist theory, the intellectual and political roots of that theory, as well as contemporary texts and debates. Graduate standing required. (3H,3C).

5984: SPECIAL STUDY
Variable credit course. X-grade allowed.

ADVANCED UNDERGRADUATE COURSES (WS)

The following 4000-level course has been approved for graduate credit:

4114: FEMINIST THEORY
An examination of the principal conceptual bases underlying feminist theory across the disciplines. Senior standing required. Pre: 1824. (3H,3C).

4704 (STS 4704): GENDER AND SCIENCE
Investigates the gender dimensions of science in both historical and contemporary perspectives. Discusses feminist studies of science, exploring strengths and limitations. Assesses implications of cultural assumptions about gender for practicing scientists. A 3000 level course in science or engineering may satisfy prerequsite. Pre: 2224 or HST 1504. (3H,3C).

WOOD SCIENCE & FOREST PRODUCTS

Paul M. Winistorfer, Head

Professors: R.J. Bush; A.L. Hammett; F.A. Kamke; D.E. Kline; J.R. Loferski; M.S. White; P.M. Winistorfer
Professor Emeriti: G. Ifju; W.G. Glasser; C. Skaar; F. E. Woeste; R. L. Youngs
Associate Professors: C.E. Frazier; R.L. Smith; A. Zink-Sharp
Assistant Professor: B.H. Bond; J.K. Han; D. P. Hindman; M. Roman
Adjunct Senior Research Scientist: P.A. Araman
Career Advisor: P.M. Winistorfer (231-8853)

[1] Joint with Biological Systems Engineering.

E-mail: garnandd@vt.edu
Web: www.woodscience.vt.edu

The Department of Wood Science and Forest Products administers graduate programs leading to the M.S., M.F. and Ph.D. With the exception of the M.F. program, each graduate student must conduct research, the results of which normally culminate in a M.S. thesis or Ph.D. dissertation. The M.F. program requires a paper and is considered a terminal, professional degree. Graduate research projects are conducted in many areas, including: wood chemistry; wood anatomy and structure; manufacturing systems; wood physics; wood mechanics and engineering; wood-based composites; wood products processing, process control and automation; wood pallet and container design; wood properties; forest product marketing; and wood industry management. Graduates at the M.S., M.F. and Ph.D. levels are of high demand by universities, public and private research organizations, the wood industry and its suppliers.

SPECIAL FACILITIES

The department maintains offices and laboratories in Julian Cheatham Hall and at the Thomas M. Brooks Forest Products Center. In Cheatham Hall, laboratories are dedicated to wood chemistry research and quantitative wood anatomy. The analysis equipment in those laboratories include liquid and gas chromatographs, U.V., I.R. and fourier transform infrared spectrometers, dynamic mechanical thermal analyzer and a scanning electron microscope. A specialized teaching laboratory and offices for graduate assistants are located in Cheatham Hall. The Thomas M. Brooks Forest Products Center is a 35,000 sq. ft. facility dedicated entirely to wood science and technology research. Among the equipment available at the center are a portable sawmill, two dry kilns, a vacuum kiln, five mechanical properties testing machines, environmental chambers and rooms, an image analysis system, computer facilities, a complete composite panel making system, and a pilot-scale steam explosion plant. The department's machine and wood shops and skilled technical support personnel are involved in developing new specialized equipment and systems for graduate student research projects. Graduate student offices also are maintained at the T. M. Brooks Forest Products Center.

SPECIAL DEGREE REQUIREMENTS

Each student must complete a set of core courses or document that equivalent courses have been completed elsewhere. Additional course requirements are determined by the student's graduate advisory committee. All students in the M.S. and Ph.D. programs must conduct research designed by the student in consultation with the committee. A written plan of work is submitted by the candidate for approval. All Ph.D. candidates are required to pass a qualifying examination within a year of residency. A preliminary exam is also administered for each Ph.D. student as required by the Graduate School. Students whose undergraduate degrees are not in the general area of wood science and technology may be required to take undergraduate course which normally do not earn credit toward graduate degrees.

COOPERATIVE ARRANGEMENTS

The department has strong ties with two USDA Forest Service research units. The Southern Research Station, located at the Brooks Forest Products Center, is devoted to tree quality assessment, automated wood processing, non-timber forest products, and solid wood recovery, reuse and recycling research. The mission of the unit is to enhance wood resource conservation and sustainability through advanced timber analysis and wood processing, and effective wood product recovery, reuse, and recycling. Scientists with this program are integrated into the department's processing, process automation, and forest product marketing programs. Scientists with the Northeastern Research Station in nearby Princeton, West Virginia, are involved in departmental programs. In particular, scientists with the Eastern Forest Use in a Global Economy work unit NE-4803 are involved in providing economic, market, and wood-use information that will support health and sustainability of forest-based industries, hardwood forests, and forest communities in the eastern United States. The Efficient Use of the Northern Forest Resource NE-4701 work-unit works toward development of more effective production control methods and computer software that enable the forest industry to more efficiently utilize the hardwood resource. More efficient use of wood resources can help forest industries meet the growing demand for wood products, while curbing the growth rate in demand for timber. Some USDA Forest Service scientists assigned to the above projects are adjunct faculty members of the department and actively participate in graduate teaching and research. The department has close ties and cooperative arrangements with other departments on campus such as marketing, chemistry, chemical engineering, computer science, civil engineering, agricultural engineering, and electrical engineering.

GRADUATE COURSES (WOOD)

5004: FOREST PRODUCTS GRADUATE SEMINAR
Gives graduate students experience in presenting results or reviews of forest products and wood science topics. The course also provides opportunities for students to learn about recent developments in forest products from invited speakers. Pass/Fail only. (1H,1C).

5314: PHYSICAL & MECHANICAL BEHAVIOR OF WOOD
Physical and mechanical properties of wood. Thermodynamics and theories of moisture sorption and measurement. Hygroexpansion. Transport of fluids, heat, and electricity. Orthotropic elasticity and structure. Mechanics of solid wood axial, bending, and torsion elements. Failure mechanisms, rheological behavior, and environmental effects. Pre: 4316. (3H,3L,4C).

5324: TIMBER ENGINEERING
Rationale behind current design procedures for wood structures and components. Advanced topics such as reliability-based design, fracture mechanics, cumulative damage theory, and the effects of a changing resource and technology base. Pre: 5314. (3H,3C).

5414: ADVANCED WOOD CHEMISTRY & STRUCTURE
Structure and ultrastructure of wood. Chemical properties and reactions of tree constituents. Non-destructive methods for wood (and plant) analysis. Description of processes for the selective removal of wood components. Biotechnological applications for wood and biomass. Pre: 3224. (3H,3L,4C).

5614 (FOR 5614): FOREST PRODUCTS MARKETING & MANAGEMENT STRATEGIES
Examination of forest products markets, industry structure, distribution channels, and strategic management trends. Case studies demonstrate the impact of these factors on decision-making in the forest products industry. Pre: 4614 or FOR 3424. (3H,3C).

5894: FINAL EXAMINATION
Pass/Fail only. (3H,3C).

5954: STUDY ABROAD
Variable credit course.

5974: INDEPENDENT STUDY
Pass/Fail only. Variable credit course.

5984: SPECIAL STUDY
Variable credit course.

5994: RESEARCH & THESIS
Variable credit course.

6214: QUANTITATIVE WOOD ANATOMY
Quantitative approach to the characterization of the structure of wood and wood-based materials. Geometrical-statistical relationships for form, size distribution, and spatial distribution of anatomical elements of wood. Principles and applications of stereology and morphometry to wood and wook products. Structure-propety relationships. Pre: 3114, 5414. (2H,3L,3C).

6414: WOOD BIOCHEMISTRY AND BIOTECHNOLOGY
Regulation and biosynthesis of woody plant and other biomass materials. Responses to wounding, decay, and biodegradation. Bioconversion of wood, bark, and foliage constituents. Pre: 5414. (3H,3C).

6424: STRUCTURAL BIOPOLYMERS AND BIOCOMPOSITES
Description of nature's structural polymers and composites. How biomaterials are composed to meet performance needed by by plants and animals. Proteins, polysaccharides, natural rubbers, lignins, and inorganic polymers; pliant and stiff composites; ceramics. Pre: (CHEM 4634, BIOL 1106) or (BCHM 4116). (3H,3C).

7994: RESEARCH AND DISSERTATION

Variable credit course.

ADVANCED UNDERGRADUATE COURSES (WOOD)

The following 4000-level courses have been approved for graduate credit:

4154: COMPUTER APPLICATION SYSTEMS IN FOREST PRODUCTS
Computer control systems with applications in the forest products industry. Survey of systems for gathering, inputting, conditioning, and managing information. Hardware and software systems for computer control applications. Use of information technologies to integrate control subject to raw material, quality, and market fluctuations. Forest products case studies in data acquisition, data analysis, database management production planning, process control, inventory control, and systems specification. Junior standing is required. (2H,3L,3C).

4445-4446: WOOD ADHESION AND COMPOSITES
4445: Introductory polymer science and surface chemistry. Fundamentals of adhesion and fracture in adhesively bonded wood. Industrially significat adhesive systems used for bonding wood with emphasis on wood-based composites. Introduction to wood coatings, formulation, application and weather durability. 4446: Processing of wood-based composites, product design and performance; product testing and standards. Pre: 3434 for 4445; 4445 for 4446. (2H,3L,3C).

APPENDIX I

PREPARATION OF DISSERTATION, THESIS OR MAJOR PAPER

All students must submit their thesis, dissertation, or major paper electronically. Complete instructions are located on the Electronic Thesis and Dissertation (ETD) homepage at http://etd.vt.edu/. Exceptions to this policy must be granted by the graduate dean. Students requesting exceptions should make an appointment and bring a draft copy to Room 314 Sandy Hall for review.

The general requirements for the preparation of theses/dissertations/major papers, as presented herein, pertain primarily to mechanical considerations. The purpose of stipulating such is to provide a degree of uniformity and to assure that each thesis or dissertation is fully legible, and is of value to researchers and scholars reading it.

WHAT IS AN ELECTRONIC THESIS OR DISSERTATION (ETD)?

An ETD is a document that explicates the research or scholarship of a graduate student. It is expressed in a form simultaneously suitable for machine archives and worldwide retrieval. The ETD is *similar* to its paper predecessor. It has figures, tables, footnotes, and references. It has a title page with the author's name, the official name of the university, the degree sought, and the names of the committee members. It documents the author's years of academic commitment. It describes why the work was done, how the research relates to previous work as recorded in the literature, the research methods used, the results, and the interpretation and discussion of the results, and a summary with conclusions.

The ETD is *different*, however. It provides a technologically advanced medium for expressing your ideas. You prepare your ETD using nearly any word processor or document preparation system, incorporating relevant multimedia objects, without the requirement to submit multiple copies on 50 percent cotton bond paper. Consequently, ETDs are less expensive to prepare, consume virtually no library shelf space, and never collect dust. They will be available to anyone that can browse the World Wide Web.

The thesis/dissertation/major paper is a public display of the quality of work acceptable to the student's department and to the university for meeting graduate degree requirements.

It is the responsibility of the student's advisory committee to judge the acceptability of the thesis/dissertation/major paper from all standpoints, including writing quality, neatness, mechanical considerations, and technical and professional competency. Committee members attest to acceptability when they sign the ETD Approval Form. Therefore, it is important that they be provided with a view of the thesis, dissertation, or major paper before the student's defense.

The Graduate School strongly encourages publication of research results, and scholarly inquiry. Graduate students can utilize the traditional format for theses and dissertations or a manuscript format. The format must be acceptable to the departments and to the Graduate School.

For a brief period, the ETD may be limited to university access.

THESIS AND DISSERTATION DOCUMENT DIVISIONS

The thesis or dissertation is divided into front matter, body matter, and back matter.

FRONT MATTER

The front matter contains the following items, in the order each should appear:

TITLE PAGE:

- *Title*–This is the full title of your thesis or dissertation.
- *Author*–You alone are the author of your thesis or dissertation.
- *School*– The official name of the university is "Virginia Polytechnic Institute and State University."
- *Degree*–Usually, this is either "Master of Arts," "Master of Science," "Doctor of Education," or "Doctor of Philosophy."
- *Major*–Put the official graduate program name for your major.
- *Approval names*–These are the members of your committee. List the chair (or chairs) first. Do not include signature lines
- *Date of Defense*–Put the date you defended, e.g. "October 23, 1998."
- *City, State*–Put the city and state in which you defended.
- *Keywords*–Four to six keywords or short key phrases aid the catalogers who provide bibliographic access to your document through the local online catalog (like VTLS at Virginia Tech) and an international database, OCLC. These words will be indexed along with all the words that appear in your title and abstract.
- *Copyright*– In any work, copyright implicitly devolves to the author of that work. One may make this statement of ownership explicit, however, by including a copyright notice, such as "Copyright 1996, Albert J. Kippleby."

ABSTRACT: Each ETD must be accompanied by an abstract that has been approved by the student's committee. Abstracts will be part of the bibliographic record in the library's online catalog: Limit the abstract for a doctoral dissertation to 350 words. Limit the abstract for a master's thesis to 250 words. Additionally, abstracts for dissertations will be published in *Dissertation Abstracts*. Include the thesis/dissertation title and your name above the word Abstract, centered at the top of the abstract page.

GRANT INFORMATION (OPTIONAL): You may acknowledge any granting institution here.

DEDICATION (OPTIONAL): You may provide a dedication.

AUTHOR'S ACKNOWLEDGMENTS (OPTIONAL): Here you may acknowledge those that assisted you in your work.

TABLE OF CONTENTS: Include the chapter and section numbers and title along with the page on which each chapter or section begins.

LISTS OF MULTIMEDIA OBJECTS: For each multimedia type (table, graph, diagram, equation, etc.) list the number and title of the object and the page on which it occurs.

ABBREVIATIONS/SYMBOLS (OPTIONAL): A listing of abbreviations or symbols used in the body of the document

BODY MATTER

There are two permissible overall formats for presenting the thesis or dissertation. They are the traditional and manu–script format.

The body matter for a traditional format contains the chapters of the thesis or dissertation, in logical order, each with its own title. Chapter titles may include:

Introduction
Literature Review
Materials and Methods
Results
Discussion
Conclusions
Summary

The body matter for a manuscript format will vary but generally contains the chapters of the thesis or dissertation, in logical order, each with its own title. Chapter titles may include:

Introduction
Literature Review
Chapters 1…
- Title
- Abstract
- Introduction
- Materials and Methods
- Results
- Discussion

Conclusions
- Overall conclusion
- Data summary
- Overall model if appropriate (text or illustration if appropriate)
- Suggested future investigations

Bibliography
Appendices (if needed)

Consult your department or the Graduate School for specifics.

BACK MATTER

The back matter contains the references (bibliography), and appendices. Students have the option of including their vita.

REFERENCES: Consult your departmental guidelines for the standard forms for citation.

APPENDICES: The student may include the source code or output of computer programs as an enumerated appendix. Place figure references with PDF links to multimedia objects here also.

OPTIONAL VITA: The vita is an autobiographical sketch, based on your academic and professional experience. Include your name (as it appears on the title page), positions held, and degrees earned. You may also mention your family and date of birth.

STYLE

Each department is requested to specify or develop an acceptable style or styles for theses/dissertations/major papers prepared by its graduate students. Generally, the style should conform to the major professional or scientific journals in the student's area of study. If there is available a suitable style manual, such as the Style Manual for Biological Journals or the APA Publication Manual, the department may wish to specify such as being an acceptable style. If a style manual is not available, the department may wish to develop its own or suggest the major journals whose style is acceptable. Students should inquire of their major professor regarding an acceptable style and should become thoroughly familiar with it before they begin preparing their thesis.

Do not use a thesis previously submitted by another student as a style guide. There are many appropriate books that deal specifically with writing style. Among those not specifically limited to style for a particular area are the following: A Manual for Writers of Term Papers, Theses, and Dissertations, by Kate L. Turabian; Form and Style in Thesis Writing, by William G. Campbell; The Elements of Style, by William Strunk, Jr. and E.B. White.

NUMBERING OF PAGES

Except for the title page and abstract, all pages of the thesis, including tables, graphs, figures, photographs, etc. must be numbered. The sections of the thesis should be arranged and numbered in the following order:

1. Title page: Not numbered, but considered as small Roman numeral i.
2. Abstract: Not numbered, but considered as small Roman numeral ii.
3. Dedication: Numbered small Roman numeral iii (plus consecutive small Roman numerals for more than one page of dedication).
4. Acknowledgments: Numbered small Roman numeral iv (plus consecutive small Roman numerals for more than one page of acknowledgments).
5. Table of Contents: Small Roman numerals, continuing from where Acknowledgments ended. All Roman numerals should appear at the bottom of the page.
6. Introductory section: Arabic numerals, starting with 1.
7. Review of literature: Arabic numerals, continuing from Introduction.
8. Materials and methods: Arabic numerals, continuing.
9. Results: Arabic numerals, continuing.
10. Discussion: Arabic numerals, continuing.
11. Conclusions: Arabic numerals, continuing.
12. Summary: Arabic numerals, continuing.
13. Literature cited: Arabic numerals, continuing.
14. Appendix: Arabic numerals, continuing.

Pagination set forth by the Graduate School takes preference over all style manuals.

MULTIMEDIA OBJECTS: FIGURES, TABLES, GRAPHS, AND OTHER ILLUSTRATIONS

Figures and tables may be included in the text or placed on separate pages. If necessary tables and figures may be included in landscape orientation and tables may be more than a single page.

All tables, figures, etc. shall be numbered according to the method specified by the student's major department or used in the major journals whose style is being followed. Each table, figure, graph, or photograph should have a concise descriptive title.

The title (caption) of a table must be placed above **the table**, with footnotes shown at the bottom of the table. Titles (caption) of figures, graphs, and photographs are usually placed on the page **below** the material presented. All tables, figures, graphs, and photographs should be arranged or centered on the page.

Scanned photographs and drawings should be labeled like figures.

The files that comprise the ETD should be in standard formats such as pdf, jpg, avi, wav, and xml.

COPYRIGHTING THESIS OR DISSERTATION

See note under "Copyrighting," Chapter Three.

SUBMISSION OF THESIS AND DISSERTATION

The thesis, dissertation or major paper is submitted using the on–line submission tool (http://etd.vt.edu). Single or multiple PDF files may be submitted. All degree candidates must also submit a completed ETD approval form signed by the advisory committee before the thesis or dissertation will be reviewed and approved by the Graduate School.

APPENDIX II

GRADUATE STUDENT APPEALS

Graduate education is a complex activity involving a high order of student–faculty relationship. It follows that the evaluation of the graduate student's progress is, and must be, dependent in large part on the judgment of the major professor, augmented by the collective judgment of the members of the advisory committee. Of course, the university, through the agency of the Graduate School, can define minimal entrance standards and can prescribe general rules governing eligibility for continuation. But the crucial agency in student evaluation is the department where the student's work is centered, and the crucial evaluator must be the faculty advisor.

It is important, therefore, that each graduate student be fully informed, not only of the university's expectations but of the department's expectations as well. It is incumbent on each department to prepare, in outline form, a statement for each of its graduate degrees. The statement should cover such items as course requirements, the nature and timing of oral and written examinations and the evaluation that will be given to the thesis. A copy of each departmental statement should be on file in the Office of the Graduate School and should be made available to each student at the time of matriculation.

It can safely be assumed that most disputes over evidence of unsatisfactory progress will be informally discussed and reconciled at the departmental level. Indeed, most discussions of this kind will commonly occur among the student, the major professor, and the other members of the advisory committee. Nonetheless, there will from time to time arise serious questions regarding both the status of a graduate student (whether in a given course or as a candidate for the degree) and the basis of the evaluation that has placed his status in jeopardy. On these occasions it is important that the university provide full opportunity for the student's grievance to be reviewed in a judicious manner.

THE DEPARTMENTAL APPEAL

Whenever a graduate student believes that any work has been improperly evaluated, or believes that there has been unfair treatment, it is expected that the student will take up the questions directly with the faculty member involved. This may be the committee chairman, another faculty member, or an instructor responsible for a course. If, after earnest inquiry, the matter remains unreconciled, the graduate student will be expected to appeal the question to the head of his department. If the department head is himself a party to the grievance, the dean of the academic college will assume this responsibility. The department head, in consultation with the academic dean, shall take all reasonable and proper actions to resolve the question at the departmental level. (The Faculty Handbook states "The assigning of grades is the responsibility of the individual instructor in every case. The basis on which grades are assigned rests on his/her judgment alone....") The student shall be informed in writing of the results no later than one month after the appeal to the department head.

THE UNIVERSITY APPEALS PROCEDURE

Should the aggrieved student believe that their rights were abridged at the departmental level, the student may file a request for review with the dean of the Graduate School. In a statement to the dean, the aggrieved student must clearly state the substance of the appeal. The dean of the Graduate School shall take all reasonable and proper actions to resolve the question; if not so resolved, the dean will refer it to the Graduate Appeals Committee for its review. As a standing committee of the Commission on Graduate Studies and Policies, this committee will consist of three faculty members and one student. For each appeal the dean shall appoint to the committee one additional faculty member knowledgeable in the academic area of the appeal.

The review by the Graduate Appeals Committee will have available to it the entire record of the student's work in the university and (a) the department's statement concerning its degree expectations, (b) a summary of the department's action on the appeal, and (c) copies of the student's statement to the dean of the Graduate School recording the students view of alleged irregularities (i.e., the basis for university appeal).

The Graduate Appeals Committee may hold a formal hearing on grievance appeals referred to it by the dean of the Graduate School. The hearing will be conducted with the following procedural safeguards:

1. All parties to the dispute will be notified of the time and place of the hearing at least 48 hours in advance;
2. The aggrieved student will be permitted, if the student chooses, to invite a member of the faculty or student body to represent them in the hearing;
3. All parties in the dispute will be given full opportunity to testify and to present such evidence or witnesses as seem relevant;
4. All matters on which the finding will be based must be introduced into evidence at the hearing.

The committee will file its recommendation with the dean of the Graduate School, who will convey the committee's recommendation and the final disposition of the matter to all concerned parties.

APPENDIX III

CONSTITUTION OF THE GRADUATE HONOR SYSTEM

December 1991
Passed by the University Council

ARTICLE I: PURPOSE AND DESCRIPTION

SECTION 1 - GRADUATE HONOR CODE

The Graduate Honor Code establishes a standard of academic integrity. As such, this code demands a firm adherence to a set of values. In particular, the code is founded on the concept of honesty with respect to the intellectual efforts of oneself and others. Compliance with the Graduate Honor Code requires that *all* graduate students exercise honesty and ethical behavior in all their academic pursuits here at Virginia Tech, whether these undertakings pertain to study, course work, research, extension, or teaching.

It is recognized that the graduate students have very diverse cultural backgrounds. In light of this, the term *ethical behavior* is defined as conforming to accepted professional standards of conduct, such as codes of ethics used by professional societies in the United States to regulate the manner in which their professions are practiced. The knowledge and practice of ethical behavior shall be the full responsibility of the student. Graduate students may, however, consult with their major professors, department heads, International Graduate Student Services, or the Graduate School for further information on what is expected of them.

More specifically, all graduate students, while being affiliated with Virginia Tech, shall abide by the standards established by Virginia Tech, as these are described in this Constitution. Graduate students, in accepting admission, indicate their willingness to subscribe to and be governed by the Graduate Honor Code and acknowledge the right of the University to establish policies and procedures and to take disciplinary action (including suspension or expulsion) when such action is warranted. Ignorance shall be no excuse for actions which violate the integrity of the academic community.

The fundamental beliefs underlying and reflected in the Graduate Honor Code are that (1) to trust in a person is a positive force in making a person worthy of trust, (2) to study, perform research, and teach in an environment that is free from the inconveniences and injustices caused by any form of intellectual dishonesty is a right of every graduate student, and (3) to live by an Honor System, which places a positive emphasis on honesty as a means of protecting this right, is consistent with, and a contribution to, the University's quest for truth.

SECTION 2 - IMPLEMENTATION

The Graduate Honor System was established to implement the Graduate Honor Code, and its functions shall be:

1. To promote honesty and ethical behavior in all academic pursuits, including, but not limited to, study, research, teaching, and extension.
2. To disseminate information concerning the Graduate Honor System to all new graduate students, faculty, and other interested parties.
3. To investigate all suspected violations of the Graduate Honor Code in an impartial, thorough, and unbiased manner.
4. To try all cases involving academic infractions of the Graduate Honor Code brought before the System.
5. To assure that the rights of all involved parties are protected and assure due process in all proceedings.

SECTION 3 - VIOLATIONS

All forms of academic work including, but not limited to, course work, labwork, thesis or dissertation work, research, teaching, and extension performed by any graduate student enrolled on a part–time or full–time basis under any of the admission categories listed in the Virginia Tech Graduate Catalog shall be subject to the stipulations of the Graduate Honor Code. Violations of the Graduate Honor Code are categorized as follows: Cheating, Plagiarism, Falsification, and Academic Sabotage. Violations are defined as follows:

1. *Cheating:* Cheating is defined as the giving or receiving of any unauthorized aid, assistance, or unfair advantage in any form of academic work. Cheating applies to the products of all forms of academic work. These products include, but are not limited to, in–class tests, take–home tests, lab assignments, problem sets, term papers, research projects, theses, dissertations, preliminary and qualifying examinations given for the fulfillment of graduate degrees, or any other work assigned by an instructor or professor, graduate committee, or department that pertains to graduate work or degrees.

   Any student giving or receiving unauthorized information concerning a test, quiz, or examination shall be guilty of an Honor Code violation. Submitting work that counts towards the student's grade or degree which is not the sole product of that student's individual effort shall be considered cheating, unless, for example, the professor explicitly allows group work, use of out–of–class materials, or other forms of collective or cooperative efforts. In general, all academic work shall be done in accordance with the requirements specified by the instructor or professor. In the absence of specific allowances or instructions by the professor, students shall assume that all work must be done individually.

   Some uses of permanently returned, graded material ("koofers") are cheating violations of the Code. By permanently returning graded materials, a faculty member or instructor demonstrates the intent that these materials should be accessible to all students. Such materials may be used for study purposes, such as preparing for tests or other assignments, and other uses explicitly allowed by the professor or course instructor. Once test questions have been handed out, koofers may not be used. Other specific examples of the illegal use of koofers include, but are not limited to, using koofers during closed–book exams, handing in any type of copy (e.g., a photocopy or a transcribed copy) of someone else's work (partial or complete) from a previous term, and copying a current answer key or one that was

handed out in a previous term. Students may not copy and hand in as their own work answers taken from any kind of koofer. When in doubt of what may or may not be used, students should consult with the course instructor. In the absence of specific instructions concerning koofers from the instructor, students shall assume that all submitted work must be the product of their own efforts.

2. *Plagiarism:* Plagiarism is a specific form of cheating, and is defined as the copying of the language, structure, idea, and/or thoughts of another and claiming or attempting to imply that it is one's own original work. It also includes the omitting of quotation marks when references are copied directly, improper paraphrasing (see Appendix IIIa), or inadequate referencing of sources. Sources used in preparing assignments for classes, theses, dissertations, manuscripts for publication, and other academic work should be documented in the text and in a reference list, or as directed by the instructor or professor. Sources requiring referencing include, but are not limited to, information received from other persons that would not normally be considered common knowledge (Appendix IIIa), computer programs designed or written by another person, experimental data collected by someone else, graded permanently–returned materials such as term papers or other out–of–class assignments (koofers), as well as published sources. A more detailed discussion of plagiarism may be found in Appendix IIIa.

3. *Falsification:* Students who falsify, orally, in writing, or via electronic media, any circumstance relevant to their academic work shall be guilty of a violation of this Code. Included are such actions as forgery of official signatures, tampering with official records or documents, fraudulently adding or deleting information on academic documents, fraudulently changing an examination or testing period or due date of an assignment, and the unauthorized accessing of someone else's computer account or files. Violations also include willfully giving an improper grade or neglecting to properly grade submitted material, improperly influencing the results of course evaluations, and knowingly including false data or results in any paper or report submitted for a grade, as a degree requirement, or for publication.

4. *Academic Sabotage:* Academic sabotage is purposeful vandalism directed against any academic endeavor or equipment. It includes, but is not limited to, the destruction or theft of written material, laboratory or field experiments, equipment used in teaching or research, or computer files or programs. Unauthorized tampering with computer programs or systems shall constitute a violation. Academic sabotage includes deliberately crashing or attempting to crash a computer system or the use of files intended to cause or actually causing computer systems to behave atypically, thereby impeding another person's or group's efforts. In particular, knowingly infecting any system with a virus, worm, time bomb, trap door, Trojan horse, or any other kind of invasive program shall be considered a serious violation. Note that violations under this category may also lead to University judicial action or to criminal suits charged by the University.

Misconduct in research and teaching deserves special mention in the Code since it is an area of special interest to graduate students. It is not a separate violation category since it may involve cheating, plagiarism, falsification, and/or academic sabotage as discussed above. *Misconduct in research* does not include those factors intrinsic to the process of research, such as honest error, conflicting data, or differences in interpretation concerning data or experimental design. Likewise, *misconduct in teaching* does not include honest disagreement over the method of presentation of instructional material to a class or in the evaluation of the performance of a student.

* For further information on *misconduct in research* and its definition, see the references listed under item 4 of *1991 Revision–Reference Material Used.*

SECTION 4 - COMPOSITION

The Graduate Honor System shall consist of an Advisor, a Chief Justice, one or more Investigators, an Investigative Board, and a Judicial Panel. The Dean (or designee) of the Graduate School shall be responsible for the continued operation of the System. Appointment of Graduate Honor System personnel shall be made in accordance with Article IX, Section 7.

ARTICLE II: GENERAL ADMINISTRATION

SECTION 1 - APPOINTMENT OF THE GRADUATE HONOR SYSTEM ADVISOR

A member of the staff of the Dean of the Graduate School shall be appointed by the President to serve as the Graduate Honor System Advisor. The Advisor shall serve in an advisory capacity to the Chief Justice and shall be present (or represented) at all hearings of both the Investigative Board and the Judicial Panel.

SECTION 2 - DUTIES AND FUNCTIONS OF THE ADVISOR

The following duties and functions shall be performed by the Advisor:

1. The Advisor shall have the responsibility to train the Chief Justice, Investigators, and new board and panel members.

2. The Advisor shall provide counsel to the Chief Justice and Investigators in the preparation of cases.

3. The Advisor shall provide staff for handling training sessions, scheduling meetings, and other matters related to the administration of the Graduate Honor System.

4. The Advisor shall counsel faculty or students referring cases as well as those students charged with offenses.

5. The Advisor (or designee) shall attend all hearings.

6. The Advisor, in consultation with the Chief Justice, shall be responsible for appointing the Investigators.

7. The Advisor, upon the receiving the recommendation of the Chief Justice, shall be responsible for approving the membership of the Investigative Board and Judicial Panel.

SECTION 3 - APPOINTMENT OF THE CHIEF JUSTICE

1. Nominations for the position of Chief Justice shall be accepted from the Graduate Student Assembly, College Deans, and other members of the academic community, and applications by qualified persons shall be welcomed. Candidates for the position of Chief Justice must be graduate students in good standing and must have been in residence for at least one (1) semester immediately preceding nomination. Preferably, the nominee will have served as an Investigator or as a graduate student panel member of the Graduate Honor Court for at least one (1) semester prior to appointment.

2. The term of office shall be one (1) year, but if available and willing, the current Chief Justice may be reappointed by the President of the University to serve subsequent terms, up to four (4) years, upon the recommendation of the Graduate Honor System Advisor.

3. The Chief Justice Nominating Committee shall be convened by the Dean upon the resignation of the current Chief Justice, upon completion of term of office, or upon termination of office. This committee shall consist of the Graduate Honor System Advisor (Chair), up to three (3) graduate student members of the Graduate Honor System, and one (1) faculty member having previously served on the Judicial Panel and appointed by the Dean of the Graduate School. All members shall have equal voting privileges. The function of this committee shall be to nominate a candidate for appointment by the President. The nomination process shall be: (1) to invite nominations and accept applications, (2) to review applications and conduct interviews with applicants, and (3) to recommend to the President of the University from among these applicants a nominee for the position of Chief Justice. The recommendation of this committee shall be by majority vote.

4. The recommendation of the nominating committee is voted on by the Graduate Student Assembly and the Commission on Graduate Studies.

5. Dean of the Graduate School will forward the nomination to the President conveying the vote of the GSA and CGS.

6. The President shall appoint the Chief Justice.

7. In the absence of a timely appointment, the President through the recommendation of the Dean, can appoint the nominee as an interim Chief Justice until the conclusion of the appointment process.

SECTION 4 - DUTIES AND FUNCTIONS OF THE CHIEF JUSTICE

The Chief Justice shall perform the following duties and functions:

1. The Chief Justice shall receive violation reports and assign cases to the Investigative Board.

2. The Chief Justice shall preside at all Judicial Panel hearings. The Chief Justice may request a member of the Judicial Panel to preside in his or her place.

3. The Chief Justice shall assure justice, fairness, and due process.

4. The Chief Justice shall secure nominations and select graduate student and faculty members of the Investigative Board and Judicial Panel, subject to approval by the Graduate Honor System Advisor.

5. The Chief Justice shall assume responsibility for the instruction and training of graduate student and faculty members in the operation, function, and responsibility of the Graduate Honor System.

6. The Chief Justice shall orient entering graduate students and new faculty to the values and obligations of the Graduate Honor Code.

7. The Chief Justice shall conduct information activities.

8. The Chief Justice shall coordinate activities of the Graduate Honor System.

9. The Chief Justice shall administer the operation of the Graduate Honor System throughout the entire calendar year.

10. The Chief Justice shall keep the graduate community apprised of relevant activities of the Graduate Honor System.

11. The Chief Justice shall consult with the Graduate Honor System Advisor in the appointment of the Investigators.

12. The Chief Justice shall select the Judicial Panel subcommittees to hear the cases.

SECTION 5 - STAFF OF THE CHIEF JUSTICE

The Chief Justice, with the approval of the Graduate Honor System Advisor, shall appoint sufficient staff to assist with the duties of the office.

SECTION 6 - APPOINTMENT OF INVESTIGATORS

1. The Graduate Honor System Advisor, in consultation with the Chief Justice, shall appoint one or more Investigators. Nominations for this position shall be accepted from the Graduate Student Assembly, College Deans, and other members of the academic community; and applications from qualified personnel shall be welcomed. Members of the Investigative Panel will be invited to apply. Students being considered for Investigator positions must be graduate students in good

standing and must have been in residence for at least one (1) semester immediately preceding appointment. Preferably, the nominee will have served as a graduate student panel member of the Graduate Honor System for at least one (1) semester prior to the appointment. Investigators shall serve a one (1) year term but may be re–appointed to serve subsequent terms, up to four (4) years, if available and willing.

2. The appointment of the new Investigator(s) shall be made upon the resignation of the current Investigator(s), upon completion of term of office, or upon termination of office.

SECTION 7 - DUTIES OF INVESTIGATORS

Investigators shall perform the following duties:

1. Investigators shall gather evidence and conduct interviews with the referrer and the accused student(s).

2. Investigators shall prepare a brief report summarizing the evidence for review by the Investigative Board.

3. Investigators shall select the Investigative Board subcommittee for reviewing the evidence.

4. Investigators shall convene and chair Investigative Board meetings.

5. Investigators shall prepare a brief report for the Chief Justice which summarizes the decision of the Investigative Board and shall brief the Chief Justice on all the details of the case at hand.

6. Investigators shall present the evidence before the Judicial Panel.

7. Investigators shall aid the Chief Justice in convening and conducting training sessions for Investigative Board members.

ARTICLE III: INVESTIGATIVE BOARD

SECTION 1 - COMPOSITION

1. The Investigative Board shall consist of a minimum of one (1) graduate student from each College, a minimum of one (1) faculty member from each College, one or more Investigators, and the Graduate Honor System Advisor.

2. Student members shall be selected by the Chief Justice upon consultation with the College Deans and the Graduate Student Assembly and shall be approved by the Graduate Honor System Advisor. The term of office shall be one (1) year, beginning during the Fall Semester. If available and willing, students may be re–appointed to serve subsequent terms, up to four (4) years.

3. Faculty members shall be selected by the Chief Justice upon consultation with the College Deans and shall be approved by the Graduate Honor System Advisor. The term of office shall be two (2) years, beginning during the Fall Semester. If available and willing, faculty may be re–appointed to serve subsequent terms, up to four (4) years.

4. Graduate student members of the Investigative Board shall have full voting privileges, whereas the faculty members shall serve in an advisor capacity to the student members and shall not have voting privileges.

5. The Investigators (or designees) shall chair Investigative Board meetings and shall not have voting privileges.

6. The Graduate Honor System Advisor shall be a non–voting member and shall serve in an advisory capacity to the Investigator and the Investigative Board.

SECTION 2 - FUNCTIONS OF THE INVESTIGATIVE BOARD

The Investigative Board shall perform the following functions:

1. It shall gather and evaluate evidence.

2. It shall decide whether a hearing before the Judicial Panel should be held.

3. It shall select an individual from its membership to present the evidence before the Judicial Panel. This normally will be the Investigator, but it may be any member present at the Investigative Board meeting.

SECTION 3 - OPERATION

1. For each case, a hearing shall be conducted by a subcommittee of the Investigative Board, consisting of a minimum of five (5) graduate students and at least two (2) faculty members, to be selected by the Investigator. The Investigator shall serve as chair. In addition, the Graduate Honor System Advisor shall be a non–voting member and shall serve in an advisory capacity to the Investigator and the Investigative Board.

2. Investigations shall adhere to the basic tenets of due process for an academic honor violation as outlined in *University Policies for Student Life.**

3. A decision to send the case to the Judicial Panel should be based upon substantive evidence to support the charge. The lack of such evidence should lead the Investigative Board to vote against sending the case to the Judicial Panel and consequently lead to the termination of the proceedings. Otherwise, the Investigative Board should send the case forward for the further scrutiny of the Judicial Panel. The fact that the case is forwarded to the Judicial Panel shall in no way imply guilt; the Investigative Board is simply stating that the case should be reviewed with the aid of personal testimonies.

4. The student members shall have full voting privileges while the faculty members serve in an advisory capacity. Recommendations of the Investigative Board must be by majority vote of the graduate student members present. In the event of a tie vote, the case will go forward.

* "Provisions for Due Process," Section VI–The University Judicial System, *University Policies for Student Life*, Virginia Tech (1990–91), p. 37.

ARTICLE IV: JUDICIAL PANEL

SECTION 1 - COMPOSITION

1. The Judicial Panel shall consist of a minimum of one (1) graduate student from each College, a minimum of one (1) faculty member from each College, the Chief Justice, and the Graduate Honor System Advisor.

2. Graduate student members shall be selected by the Chief Justice upon consultation with the College Deans and the Graduate Student Assembly and shall be approved by the Graduate Honor System Advisor. The term of office shall be one (1) year, beginning during the Fall Semester. If available and willing, students may be re–appointed to serve subsequent terms, up to four (4) years.

3. Faculty members shall be selected by the Chief Justice upon consultation with the College Deans and shall be approved by the Graduate Honor System Advisor. The term of office shall be two (2) years, beginning during the Fall Semester. If available and willing, faculty may be reappointed to serve subsequent terms, up to four (4) years.

4. Both graduate student and faculty members of the Judicial Panel shall have full voting rights.

5. The Chief Justice (or designee) shall be a non–voting member and shall serve as the panel moderator.

6. The Graduate Honor System Advisor shall be a non–voting member and shall serve in an advisory capacity to the Chief Justice and the Judicial Panel.

SECTION 2 - FUNCTIONS OF THE JUDICIAL PANEL

The Judicial Panel shall perform the following functions:

1. It shall hear evidence gathered by the Investigative Board.

2. It shall hear testimony of the referrer, accused, and witnesses.

3. It shall hear the remarks of the University community representative of the accused.

4. It shall assure that the rights of the accused and the referrer are protected and assure due process.

5. It shall determine guilt or innocence.

6. It shall recommend the penalty when the accused is determined to be guilty of the charge.

SECTION 3 - OPERATION

1. For each case, a hearing shall be conducted by a subcommittee of the Judicial Panel, consisting of the Chief Justice, a minimum of four (4) graduate students, a minimum of three (3) faculty members, and the Graduate Honor System Advisor. The number of voting faculty shall not exceed the number of voting graduate students present. The graduate students and faculty members shall be selected by the Chief Justice with the approval of the Graduate Honor System Advisor. Each graduate student and faculty member shall have full voting privileges, while the Chief Justice (or designee) shall be a non–voting member and shall serve as the moderator of the hearing. In addition, the Graduate Honor System Advisor shall be a non–voting member and shall serve in an advisory capacity to the Chief Justice and the Judicial Panel.

2. All Judicial Panel hearings shall adhere to the basic tenets of due process of an academic honor violation as outlined in *University Policies for Student Life.*

3. All persons involved with the hearing have the right to be treated with respect. Persons displaying disrespect for another person at the hearing or contempt for the proceedings shall be dismissed, and the hearing shall be concluded in their absence.

4. All evidence regarding cases should be submitted to the Investigators during the investigation and interviewing process (prior to the Investigative Board meeting). If additional information is submitted after the case is sent forward by the Investigative Board, the Judicial Panel will decide the relevancy of that information.

5. The accused must be adjudged guilty before any consideration is given to the penalty, unless the accused pleads guilty, in which case the deliberations shall focus solely on the penalty.

6. In evaluating evidence and testimony regarding guilt or innocence, each member of the Judicial Panel shall consider whether or not there exists substantive evidence of guilt. The verdict of guilt or innocence shall be determined solely on the basis of the facts regarding the charge, i.e., based on evidence collected and testimony presented at the Judicial Panel hearing.

7. At the conclusion of the deliberations on guilt or innocence for each charge against the student the Chief Justice shall poll the members of the Panel on the question: "Is the student guilty of the alleged violation?" An affirmative vote represents "guilty," while a negative vote represents "not guilty." A determination of guilt shall require a majority vote. In the absence of such a vote, the Panel shall be deemed to have found the student "not guilty." An abstention shall not be counted as a vote. In the unlikely event that a majority of the Judicial Panel members do not vote, then the current panel shall be dismissed and a new panel shall be convened to re–hear the case.

8. In determining the appropriate sanction, such factors as the accused student's past history of violations, attitude, intent, severity of the violation, and the degree of cooperation may be considered.

9. Recommendations of penalty shall be by majority vote. An abstention shall not be counted as a vote.

10. A taped recording of the proceedings, the confidential recommendations of the Judicial Panel, together with all submitted evidence and votes recorded, shall be held in the Chief Justice's confidential file. The Chief Justice shall inform the Dean of the Graduate School (or designee), in writing, of the findings and recommendations of the Judicial Panel.

ARTICLE V: UNIVERSITY ACTION

SECTION 1 - REVIEW AND DECISION

1. The recommendations (verdict, and penalty if required) of the Judicial Panel shall be submitted in writing by the Chief Justice to the Dean of the Graduate School (or designee) for review and decision.

2. No penalty shall be announced until an official decision shall have been rendered by the Dean of the Graduate School (or designee).

3. The official decision of the Dean of the Graduate School (or designee) shall be transmitted in writing to the accused, the referrer, and the course instructor (or major professor for a research-related violation). The accused shall also be notified of the right to appeal the decision.

4. When the Judicial Panel's recommendation is not accepted by the Dean (or designee), the Panel shall be notified of the final decision of the Dean (or designee).

SECTION 2 - APPEALS

1. The accused may appeal the official decision to the Dean of the Graduate School on grounds of (1) failure of the Graduate Honor System to follow proper procedures, (2) introduction of new evidence, and/or (3) severity of the penalty. The imposition of the penalty shall be deferred until the termination of the appeals process.

2. The Dean of the Graduate School must be notified of an intention to appeal within seven (7) calendar days after the accused receives written notification of the verdict and penalty.

3. In the event of an appeal, the Dean of the Graduate School (or designee) shall convene an Appeals Board. The Board shall consist of two (2) members [one (1) graduate student and one (1) faculty] from the Commission on Graduate Studies and Policies and one (1) faculty and one (1) graduate student representative selected at large. The members of the Appeals Board shall be appointed by the Dean of the Graduate School. When convened, the Board shall serve in an advisory capacity and the Dean of the Graduate School shall preside.

4. The accused and the University community representative of the accused may present the argument of the defense before the Appeals Board. The case of the Graduate Honor System shall be presented by one (1) graduate student and one (1) faculty member, both selected by the Chief Justice, who were members of the Judicial Panel that considered the case. The Chief Justice and the Graduate Honor System Advisor shall normally present the case findings of the Graduate Honor System.

5. The appeals hearing is not a retrial and must be focused soley upon one or more of the following: (1) failure of the Graduate Honor System to follow proper procedures, (2) introduction of new evidence, (3) severity of penalty. The hearing shall be limited to the consideration of the specific information pertaining to one or more of the above. The burden shall be placed on the appealing student to demonstrate why the original finding or sanction should be changed.

6. The decision of the appeals committee is limited to grounds of the appeal. Judgments are made according to the following guidelines:

a. *Failure of the Graduate Honor System to Follow Proper Procedures*
Determine whether or not the Graduate Honor System followed proper procedures. If proper procedures were followed, then the official decision is enforced. If proper procedures were not followed, then the student is acquitted and the case is closed.

b. *Introduction of New Evidence*
Determine whether or not the new evidence is relevant to the official decision. In the event that the information is determined to be relevant, the appeals board would request a new judicial panel hearing with no members from a previous panel. If information is determined to be irrelevant, then the official decision is upheld.

c. *Severity of Penalty*
Determine if the penalty is too severe for the violations of which the student was found guilty. The finding of guilt is not appealable and the case will not be retried. In the event that the penalty is found to be too severe, a lower penalty may be given from those specified under Article VI of this Constitution.

7. The final determination of an appeal shall be the sole responsibility of the Dean (or designee) of the Graduate School. The student shall be notified in writing of the disposition of the appeal.

ARTICLE VI: ACTIONS OF THE GRADUATE HONOR SYSTEM

SECTION 1 - PENALTIES

Where guilt is determined, the Judicial Panel shall also be responsible for determining an appropriate sanction. There are four major penalty levels (1–4) with increasing severity. These penalties are (1) Graduate Honor System Probation, (2) Suspension in Abeyance, (3) Suspension, and (4) Permanent Dismissal. For each charge of a Graduate Honor Code violation for which a student is found (or pleads) guilty, one of these four penalties must be given.

For those cases where suspension or dismissal is not warranted, the subparts of penalty 1 (Graduate Honor System Probation) provide a further gradation in the penalty action. Whereas penalties 2, 3, and 4 must be given as a whole (i.e., no parts may be given without the others), penalty 1 may be given in part or in full. However, *if penalty*

1 is selected, parts a and b must always be given. Only parts c–g of penalty 1 shall be optional. The very minimum penalty given shall be penalty 1, parts a and b.

1. GRADUATE HONOR SYSTEM PROBATION (parts a and b mandatory, parts c–g optional)

a. The accused shall not be suspended from the University, but shall be placed on Graduate Honor System Probation until graduation or termination of enrollment. The sentence of Probation is a warning and is intended to serve as a deterrent against future misconduct. In the event of any other University or Graduate Honor Code violation, the appropriate parties shall be notified of the previous history of the accused. In the event of resignation and re–enrollment within a period of one (1) year, the accused shall be reinstated on Graduate Honor System Probation (penalty 1, part a only) subsequent to re–enrollment.

b. The accused shall also automatically receive a zero on the assignment on which the violation occurred. In cases other than those involving coursework (or other similar work where a zero is applicable), action shall be taken to negate any advantages obtained by the violation.

c. A record of the action shall be kept in the accused's folder (*not* the official transcript) in the Office of the Registrar until graduation from the University or termination of enrollment.

d. The accused shall be required to attend a meeting or meetings with the Chief Justice and the Dean of the Graduate School for the purpose of achieving a better understanding on the students part of the requirements and purpose of the Graduate Honor System. Failure to participate in this meeting(s) shall constitute grounds for the *automatic* invocation of part "f" below.

e. The accused may be sanctioned to perform an appropriate number of hours (not to exceed 50) of service to the home academic department or other appropriate entities within the university. Failure to perform this service as specified by the Graduate Honor System shall constitute grounds for the *automatic* invocation of part "f" below.

f. The notation "placed on Graduate Honor System Probation" shall appear on the student's permanent record (transcript) under the semester in which the violation occurred.

g. If substantial unfair academic advantage was gained, that is to say, if the violation, undetected, would have led to a substantial grade advantage over the other students (or if the accused thought it would), then a grade of "F for violation of the Graduate Honor Code" for the course in which the offense occurred shall also be a penalty action under this part. This grade shall appear on the student's grade report and permanent record (transcript) as an "F*", and it shall be a permanent notation.

2. SUSPENSION IN ABEYANCE (all parts mandatory)

a. The accused shall be allowed to remain in the University to complete the semester in which the offense occurred or in which the hearing is held.

b. The penalty shall automatically include a grade of "F for violation of the Graduate Honor Code" for the course (or equivalent) in which the offense occurred. This grade shall appear on the student's grade report and permanent record (transcript) as an "F*", and it shall be a permanent notation.

c. After the completion of the semester as specified in item (a) above, the accused shall be suspended for a period not to exceed two (2) successive semesters or one (1) full academic year as specified by the official notification of the University action (as specified under Article V, Section 1, item 3 of this Constitution).

d. The notation "suspended for violation of the Graduate Honor Code" shall appear on the student's permanent record (transcript) under the semester in which the violation occurred.

e. Upon the accused's re–enrollment at Virginia Tech at the end of the period of suspension, the student shall be placed on Graduate Honor System Probation (penalty 1, part a only) until graduation or termination of enrollment.

3. SUSPENSION (all parts mandatory)

a. Suspension is immediate and the student shall not be allowed to complete the current semester. In addition, the accused shall be suspended for a period not to exceed two (2) successive academic semesters or one (1) full academic year following the current semester (as specified under Article V, Section 1, item 3 of this Constitution).

b. All credits shall be lost for work done during the semester in which the student is currently enrolled. The penalty shall automatically include a grade of "F for violation of the Graduate Honor Code" for the course (or equivalent) in which the offense occurred. This grade shall appear on the student's grade report and permanent record (transcript) as an "F*", and it shall be a permanent notation.

c. The notation "suspended for violation of the Graduate Honor Code" shall appear on the student's permanent record (transcript) under the semester in which the violation occurred.

d. Upon the accused's re–enrollment at Virginia Tech at the end of the period of suspension, the student shall be placed on Graduate Honor System Probation (penalty 1, part a only) until graduation or termination of enrollment.

4. PERMANENT DISMISSAL (all parts mandatory)

a. The accused shall be permanently dismissed from the University without being allowed to complete the current semester.

b. All credits shall be lost for work done during the semester in which the student is currently enrolled. In addition, if the offense did not occur during the semester in which the hearing is held, then a grade of "F for violation of the Graduate Honor Code" shall also be assigned for the course in which the offense was committed. This grade shall appear on the student's grade report and permanent record (transcript) as an "F*", and it shall be a permanent notation.

c. The accused may never re–enroll in the University.

d. The notation "permanently dismissed for violation of the Graduate Honor Code" shall appear on the student's permanent record (transcript) under the semester in which the violation occurred.

SECTION 2 - ACQUITTAL

In the event of acquittal by the Graduate Honor System, all records of any description in conjunction with the trial shall be completely destroyed, except the "charges" and the "Findings of the System," which shall be filed in the Chief Justice's confidential file.

SECTION 3 - ANNOUNCEMENT

1. In cases where students are found (or plead) guilty, the penalty and specifications may be published without names when the case is resolved in such media as the *Collegiate Times,* the *Preston Journal,* the *Spectrum*, and the *Apex*.

2. Exonerations may also be published (without names) if the accused so desires. A written release must be obtained from the accused prior to publication.

ARTICLE VII: RIGHTS AND OBLIGATIONS OF THE ACCUSED

SECTION 1 - RIGHTS OF THE ACCUSED

A student accused of violating the Graduate Honor Code shall have certain procedural guarantees to ensure fair judicial hearing of evidence. These rights under the Graduate Honor Code shall be as follows:

1. Students shall be considered innocent until judged guilty.

2. Students shall have the right to refrain from speaking for or against themselves.

3. Students shall have the right to speak in their own behalf.

4. Students may choose a member of the university community, such as a fellow student, faculty member, or staff member who is willing to assist them in preparing their defense. The student's representative shall only be allowed to address the Judicial Panel; they may not question witnesses. Lawyers retained by accused students shall not be permitted in Judicial Panel hearings.

5. Students may at any time privately seek counsel with their university community representative. Statements made at this time shall be confidential.

6. Students may have any Graduate Honor System function that they are entitled to attend stopped at any time for a point of clarification.

7. Students may leave any Graduate Honor System function at any time; however, it is in their best interest to remain until they are made aware of all the details.

8. Students shall have the right to receive written notice of the charges, the "Order of Events for Judicial Panel Hearings," and any other pertinent information sufficiently in advance of the Judicial Panel hearing and in reasonable enough detail to allow them to prepare a case in their behalf. Likewise, students shall have the right to examine all evidence collected during the investigation prior to the Judicial Panel hearing. The students and their representatives shall have a copy of the evidence during the Judicial Panel hearing.

9. Students shall have the right to be aware of all testimony.

10. Students shall have the right to face the referrer, when such opportunity exists, at the Judicial Panel hearing and to present a defense against the charges, including presenting witnesses on their behalf. Consequently, students shall be consulted in the scheduling of the Judicial Panel hearing. However, students shall only be allowed to reschedule the Judicial Panel hearing once. Except under extenuating circumstances, Judicial Panel hearings shall not be rescheduled unless the Chief Justice or the Graduate Honor System Advisor is notified of the requested change prior to three (3) days preceding the scheduled hearing date.

11. Failure of students to be present at Judicial Panel hearings, assuming reasonable effort has been made to ensure their presence, shall indicate that they are waiving their rights to face the referrer and to appear before the Judicial Panel.

12. Students may ask that a panel member be excused from the Judicial Panel hearing if they can give reasonable cause why that panel member may be biased or have some other conflict of interest. The Chief Justice and the Graduate Honor System Advisor shall make a final ruling on any such request.

13. Students shall have the right to an appeal as specified under Article V, Section 2.

SECTION 2 - OBLIGATIONS OF THE ACCUSED

Students accused of Graduate Honor Code violations shall have the responsibility of cooperating with Graduate Honor System personnel. Furthermore, when a case involves other students, these students' rights to privacy should be observed.

Article VIII: Rights and Obligations of the Referrer

Section 1 - Rights of the Referrer

A person referring charges of a Graduate Honor Code violation against a graduate student shall be accorded the following rights:

1. Discussion of the charges between the referrer and accused prior to the Judicial Panel hearing shall be allowed, although the referrer shall have the right to decline to discuss the charge with the accused. The referrer shall have the right, with the permission of the accused, to have witnesses present when talking with the accused about the alleged violation.

2. The referrer shall have the right to receive a copy of the evidence collected during the investigation, the "Order of Events for Judicial Panel Hearings," and any other pertinent information, if the Investigative Board sends the case to the Judicial Panel.

3. The referrer shall have the right to choose one person (any member of the university community, such as a graduate student, a faculty or staff member, or department head) to assist them in preparation of the case. This person is not allowed to be present at the Judicial Panel hearing.

4. The referrer shall have the right to receive written notification of the final disposition of the case.

5. The referrer shall have the right to be secure in person and property.

6. Professors referring charges of violations may opt to grade or refrain from grading any assignment under investigation by the Graduate Honor System. It is recommended that instructors, if they are able to do so, grade the assignment with the assumption that the student is innocent of the charge. However, an incomplete grade may be assigned to the accused student pending the decision of the Graduate Honor System. The incomplete grade will be removed when the case is resolved.

Section 2 - Obligations of the Referrer

A person bringing charges of a Graduate Honor Code violation against another shall accept the following obligations:

1. The referrer shall cooperate with the Chief Justice, the Graduate Honor System Advisor, the Investigator, and any other personnel of the Graduate Honor System.

2. The referrer shall be expected to appear at the Judicial Panel hearing.

3. The referrer shall have the responsibility of maintaining confidentiality in all matters pertaining to the case. However, referrers may discuss the case with their counsel (see Article VIII, Section 1, item 3).

Article IX: General

Section 1 - Reporting of Violations

It is the obligation of all members of the academic community to report alleged violations of the Graduate Honor Code. *Reporting the observance of a Graduate Honor Code violation shall not be optional; it shall be mandatory*. Reports should be submitted in writing to the Chief Justice or the Graduate Honor System Advisor on forms provided for that purpose, which are available ºat *http://www.gradhonor.grads.vt.edu*. The report form also may be obtained at the Graduate School.

Alleged violations of the Graduate Honor Code should be reported within ten (10) class days after the date of discovery. Only under very special circumstances shall exceptions to this policy be granted, and then only at the discretion of the Chief Justice and the Graduate Honor System Advisor. A possible reason for exception could include, but is not limited to, unavoidable delays in obtaining the evidence.

Section 2 - Off-Campus Violations

1. Students engaged in graduate studies off-campus shall be subject to all provisions of this Constitution.

2. Designated members of the Investigative Board shall gather evidence. The evidence obtained shall be presented to the Investigative Board and shall be evaluated in a manner prescribed in Article III of this Constitution.

3. Unless otherwise designated by the Chief Justice, with the approval of the Dean of the Graduate School, all hearings shall be conducted in Blacksburg.

Section 3 - Summer School

Because of the decreased availability of graduate student and faculty board and panel members during the summer, delays in processing and hearing cases may result. Thus, reasonable delays of this sort shall not be considered as violating the student's rights or as grounds for an appeal.

Section 4 - Graduate Students Enrolled in Undergraduate Classes

Graduate students shall be subject to stipulations within this Constitution regardless of whether they are enrolled in undergraduate or graduate classes.

Section 5 - Undergraduate Students Enrolled in Graduate Classes

The undergraduate honor system, commonly referred to as The Virginia Tech Honor System, shall have jurisdiction over cases involving undergraduate students in graduate classes unless the student is also enrolled in the Graduate School and taking graduate classes for graduate credit under the classification of "Dual Student" or "Honors Dual Student," in which case the Graduate Honor System shall have jurisdiction.

Section 6 - Violations Involving Graduate Students Already Graduated

If the degree towards which the student was working at the time of the alleged violation has already been awarded, the case shall be referred to the Dean of the Graduate School who shall convene a committee to review and investigate the charge and make recommendations. The committee

composition shall be determined by the Dean of the Graduate School. The Chief Justice of the Graduate Honor System shall be an ex officio member of this committee and shall have the same voting privileges as the other members of this committee.

SECTION 7 - RECRUITMENT OF GRADUATE HONOR SYSTEM MEMBERS

Recognizing that it is strongest when it fosters and reflects the support of all graduate students and faculty at the University, the Graduate Honor System shall seek to be as broadly representative of the graduate student and faculty bodies at Virginia Tech as possible. To this end, all qualified graduate students and faculty shall be encouraged to participate in the Graduate Honor System. No otherwise qualified graduate student or faculty may be excluded from membership on the basis of race, sex, handicap, age, veteran status, national origin, religion, political affiliation, or sexual orientation.

SECTION 8 - CLEARANCE OF GRADUATE STUDENT RECORDS

Graduate students volunteering or appointed to serve on the Graduate Honor System must receive clearance of their personal disciplinary records and their academic records through the Dean of the Graduate School. Such clearances shall be conducted consistent with the University's regulations on the confidentiality of records and shall assure a minimum academic quality credit average of 3.00 and no previous or current disciplinary action for each appointee.

SECTION 9 - CONFIDENTIALITY

All investigations, hearings, reviews, and other associated activities of the Graduate Honor System shall conform to the University's "Statement on Confidentiality of Student Records."

SECTION 10 - SUBSTITUTION OF GRADUATE HONOR SYSTEM PERSONNEL

The Chief Justice or the Graduate Honor System Advisor shall be authorized, when circumstances dictate, to appoint substitutes for any Graduate Honor System personnel in any case before the Graduate Honor System. However, faculty may not be substituted for graduate students and vice versa.

SECTION 11 - UNIVERSITY POLICIES

Where appropriate, the Graduate Honor System shall abide by all applicable policies, statements, and principles as contained in the *University Policies for Student Life.*

ARTICLE X: AMENDMENTS

Proposed amendments to the Constitution of the Graduate Honor System may be initiated through one of the following channels: (1) by a majority vote of the Graduate Student Assembly, (2) by a majority vote of the Commission on Graduate Studies and Policies, or (3) by direct submission to the Chief Justice or the Dean of the Graduate School. Also, at the discretion of the Chief Justice and the Graduate Honor System Advisor, amendments may be initiated through the Graduate Honor System. Upon receiving such proposals, the Dean of the Graduate School shall convene the Constitution Revision Committee. With the approval of two-thirds of this committee, proposed amendments shall be forwarded for approval by the Commission on Graduate Studies and Policies and thereafter through the proper channels of the University governance structure (which at the time of this revision, would be the Commission on Student Affairs and University Council). Any substantive changes in proposed amendments as they proceed through subsequent levels of approval shall be resubmitted to the Constitution Revision Committee for its approval.

The Constitution Revision Committee shall consist of the Chief Justice (chair), the Graduate Honor System Advisor, a minimum of three (3) members of the Investigative Board (minimum of two (2) graduate students and one (1) faculty), a minimum of three (3) members of the Judicial Panel (minimum of two (2) graduate students and one (1) faculty), and up to two (2) other representatives from the graduate student body to be nominated by the Graduate Student Assembly.

1991 REVISION

SUMMARY

Following the conclusion of the 1987 University Self-Study, a Constitution Revision Committee was convened to evaluate the Graduate Honor System. Since the Constitution had not received serious scrutiny in a decade or more, and since the Graduate Honor System has now matured to a level where the old Constitution is hardly serviceable, the ultimate goal of this committee from the outset was a revision of the Constitution. Much work has gone into ensuring that this revision will stand the test of time and will be instructive in guiding the operation of the Graduate Honor System in the years ahead.

REFERENCE MATERIAL USED

Revision of this document was based on a variety of materials; these include:

1. Constitution to the Virginia Tech [Undergraduate] Honor System, published in the Pylon (1988-89). (Article VII, Article VIII, several sections of Article IX, and Appendix A are used with and without modifications by permission of the Virginia Tech [Undergraduate] Honor System). Also, a report written by the Virginia Tech [Undergraduate] Honor System Self-Study Committee was used.

2. The University Judicial System's Manual for Hearing Officers, published by the Dean of Students Office, Virginia Tech (1989).

3. Several ideas and sentences from the following sources have been used with and without modification in the writing of the section "Purpose and Description of Graduate Honor Code" (Article I, Section 1):

a. Reference 1.

b. *Cornell University Course of Study*, "Code of Academic Integrity", (1989-1990), pp. 33-35.

c. *Bulletin of Duke University Graduate School*, "Standards of Conduct", (March 1990), pp. 56–58.

d. *Record of the University of North Carolina at Chapel Hill, The Graduate School*, "The Honor Code", (April 1990), pp. 70–72.

e. *University of Virginia Graduate Record*, "The Honor System", (1987–1988), p.20 and p. 30.

4. Information used in defining "Misconduct in Research" (Article I, Section 3):

a. Recommendations on "Research Misconduct and Graduate Students at VPI&SU" submitted to the Constitution Revision Committee by the Degree Requirements, Standards, Criteria and Academic Policies Committee (DRSCAPC) of the Commission on Graduate Studies, January 18, 1990.

b. "Narrower Definition of Misconduct Urged," Public Affairs Newsletter, Federation of American Societies for Experimental Biology, Vol. 21, No. 12 (December 1988) p. 1.

c. *Federal Register*, Vol. 54, No. 151, (August 8, 1989) 32449.

d. "New Rules on Misconduct," *Science*, (August 11, 1989) p. 593. :eol.

5. "Computer Science Department Policy on Koofers, Old Programs, Cheating, and Microcomputer Use," *CS Bits & Bytes* (CS Dept. VPI&SU), Wednesday, February 15, 1989, pp. 7–8. (Ideas and and wording from this policy were used in Article I, Section 3.)

APPENDIX IIIA

PLAGIARISM

The following text is reproduced, with permission, from Appendix II of the Constitution of the Virginia Tech [Undergraduate] Honor System. Any notes appearing in brackets, [], have been added for completeness by the Graduate Honor System. (The Constitution of the Virginia Tech [Undergraduate] Honor System may be obtained from the Provost's Office.)

DEFINITION

The Virginia Tech honor system constitution states that "Plagiarism includes the copying of the language, structure, ideas, and/or thoughts of another and passing off same as one's own, original work." The violation, then, consists of both *copying* and *misrepresenting the material in question*.

Since the matter of *misrepresentation* is easier to define and understand, let us consider it first. Generally, when a student places his or her name on any kind of work, whether it is specifically pledged or not, he or she claims responsibility for the originality of the contents except for those parts that are specifically attributed to another or that are considered common knowledge. (The concept of common knowledge poses a problem of definition, and the student should consult the section of this handbook that addresses that area.) Thus, if a student has consulted any outside source, whether published or not, and has incorporated any of its "language, structure, ideas, and/or thoughts" into his or her work without acknowledging that source, he or she may be guilty of misrepresenting the work's originality. [Furthermore, in citing a reference, the student must change both the sentence structure and the vocabulary (where possible) in expressing the original material in his or her own words.]

On the other hand, *copying* includes a whole range of offenses. Everyone is undoubtedly familiar with stories involving a student who has "borrowed" or bought a term paper or laboratory report from a so–called research service, a fraternity or sorority file, a fellow student, or another similar source. Such wholesale copying is akin to the lifting of an assignment in its entirety from a book or journal article. In either case, the student in question submits work that is literally copied and transferred from one piece of paper to another; by claiming this work as his or her own, the student is clearly guilty of the most flagrant kind of plagiarism.

Another type of copying that is not as obvious, though equally serious, involves the translation of a part of a book, article, or other source into different words–paraphrasing. Although the language is not the same because the exact words of the source have been changed, the structure, ideas, and thoughts of the original author have been copied. Thus, the student who submits an assignment that simply paraphrases a source without identifying it may also be guilty of plagiarism.

Similarly, any combination of simple copying and paraphrasing, whether from one source or from many, is also a type of plagiarism, and the offender may be equally guilty as those students described above.

Because a person's ideas can be conveyed in many ways besides the written word, students should be aware that the copying of drawings, designs, photographs, maps, graphs, illustrations, tables, primary data, derived equations, computer programs, verbal communications of information and ideas, and other sources may also constitute plagiarism,

unless the source is acknowledged and properly documented.

For the purposes of the Virginia Tech honor system, plagiarism can be broadly defined as the act of appropriating the literary composition, language, structure, ideas, and/or thoughts, drawings, laboratory reports, or computer programs of another or parts or passages thereof, and of passing them off as the original product of one's own mind. To be liable for plagiarism under the university's honor system, it is not necessary to duplicate another's literary work exactly; it being sufficient if unfair use of such work is made by lifting of substantial portions of it. Plagiarism is not confined to literal copying, but also includes any of the evasive variations and colorable alterations by which the plagiarist may disguise the source from which the material was copied. On the other hand, even an exact counterpart of another's work does not constitute plagiarism if such counterpart was arrived at independently.

The next several pages of this handbook will illustrate the major types of plagiarism and will also indicate how these offenses can be avoided through proper documentation of sources.

EXAMPLES OF CORRECT AND INCORRECT USES OF SOURCES

The following four examples provide illustrations of three kinds of plagiarism, as well as the proper use and acknowledgement of sources. The excerpt from Niccolo Machiavelli's *The Prince* is quoted from W. K. Marriott's translation (New York: E. P. Dutton, 1908), p. 37. The excerpts from student papers have been written by the committee for the purposes of this handbook.

FLAGRANT PLAGIARISM

EXCERPT FROM *THE PRINCE*

Whenever those states which have been acquired as stated have been accustomed to live under their own laws and in freedom, there are three courses for those who wish to hold them: the first is to ruin them, the next is to reside there in person, the third is to permit them to live under their own laws, drawing a tribute, and establishing within it an oligarchy which will keep it friendly to you. Because such a government, being created by the prince, knows that it cannot stand without his friendship and interest, and does its utmost to support him; and therefore he who would keep a city accustomed to freedom will hold it more easily by the means of its own citizens than in any other way.

EXCERPT FROM A STUDENT PAPER

Whenever those *nations* which have been acquired have been accustomed to *living* under their own laws and in freedom, then there are three *options* for those who wish to *keep* them; the first is to ruin them, *second* is to reside there in person, and the *last* is to permit them to live under their own government, drawing a tribute, and establishing within it an oligarchy which will keep it friendly to you. Because such a government, being created by the *ruler*, knows that it cannot stand without his friendship and interest, and does its utmost to gain his support, and therefore, he who would keep a city accustomed to freedom will hold it more easily by the means of its own citizens than in any other way.

COMMENTS

This student paper is an example of the most obvious form of plagiarism. The writer has copied Machiavelli almost verbatim without any acknowledgment. There have been some minor changes. For example, the italicized words have been changed. "States" becomes "nations," "courses" becomes "options," etc.

PLAGIARISM THROUGH PARAPHRASING

EXCERPT FROM *THE PRINCE*

Whenever those states which have been acquired as stated have been accustomed to live under their own laws and in freedom, there are three courses for those who wish to hold them: the first is to ruin them, the next is to reside there in person, the third is to permit them to live under their own laws, drawing a tribute, and establishing within it an oligarchy which will keep it friendly to you. Because such a government, being created by the prince, knows that it cannot stand without his friendship and interest, and does its utmost to support him; and therefore he who would keep a city accustomed to freedom will hold it more easily by the means of its own citizens than in any other way.

EXCERPT FROM A STUDENT PAPER

There are basically three methods to maintain control over nations which formerly enjoyed their independence. First the nation can be completely destroyed. Second, the king can personally reside in the conquered territory. Finally, the king can permit them to live under their own rules; he would then levy a tax and establish a ruling clique which would be loyal to him. Since this government is created and maintained by the conquering power, the puppet government will do its utmost to support him in order to keep his friendship. In addition, by establishing a puppet government in such a manner, he will gain the allegiance of its citizens.

COMMENTS

By paraphrasing the paragraph taken from Machiavelli, the student attempted to disguise the source of material. Nevertheless, it is quite obvious that the sentences of this writer parallel those of the Machiavelli text and are identical in meaning.

PLAGIARISM OF AN IDEA

EXCERPT FROM *THE PRINCE*

Whenever those states which have been acquired as stated have been accustomed to live under their own laws and in freedom, there are three courses for those who wish to hold them: the first is to ruin them, the next is to reside there in person, the third is to permit them to live under their own laws, drawing a tribute, and establishing within it an oligarchy which will keep it friendly to you. Because such a government, being created by the prince, knows that it cannot stand without his friendship and interest, and does its utmost to support him; and therefore he who would keep a city accustomed to freedom will hold it more easily by the means of its own citizens than in any other way.

EXCERPT FROM A STUDENT PAPER

When the British established their empire in Asia and Africa during the eighteenth and nineteenth centuries, they were faced with the problem of how to govern and control effectively these areas which had formerly lived under their own government. There were essentially three methods of achieving this end: destroying the country; establishing direct rule through governors appointed by the king; and maintaining indirect control through the already established governing structure. The British chose indirect rule. Through indirect rule, the former officials realized that their position was now dependent upon the British. Consequently, their allegiance was assured, and through them the British obtained substantial economic benefits. In addition, the people, seeing their leaders still in power, obediently supported the indirect rule of the British.

COMMENTS

The student has used the ideas of Machiavelli in describing a historical event. Machiavelli lists three methods of governing and controlling a state that had formerly been independent, and then shows the relative advantage of pursuing the last method. The student does not acknowledge the use of the description of the three methods of control nor the advantages of the last method when applying Machiavelli's idea to a specific example.

CORRECT USE OF PARAPHRASING AND DIRECT QUOTATIONS

EXCERPT FROM *THE PRINCE*

Whenever those states which have been acquired as stated have been accustomed to live under their own laws and in freedom, there are three courses for those who wish to hold them; the first is to ruin them, the next is to reside there in person, the third is to permit them to live under their own laws, drawing a tribute, and establishing within it an oligarchy which will keep it friendly to you. Because such a government, being created by the prince, knows that it cannot stand without his friendship and interest, and does its utmost to support him; and therefore he who would keep a city accustomed to freedom will hold it more easily by the means of its own citizens than in any other way.

EXCERPT FROM A STUDENT PAPER

When the British established their empire in Asia and Africa during the eighteenth and nineteenth centuries, they were faced with the problem of how to govern these formerly independent areas effectively. According to Niccolo Machiavelli, in *The Prince*, a ruler had three options. He could destroy them, "reside there in person," or "permit them to live under their own laws, drawing a tribute and establishing within it an oligarchy which will keep it friendly to you."[1] Machiavelli felt that through this third method the conqueror gained the support of the former leaders and their subjects.[2]

The British seemed to apply this third method through their indirect rule concept. In other words, the British maintained control using the former leaders as figureheads. The former leaders realized that their position was now dependent upon the British. Consequently, their allegiance was assured and through them substantial economic benefits were obtained. In addition, the people, seeing their leaders still in power, obediently supported the indirect rule of the British.

[1] Niccolo Machiavelli, *The Prince,* trans. and intro. W. K. Marriott (New York; E.P. Dutton, 1908), p.37.

[2] Machiavelli, p.37.

COMMENTS

In this instance, the student has correctly footnoted the ideas of Machiavelli, which he has paraphrased and quoted. The writer has then applied Machiavelli's ideas to a more recent historical event.

THE PROBLEM OF COMMON KNOWLEDGE

The concept of common knowledge is one of the more difficult points to explain in any consideration of plagiarism. How can a student, often a novice in the subject, determine whether an idea or fact included in a paper is so widely known that it is considered common knowledge and requires no documentation? A few general guidelines for solving this dilemma can be suggested, but none is inviolate. Given the seriousness of plagiarism, the prudent writer cites a reference whenever he or she is uncertain.

1. Concepts and facts *widely* known outside of the specific area of study are generally considered common knowledge. These include undisputed dates (e.g. the adoption of the Declaration of Independence on July 4, 1776), scientific principles (e.g. Newton's Laws of Motion), and commonly accepted ideas (e.g., Hamlet's role as a tragic hero). Such data require no specific reference. Students should be aware, however, that the addition of minor informational embellishments might require documentation (e.g., that the Declaration of Independence was unanimously adopted by the American colonies on July 4, 1776, despite the abstention of New York).

2. The fact that material appears in a dictionary, encyclopedia, handbook, or other reference work or textbook does not guarantee that it is common knowledge. Such books are written by experts, and most of the information they contain is not widely known.

3. There is no simple test to determine whether information is common knowledge. In case of doubt, the student should consult his or her instructor.

DOCUMENTATION

To avoid plagiarism in writing, the student must be familiar with the concept of documentation. Terminology and methodology concerning proper ways to acknowledge sources are probably more confusing to students than any other aspect of research reporting. The purpose of documenting a source is first to give proper credit to others for their original words, thoughts, and ideas, and second to enable the interested reader to locate the original source in order to read or study further. Keeping this latter purpose in mind, one finds that the rules regarding documentation make more sense. Therefore, students should familiarize themselves with the proper methods of providing citations and bibliographies both to document their sources and to provide the reader with the necessary data to locate further information on the subject.

INDICATING QUOTATIONS

Whenever the exact wording of a source appears in a student paper, that fact must be made apparent to the reader. This goal can be accomplished in two ways. Brief quotations should be enclosed in quotation marks, whether complete sentences, phrases, or single significant words which have been incorporated into the student's own sentence or into a paraphrase or a longer excerpt of the source. The student should be careful to denote precisely where the source's exact wording begins and ends by the appropriate placing of opening and closing quotation marks.

Longer quotations (of more than three lines) should be indented ten spaces from the left–hand margin. Again, the beginning and ending of quoted material should be clearly indicated.

All direct quotations must be signified in one of these ways.

CITATIONS

Immediately following *every* piece of quoted or paraphrased material, some type of reference is required. The method used varies according to the field of study for which the paper is written; thus, students should ask instructors which style manual to use in preparing papers for their courses. Examples of two commonly used methods follow.

1. Footnotes or Endnotes: A small numeral in the text refers to a complete reference, similarly numbered, at the foot of the page or at the end of the paper. Notes should be numbered sequentially, beginning with "1."

Example:
"Congruence...between the self concept and the ideal self is one of the most fundamental conditions for both general happiness and for satisfaction in specific life areas."[1]

[1]Alfred L. Brophy, "Self, Role, and Satisfaction," *Genetic Psychology Monographs*, 59 (May 1959),300.

2. Author–Date Citation: Following a quotation or paraphrase, the author's name and the publication date of the work appear in parentheses and refer the reader to the bibliography at the end of the paper.

Example:
For a person to be truly happy, his or her self concept must more or less coincide with the ideal self he or she envisions (Brophy, 1959).

BIBLIOGRAPHY OR LIST OF CITED REFERENCES

A list of all sources used, arranged alphabetically by the authors' last names, should appear at the end of every paper. Each entry should contain all information necessary for a reader to retrieve the work. Book entries usually include author's name, book title, and publication data (city, publisher, and date). Entries for periodical articles generally include author's name, article title, periodical title, volume number, date of issue, and pages on which the article appears. Students should make whatever adjustments that are necessary to these general rules so that entries coincide with the format prescribed by an instructor or by a specific manual. (An example of one type of bibliography format can be found in the list of style manuals which follows.)

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This appendix is not intended to suggest or endorse any specific method of documentation. Rather, its purpose is to remind the student that acknowledgment of sources is necessary. The examples given above are provided as illustrations of some of many possibilities. The final authority regarding methods of documentation is the course instructor; students should choose a system of documentation and use it consistently throughout a paper. The following style manuals are commonly used.

American Psychological Association, *Publication Manual*, 2nd ed. Washington: APA, 1974.

Campbell, William G., Stephen V. Ballou, and Carole Slade. *Form and Style: Theses, Reports, Term Papers*. 6th ed. Boston: Houghton Mifflin, 1982.

Council of Biology Editors, Committee on Form and Style *CBE Style Manual*. 4th ed. Washington: American Institute of Biological Sciences, 1978.

Hodges, John C., and Mary E. Whitten. *Harbrace College Handbook*. 9th ed. New York: Harcourt Brace Jovanovich, 1982.

Modern Language Association. *MLA Handbook for Writers of Research Papers, Theses, and Dissertations*. New York: MLA. 1977.

Turabian, Kate L. *A Manual for Writers of Term Papers, Theses, and Dissertations*. 4th ed. Chicago: University of Chicago Press, 1973.