# 1994

NORTH CAROLINA STATE UNIVERSITY

# GRADUATE

# Catalog

North Carolina State University Bulletin
Raleigh, North Carolina

This catalog is intended for informational purposes only. Requirements, rules, procedures, courses and informational statements set forth herein are subject to change. Notice of changes will be conveyed to duly enrolled students and other appropriate persons at the time such changes are effected.

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THE
GRADUATE
SCHOOL

# Graduate Catalog

**North Carolina State University**

Raleigh, North Carolina

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# NORTH CAROLINA STATE UNIVERSITY

North Carolina State University (NCSU) is a national center for research, teaching and extension. As a Land-Grant state university, it shares the distinctive characteristics of these institutions nationally--broad academic offerings, extensive public service, national and international activities, and large-scale extension and research programs.

North Carolina State University is committed to equality of educational opportunity and does not discriminate against applicants, students or employees based on race, color, national origin, religion, sex, age or handicap. Moreover, NCSU is open to people of all races and actively seeks to promote racial integration by recruiting and enrolling a larger number of African-American students.

NCSU's rich and varied academic program is comprised of 96 undergraduate degree programs in 89 fields of study, master's degrees in 91 fields of study, 54 doctoral degree programs and the doctor of veterinary medicine program. The University offers approximately 2,900 courses.

Research activities span a broad spectrum of scientific, technological and scholarly endeavors with a budget of some $170 million annually.

Extension offices in each of the state's 100 counties and on the Cherokee Indian reservation assist in carrying the University's teaching and research programs throughout the state. The diversity of these programs spans such fields as agriculture, design, education, engineering, forestry, humanities, management, marine and environmental sciences, textiles, veterinary medicine, and the physical, social and life sciences.

The University's annual expenditures reach approximately $454 million, and its employees total about 6,865. There are more than 2,623 faculty and professional staff, including more than 2,000 graduate faculty. Among the many honors and recognitions received by members of the faculty are seven memberships in the National Academy of Science and five in the National Academy of Engineering, 43 named professorships, 14 distinguished university professorships and 12 Graduate Alumni Distinguished Professors.

NCSU's campus, located just west of the downtown area of Raleigh, totals some 1,800 acres. This includes the central campus of 623 acres with some 166 build-

ings, the adjacent Centennial Campus of 1,000 acres under development, and the 182-acre College of Veterinary Medicine campus.

In addition, the University has some 88,000 acres statewide, including one research and endowment forest of 78,000 acres. Near the campus are 2,500 acres containing research farms; biology and ecology sites; genetics, horticulture and floriculture nurseries; teaching and research forests; and Carter-Finley Stadium.

With a total enrollment of more than 27,170, the University has approximately 18,644 undergraduate students, 4,553 graduate students, 3,692 lifelong education students and 281 in veterinary medicine. The student population consists of approximately 16,432 men and 10,738 women, including 2,488 African-Americans and 1,130 other minority students. Students come to NCSU from every state in the union and at least 90 foreign countries are represented by 1,127 international students.

The University is organized in nine colleges, the School of Design and the Graduate School. The nine colleges are Agriculture and Life Sciences, Education and Psychology, Engineering, Forest Resources, Humanities and Social Sciences, Management, Physical and Mathematical Sciences, Textiles and Veterinary Medicine. In addition, a complex of divisions and programs provides for a wide range of special programs in academic affairs, research and extension.

North Carolina State University is one of three Research Triangle Universities along with Duke University and the University of North Carolina at Chapel Hill. In the 30-mile triangle formed by the universities is the Research Triangle Park which includes the Research Triangle Institute, a not-for-profit, contract research organization founded by the three universities.

NCSU is a member of the National Association of State Universities and Land-Grant Colleges. It is also a member of the American Council on Education, the College Entrance Examination Board, the Council of Graduate Schools, the National Commission on Accrediting and the Southern Association of Colleges and Schools.

The University is accredited by national and regional accrediting agencies applicable to the University and its numerous professional fields.

## Additional Information

If additional information is needed, contact the Graduate School, 103 Peele Hall, P. O. Box 7102, North Carolina State University, Raleigh, N.C. 27695-7102 (telephone 919/515-2872).

# Nondiscrimination Statement

North Carolina State University is dedicated to equality of opportunity within its community. Accordingly, North Carolina State University does not practice or condone discrimination, in any form, against students, employees or applicants on the grounds of race, color, national origin, religion, sex, age or disability. North Carolina State University commits itself to positive action to secure equal opportunity regardless of those characteristics.

North Carolina State University supports the protection available to members of its community under all applicable Federal laws, including Titles VI and VII of the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, Sections 799A and 845 of the Public Health Service Act, the Equal Pay and Age Discrimination Acts, the Rehabilitation Act of 1973, the Americans with Disabilities Act of 1991, the Vietnam Veterans Readjustment Assistance Act of 1974, and Executive Order 11246. For information concerning these provisions, contact:

Dr. Lawrence M. Clark
Associate Provost & Affirmative Action Officer
201 Holladay Hall
P. O. Box 7101
North Carolina State University
Raleigh North Carolina 27695-7101
Phone: 919/515-3409

# Code of Student Conduct

North Carolina State University is committed to academic integrity, and all students are required to adhere to the *NCSU Code of Student Conduct*. Graduate students may also refer to the *NCSU Graduate Student Rights and Responsibilities* document.

# ADMINISTRATION

Larry K. Monteith, *Chancellor*
Phillip J. Stiles, *Provost and Vice Chancellor*
Debra W. Stewart, *Dean of Graduate School*
Franklin D. Hart, *Vice Chancellor for Research, Outreach and Extension*
George L. Worsley, *Vice Chancellor for Finance and Business*
Thomas H. Stafford Jr., *Vice Chancellor for Student Affairs*
Jeffrey P. McNeill, *Vice Chancellor for Institutional Advancement*

## Deans of Colleges and Schools

Durward F. Bateman, *Dean, Agriculture and Life Sciences*
J. Thomas Regan, *Dean, Design*
Joan J. Michael, *Dean, Education and Psychology*
Tildon H. Glisson Jr., *Interim Dean, Engineering*
Larry W. Tombaugh, *Dean, Forest Resources*
William B. Toole III, *Dean, Humanities and Social Sciences*
Richard J. Lewis, *Dean, Management*
Jerry L. Whitten, *Dean, Physical and Mathematical Sciences*
Robert A. Barnhardt, *Dean, Textiles*
Oscar J. Fletcher, *Dean, Veterinary Medicine*

## Graduate School--Administrative Office

D. W. Stewart, *Dean*
R. S. Sowell, *Associate Dean*
M. F. King, *Associate Dean*
T. Melton, *Interim Associate Dean*

# Administrative Board of the Graduate School

| | Term Expires |
|---|---|
| D. W. Stewart, *Dean* | |
| R. S. Sowell, *Associate Dean* | |
| M. F. King, *Associate Dean* | |
| T. Melton, *Interim Associate Dean* | |
| S. M. Bedair, *Professor of Electrical and Computer Engineering and Materials Science and Engineering* | December, 1997 |
| B. G. Beezer, *Professor of Educational Leadership and Program Evaluation; Associate Dean for Academic Affairs, College of Education and Psychology* | June, 1995 |
| A. J. De Grand, *Professor of History* | February, 1997 |
| H. A. Devine, *Professor of Forestry and Parks, Recreation and Tourism Management* | June, 1995 |
| J. K. Ferrell, *Dean Emeritus, College of Engineering* | June, 1994 |
| T. M. Gerig, *Professor of Statistics and Director of Graduate Programs* | June 1994 |
| B. Hammerberg, *Professor of Microbiology, Pathology and Parasitology* | December, 1995 |
| S. P. Hersh, *Charles A. Cannon Professor of Textile Engineering, Chemistry and Science; Director of Graduate Studies, College of Textiles* | September, 1996 |
| E. J. Kamprath, *William Neal Reynolds Professor of of Soil Science and Head of the Department* | June, 1995 |
| C. R. Knoeber, *Professor of Economics* | April, 1997 |
| G. E. Mitchell, *Professor of Physics and Director of Graduate Programs* | July, 1997 |
| J. L. Oblinger, *Professor of Food Science; Associate Dean and Director of Academic Programs, College of Agriculture and Life Sciences* | June, 1995 |
| M. Scotford, *Associate Professor of Graphic Design* | August, 1997 |
| S. S. Snyder, *Associate Professor of Psychology and Director of Graduate Programs* | June, 1995 |

# THE CALENDAR

*NOTE: This calendar is subject to periodic review and revision.*

**SPRING SEMESTER, 1994**

| | | |
|---|---|---|
| January 12 | Wed. | First day of classes |
| January 17 | Mon. | Holiday (Martin Luther King Day) |
| January 20 | Thurs. | Last day to add a course without permission of instructor |
| January 27 | Thurs. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course or to change from crdit to audit with a refund or reduction. *(NOTE: The tuition and fees charge is based on the official number of hourse and course carried at 5:00 p.m. on this day.)* TRACS closes at 5:00 p.m. (after this day, drops processed in 1000 Harris Hall) |
| February 10 | Thurs. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below. |
| February 23 | Wed. | Academic Difficulty Reports due |
| March 11 | Fri. | Spring vacation begins at 10:15 p.m. |
| March 21 | Mon. | Classes resume at 8:05 a.m.; 8:35 a.m. Centennial Campus; Registration advising for 1994 Fall Semester begins |
| March 25 | Fri. | Last day to withdraw or drop a course at the without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |
| March 31 | Thurs. | *Deadline for submission of theses or dissertations to the Graduate School, in final form as approved by advisory committees, by candidates for master's and doctoral degrees in May, 1994. Last day for unconditional pass on final oral examinations by candidates for master's degrees not requiring theses* |
| April 1 | Fri. | Holiday (Good Friday) |
| April 29 | Fri. | Last day of classes |
| May 2-10 | Mon.-Tues. | Final examinations |
| May 14 | Sat. | Spring Commencement |

## SUMMER SESSIONS, 1994

*First Session*

| | | |
|---|---|---|
| May 24 | Tues. | First day of classes |
| May 25 | Wed. | Last day to add a course without permission of instructor |
| May 30 | Mon. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course with a refund (*Note: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.)* |
| June 3 | Fri. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| June 10 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |
| June 24 | Fri. | Last day of classes |
| June 27-28 | Mon.-Tues. | Final examinations |

*Second Session*

| | | |
|---|---|---|
| July 5 | Tues. | First day of classes |
| July 6 | Wed. | Last day to add a course without permission of instructor |
| July 8 | Fri. | *Deadline for submission of theses and dissertations to the Graduate School, in final form as approved by advisory committees, by candidates for master's and doctoral degrees in August, 1994. Last day for unconditional pass on final oral examinations by candidates for master's degrees not requiring theses.* |
| July 11 | Mon. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course with a refund (*Note: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.*) |

| | | |
|---|---|---|
| July 15 | Fri. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| July 22 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |
| August 5 | Fri. | Last day of classes |
| August 8-9 | Mon.-Tues. | Final examinations |

**FALL SEMESTER, 1994**

| | | |
|---|---|---|
| August 24 | Wed. | First day of classes |
| August 31 | Wed. | Last day to add a course without permission of instructor |
| Sept. 5 | Mon. | Holiday (Labor Day) |
| Sept. 8 | Thurs. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course or change from credit to audit with a refund or reduction. (*NOTE: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.*) TRACS closes at 5:00 p.m. (after this day, drops processed in 1000 Harris Hall) |
| Sept. 22 | Thurs. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| October 7 | Fri. | Academic Difficulty Reports due |
| October 14 | Fri. | Fall vacation begins at 1:15 p.m.; 1:45 p.m., Centennial Campus |
| October 19 | Wed. | Classes resume at 8:05 a.m.; 8:35 a.m., Centennial Campus |
| October 24 | Mon. | Registration advising for 1995 Spring Semester begins |
| October 26 | Wed. | Honors Convocation (no classes until 12:15 p.m.; until 12:45 p.m., Centennial Campus |
| October 28 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |

| | | |
|---|---|---|
| October 30 | Sun. | TRACS registration opens for 1994 spring semester |
| November 11 | Fri. | *Deadline for submission of theses and dissertations to the Graduate School, in final form as approved by advisory committees, by candidates for master's and doctoral degrees in December, 1992. Last day for unconditional pass on final oral examinations by candidates for master's degrees not requiring theses.* |
| November 22 | Tues. | Thanksgiving vacation begins at 10:00 p.m. |
| November 28 | Mon. | Classes resume at 8:05 a.m.; 8:35 a.m. Centennial Campus |
| December 9 | Fri. | Last day of classes |
| December 12-20 | Mon.-Tues. | Final examinations |
| December 21 | Wed. | Fall Graduation Exercise |

**SPRING SEMESTER, 1995**

| | | |
|---|---|---|
| January 11 | Wed. | First day of classes |
| January 16 | Mon. | Holiday (Martin Luther King Day) |
| January 19 | Thurs. | Last day to add a course without permission of instructor |
| January 26 | Thurs. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course or to change from credit to audit with a refund or reduction. (*NOTE: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.*) TRACS closes at 5:00 p.m. (after this day, drops processed in 1000 Harris Hall) |
| February 9 | Thurs. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| February 22 | Wed. | Academic Difficulty Reports due |
| March 10 | Fri. | Spring vacation begins at 10:15 p.m. |
| March 20 | Mon. | Classes resume at 8:05 a.m.; 8:35 a.m., Centennial Campus. Registration advising for 1995 Fall Semester begins |

| | | |
|---|---|---|
| March 24 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to to change from credit to audit at the 500 or 600 level |
| March 31 | Fri. | *Deadline for submission of theses and dissertations to the Graduate School, in final form as approved by advisory committees, by candidates for master's and doctoral degrees in May, 1993. Last day for unconditional pass on final oral examinations by candidates for master's degrees not requiring theses.* |
| April 14 | Fri. | Holiday (Good Friday) |
| April 28 | Fri. | Last day of classes |
| May 1-9 | Mon.-Tues. | Final examinations |
| May 13 | Sat. | Spring Commencement |

SUMMER SESSIONS, 1995

*First Session*

| | | |
|---|---|---|
| May 23 | Tues. | First day of classes |
| May 24 | Wed. | Last day to add a course without permission of instructor |
| May 29 | Mon. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course with a refund. (*NOTE: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.*) |
| June 2 | Fri. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| June 9 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |
| June 23 | Fri. | Last day of classes |
| June 26-27 | Mon.-Tues. | Final examinations |

*Second Session*

| | | |
|---|---|---|
| July 3 | Mon. | First day of classes |

| | | |
|---|---|---|
| July 4 | Tues. | Holiday (Independence Day) |
| July 5 | Wed. | Last day to add a course without permission of instructor |
| July 7 | Fri. | *Deadline for submission of theses and dissertations to the Graduate School, in final form as approved by advisory committees, by candidates for master's and doctoral degrees in August, 1993. Last day for unconditional pass on final oral examinations by candidates for master's degrees not requiring theses* |
| July 10 | Mon. | Last day to register (includes payment of tuition and fees) or to add a course. Last day to withdraw or drop a course with a refund. (*NOTE: The tuition and fees charge is based on the official number of hours and courses carried at 5:00 p.m. on this day.*) |
| July 14 | Fri. | Last day to withdraw or drop a course without a grade at the 400 level or below. Last day to change from credit to audit at the 400 level or below |
| July 21 | Fri. | Last day to withdraw or drop a course without a grade at the 500 or 600 level. Last day to change from credit to audit at the 500 or 600 level |
| August 4 | Fri. | Last day of classes |
| August 7-8 | Mon.-Tues. | Final examinations |

# THE GRADUATE SCHOOL

Graduate instruction was first offered at North Carolina State University in 1893, and the first doctoral degree was conferred in 1926. In the ensuing years, the Graduate School has grown steadily and now provides instruction and facilities for advanced study and research in the fields of agriculture and life sciences, design, education, engineering, forest resources, humanities and social sciences, management, physical and mathematical sciences, textiles and veterinary medicine.

The Graduate School is currently composed of more than 2,000 graduate faculty members. Educated at major universities throughout the world and established both in advanced teaching and research, these scholars guide the University's nearly 4,700 master's and doctoral students from all areas of the United States and many other countries.

The faculty and students have available exceptional facilities, including libraries, laboratories, modern equipment and special research areas. Additionally, a cooperative agreement exists among the Graduate Schools of the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro, Duke University and North Carolina State University which increases the educational and research possibilities associated with each.

## Graduate Student Association

The Graduate Student Association (GSA) is an academic, political and social organization comprising all graduate students. It is governed by elected officers and representatives from departmental GSA chapters. Officially recognized by the university as the voice of graduate students, it has members on various university committees. The GSA president has full voting membership on the Administrative Board of the Graduate School and meets regularly with other university officials.

The GSA maintains a travel fund through which graduate students may obtain funds to present original research at professional conferences. The GSA co-sponsors an orientation to NCSU, a teaching effectiveness workshop and an awards ceremony to honor outstanding teaching assistants. In addition, the GSA provides support for departmental GSA chapters, maintains a computing facility exclusively for graduate student use and sponsors social events throughout the year.

The GSA can provide answers to questions regarding graduate student life and may be contacted via departmental representatives or the GSA president, whose telephone number can be obtained from the Graduate School. All are invited to attend the monthly GSA meetings.

# GENERAL INFORMATION

## Application

Applications for admission must be accompanied by the following: two official transcripts from all colleges and universities previously attended, references from at least three people who know of the student's academic record and potential for graduate study, a non-refundable application fee of $45 and, in most cases, an official statement of the student's Graduate Record Examination scores. Application and reference forms may be obtained by writing or visiting the Graduate School, 103 Peele Hall, Box 7102, North Carolina State University, Raleigh, N. C. 27695-7102. When completed, all application materials should be returned according to instructions. Application is made for a specific degree program and date of enrollment (see "Admission").

## International Students

Students whose native language is other than English, regardless of citizenship, must submit TOEFL (Test of English as a Foreign Language) scores as evidence of ability to use English at a level of competence sufficient for graduate work. The minimum requirement for admission is a TOEFL score of 550, with scores of 50 on at least two of the sections and no section score below 45. (Minimum score subject to change; departments may establish a higher minimum requirement.) The test date must be within 24 months of the application deadline date before the semester for which the application is being reviewed. An *official* score report issued by the Educational Testing Service is required. All international students must be cleared by the Department of Foreign Languages and Literatures at the beginning of their initial semester in residence and may be required to take additional course work in English. The international applicant must also provide the University with verification that the required funds are available to support the proposed program of advanced study. Foreign nationals in the United States at the time application is made must also provide information regarding their current visa status. The University provides special forms to be used by the applicant in supplying this information.

## Admission

The procedures followed in evaluating an applicant's potential for success in graduate work and the criteria used for admissions decisions vary according to departments and colleges/schools and reflect an evaluation of the applicant's potential to engage in graduate work and the capability of the individual departments to accommodate additional students. Most departments consider applications as they arrive,

while others accumulate applications and make recommendations on admission at certain times during the year. Generally, requests for admission are considered by departmental admissions committees which forward the departmental recommendations to the Dean of the Graduate School.

Students are admitted to full or provisional status in a specific degree program. Admission is granted for a specific semester or summer term. Any change in the admission date must be requested in writing and approved by the department and Graduate School. Once the requirements for that degree program have been completed, no further registration as a graduate student will be permitted unless admission to a new graduate classification has been formally approved. Students with special objectives may request admission in the "Graduate-Unclassified Status" (see next page) or register in the "Post-Baccalaureate Studies" program (see p. 16) through the Division of Lifelong Education.

## ADMISSION TO DEGREE PROGRAMS

### Full Graduate Standing

To be considered for admission in full graduate standing, an applicant must have a baccalaureate degree from a college or university recognized as standard by a regional or general accrediting agency and must have at least a "B" average in the undergraduate major or in the latest graduate degree program.

### Provisional Admission

1. Provisional admission may be granted to applicants with bachelor's degrees from accredited institutions who lack undergraduate work considered essential for graduate study in a major field. Course work, without graduate credit, will be required to make up such deficiencies before admission to full status can be granted.

Applicants with bachelor's degrees from nonaccredited institutions may be granted provisional admission when their academic records warrant this status. Additional course work will be required of such students when deficiencies in previous training are apparent.

Full graduate standing is granted when the deficiencies responsible for the provisional status are corrected, provided the student has maintained a satisfactory academic record (3.0 Grade Point Average) on all course work taken in a graduate classification. A change from provisional status to full graduate standing is effected only upon the recommendation of the department in which the student is seeking the degree.

2. Students with bachelor's degrees from accredited institutions whose scholastic records are below the standards for admission to full graduate standing may be ad-

mitted provisionally when unavoidable, extenuating circumstances affected their undergraduate averages or when progressive improvement in their undergraduate work warrants provisional admission. Students admitted provisionally under these circumstances will have their status changed to full graduate standing after completion of nine or more graduate credit hours following admission provided the student has maintained at least a "B" average.

A graduate student is not eligible for appointment to an assistantship or fellowship while on provisional status.

## MEDICAL HISTORY AND IMMUNIZATION RECORDS

All graduate students admitted to a degree program are required by State law to submit a report of medical history and immunization documentation prior to completing their initial registration. This report must document immunization against tetanus/diptheria, measles, German measles, polio and a TB skin test. NCSU students returning to Graduate School must have their medical history on file updated. The required reports should be received in the Student Health Service at least thirty days before registration.

## GRADUATE-UNCLASSIFIED STATUS

The Graduate-Unclassified status is a temporary classification and students admitted to this status are not candidates for degrees. They may take courses for graduate credit but may not apply more than 10 credits earned while in this status to any program leading to an advanced degree at this institution. Unclassified graduate students are expected to meet the same admissions requirements that apply to graduate students in full standing. Any individual having an interest in applying for admission as a Graduate-Unclassified Student should correspond with the Graduate Dean describing his or her particular interests and objectives prior to making application.

### Special Graduate-unclassified Status for International Student Visitors

1. International student visitors must state their educational objectives at NCSU and the time expected to accomplish those objectives. The educational objective may not be to seek a graduate degree at NCSU.
2. They are expected to meet the same minimum academic admission requirements that apply to graduate students in full standing.
3. They are expected to meet the same TOEFL requirements that apply to international students who are admitted to master's and doctoral programs if they plan to take courses. If they plan to register for Departmental Research 699 only, they are not required to take the TOEFL.

4. They must be recommended by the Director of Graduate Programs in the department in which they plan to take courses or do research.
5. They may be in this special admission status for a period not to exceed one year.
6. They may hold a research assistantship but may not hold a teaching assistantship.
7. They will not be eligible for tuition remission.

## POST-BACCALAUREATE STUDIES (PBS)

The Post-Baccalaureate Studies (PBS) classification is designed for U. S. citizens who wish to undertake academic work beyond the baccalaureate degree but who are not currently admitted to a degree program. This classification is not open to international students with the exception of the spouse of a regularly enrolled NCSU student. In special cases where students are sponsored by an agency of the U. S. government for specialized, non-degree study, approval may be given by the Graduate School for registration in the Post-Baccalaureate Studies classification. The following policies apply to students who wish to register for PBS:

1. All must have baccalaureate degrees from accredited institutions of higher education.
2. All classes taken for credit by PBS students will be graded in the usual manner that applies for the particular course (A,B,C,D,F or S,U). All courses taken at NCSU will show on the student's transcript. If the student is admitted as a graduate student, a maximum of nine hours may apply toward the minimum requirements of the degree for which the student is enrolled, including hours approved for graduate credit while classified as a senior, unclassified undergraduate or professional engineering student.
3. The grade point average (GPA) of a graduate student who has credits in the PBS category will include only those PBS credits which become a part of the Plan of Graduate Work. However, no course taken six (6) years prior to enrollment into a program will be considered in the GPA calculation.
4. Registration is limited to a maximum of two courses per semester. Individuals who are employed full-time should limit their PBS registrations to one course per semester.
5. The PBS classification carries with it no implication that the student will be admitted to the Graduate School in any degree classification.
6. All course work accepted for degree credit must be approved by the student's advisory committee as being germane to the program. Requests for degree credit for courses completed in the PBS classification are considered after admission to a graduate degree program when the student's Plan of Graduate Work is filed with the Graduate School.

7. PBS students are expected to familiarize themselves with Graduate School policies and to seek further advice or clarification as needed.

## EVENING DEGREE PROGRAMS

Students unable to attend day classes may complete all courses required for a graduate degree in certain areas by enrolling in late afternoon and evening classes. Some of the areas available include: public history, economics, education, English, industrial engineering, history, liberal studies, life sciences, management, public administration and technical communication. Contact the department of interest for further information.

## COLLEGE OF ENGINEERING PROFESSIONAL DEGREE PROGRAM

Professional degree students are admitted as undergraduate students, are classified as "PR" students and are subject to rules and regulations as established and administered by the Dean of the College of Engineering.

A professional degree student who is subsequently admitted to the Graduate School may, with the approval of the master's advisory committee, the major department and the Graduate School receive graduate credit for a maximum of nine hours credit for courses in which a grade of "B" or higher was received.

## COOPERATING RALEIGH COLLEGES

The Cooperating Raleigh Colleges (CRC) is a voluntary organization comprised of North Carolina State University, Meredith College, Peace College, St. Augustine's College, St. Mary's College and Shaw University. Graduate programs are currently offered only at NCSU and Meredith College, but the organization provides the opportunity for graduate students to enroll at either institution for a course or courses not offered on their home campus.

Any NCSU graduate degree student who is enrolled in at least three graduate credit hours on the NCSU campus may take a course at Meredith College during the fall or spring semester, provided that (a) the course is not taught on the NCSU campus and (b) the advisory committee considers the course educationally desirable.

NCSU students may not register for more than a total of two courses in any semester at Meredith, and no more than six of the required academic credits for a master's degree at NCSU may be accepted from that institution. Grades from Meredith are not used in computing a student's NCSU grade point average.

Under this agreement, regular tuition and fees are paid to NCSU. Certain special fees may be required for specific courses at Meredith, and the student is responsible for paying these fees.

### CERTIFICATE RENEWAL

Public school personnel who are primarily interested in "certification credit" may enroll in the PBS program through the Division of Lifelong Education without forwarding transcripts of previous work to the Graduate School. In such cases, the College of Education and Psychology will be responsible for assessing the adequacy of the applicant's qualifications for enrollment in the course(s) concerned.

## Registration and Records

The Office of Registration and Records must have authorization from the Dean of the Graduate School before a graduate student in any classification will be permitted to register for classes. This authorization will be sent to the Office of Registration and Records at the time the student is notified of acceptance for graduate study. All students attending classes must be registered for credit or audit. Grade records are furnished the students at the end of each scheduled school term.

### INTERINSTITUTIONAL REGISTRATION

North Carolina State University participates in an Interinstitutional Registration program with the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro and Duke University. Under this agreement, graduate students enrolled at NCSU may undertake course work on these campuses upon the recommendation of their advisory committees. Courses offered by North Carolina A&T University and by the University of North Carolina at Charlotte over the Microelectronics Center of North Carolina communications system are also available through Interinstitutional Registration.

Even though taking a course on another campus, the graduate student is exclusively under the administrative direction of the North Carolina State University Graduate School. Enrollment for courses on other campuses will take place on this campus, using special forms obtained from the Office of Registration and Records. The Graduate School shall consider courses taken on other campuses as a part of the student's normal load, and the billing for such work will be through the Office of Finance and Business. The procedures followed in the summer sessions are somewhat different; detailed instructions are available in the Office of Registration and Records.

When the grading system on the campus being visited is different from the North Carolina State University system, grades received under Interinstitutional Registration will be converted to the North Carolina State University system. "H," "P," "L" and "F" grades earned at the University of North Carolina at Chapel Hill and "E," "G," "S" and "F" grades earned at Duke University will be converted to "A," "B," "C" and "F" grades, respectively.

## COURSE LOAD

A full-time graduate course load is 9 to 15 credits per semester (including audits) and 3-6 credits per summer session (including audits). Audits in subjects in which the student has no previous experience will be evaluated at full credit value in determining course load. Audits taken as repetition of work previously accomplished are considered at one half of their value in calculating course loads. With the single exception of foreign language audits, all audit registrations must fall within the range of maximum permissible course loads.

Foreign students on F-1 and J-1 visas are required by the Immigration and Naturalization Service to carry a full-time course of study to remain in status.

Graduate students holding assistantships are restricted to the following maximum semester course loads: full time, 3 hours; three-quarters time, 6 hours; one-half time, 9 hours; one-quarter time, 12 hours. External employment obligations of students on assistantships plus their assistantship obligations should not exceed these limits. Additionally, graduate assistants are limited to the following maximum totals of credit hours over the duration of their appointments:

| *Assistantship Classification* | *Length of Appointment* | *Maximum Credit Hours* |
|---|---|---|
| Full time | 9 months | 6 |
| Full time | 12 months | 9 |
| 3/4 time | 9 months | 12 |
| 3/4 time | 12 months | 16 |
| 1/2 time | 9 months | 18 |
| 1/2 time | 12 months | 24 |
| 1/4 time | 9 months | 24 |
| 1/4 time | 12 months | 30 |

### Drop Dates for Minicourses

The drop date for a five-week minicourse is the last day of the third week of the mini-course. The drop date for a seven-week minicourse is the last day of the fourth week of the minicourse.

## GRADING AND ACADEMIC STANDING

Performance in lecture courses is evaluated as "A" (Excellent), "B" (Good), "C" (Passing), "D" or "F" (Failed). In order to receive graduate degree credit, a grade of "C" or higher is required. All grades on courses taken for graduate credit as an undergraduate at NCSU and all grades on courses taken in a graduate classification at NCSU in courses numbered 400 and above are included in the graduate grade point average. Courses at the 300 level and below are not considered for graduate credit and grades earned on them do not enter the grade point average.

Performance in research, seminar and special problems courses in evaluated as either "S" (Satisfactory) or "U" (Unsatisfactory), and these grades are not used in computing the grade point average. However, a student who receives a "U" on any course will not receive credit for that course and may be required to repeat it.

Courses regularly graded A,B,C,D,F may not be taken for S,U grading by graduate students. The "Master Listing of Approved Graduate Courses" identifies the approved grading (A,B,C,D,F or S,U) for each 500- and 600-level course. Generally, courses numbered through the 590 series and the 690 series will receive "S" or "U" grading. Other course numbers will carry A,B,C,D,F grading. Any deviation from the approved grading for a particular course must be requested by the department and approved by the Academic College/School Dean and the Graduate Dean prior to teaching the course. Also included in the GPA calculations and the determination of academic standing are those credits earned in a PBS classification which becomes a part of the Plan of Graduate Work.

At the discretion of the instructor, students may be given an "IN" (Incomplete) grade for work not completed because of a serious interruption in their work not caused by their own negligence. An "IN" must not be used, however, as a substitute for an "F" when the student's performance in the course is not passing. An "IN" is only appropriate when the student's record in the course is such that the successful completion of particular assignments, projects, or tests missed as a result of a documented serious event would enable that student to pass the course. Only work missed may be averaged into the grades already recorded for that student. A student who received as "IN" must complete the unfinished work to have the Incomplete converted to a final grade by the end of the next semester in which the student is enrolled provided that this period is not longer than 12 months from the end of the semester or summer session in which the Incomplete was received; otherwise, the "IN" will be automatically converted to "F" or "U," in accord with the grading approved for the particular course. All grades of "IN" must be cleared prior to graduation. Students must not register again for any courses in which they have "IN" grades; such registration does not remove "IN" grades, and the completion of

the course on the second occasion will automatically result in an "F" for the incomplete course.

Except in the case of Interinstitutional Registration (see p. 18), grades on courses transferred from another institution will not be included in computing the grade point average.

Graduate students are given a notice of academic warning if they have accumulated less than nine hours at the 400-level or above and have less than a 3.0 ("B" average). Graduate students are placed on academic probation if they accumulate nine or more but less than eighteen credit hours at the 400-level or above and have a grade point average of less than 3.0 ("B" average). A student's graduate study is terminated if eighteen or more credit hours at the 400-level or above are accumulated with a grade point average of less than 3.0 ("B" average). In the case of program termination, no further registration in a graduate classification will be permitted. Under extenuating circumstances the student will be reinstated upon the written recommendation of the department and approval by the Graduate Dean. Departments have the prerogative of recommending the termination of a student's graduate admission at any time.

Students who are eligible to attend the first summer session are eligible to attend either or both summer sessions. For example, students who receive a notice of "Graduate Admission Terminated" at the end of the first summer session may register for second summer session unless the major department recommends otherwise.

A graduate student must be in good academic standing ("B" or better average) to be eligible for appointment to an assistantship, fellowship or traineeship and must be registered in each semester in which the appointment is in effect.

## CONTINUOUS REGISTRATION

After a student is admitted to the Graduate School and enrolls for the first time, she/he is required to maintain continuous registration, *i.e.*, be enrolled each semester, excluding summer sessions, until she/he has either graduated or her/his graduate program at NCSU has been terminated. After Summer 1994, all students who graduate during the second summer session must be registered for either the first or second summer session. A student in good academic standing who must interrupt her/his graduate program for good reasons may request a leave of absence from graduate study for a definite period of time, normally not to exceed one year. The request should be made at least one month prior to the term involved. Upon endorsement of the request by the student's graduate advisory committee and Director of Graduate Programs, and approval by the Graduate School, the student would not be required to be registered during the leave of absence. The time that the

student spends on an approved leave of absence will be included in the time allowed to complete the degree, *i.e.*, 6 years for master's and 10 for doctoral. Graduate students whose programs have been terminated because of failure to maintain continuous registration and who have not been granted a leave of absence during a fall or spring semester will be required to reapply for admission if they wish to resume their graduate studies at NCSU.

## SENIORS

A member of the senior class may, with prior approval of the Dean of the Graduate School, register for graduate credit in courses at the 400 and 500 levels as long as the combined graduate and undergraduate credit load is not more than 15 hours. Seniors with an accumulated grade point average of 3.2 or better in their major may enroll for a combined graduate and undergraduate credit load of 18 hours upon the recommendation of the student's advisor and approval by the department and the Graduate School. No more than six hours of graduate credit may be accumulated by a senior, and those graduate credits may not be applied toward the requirements for a baccalaureate degree. Courses at the 600 level are not ordinarily open to undergraduates, although occasional exceptions are made for senior honor students.

Seniors desiring to take courses for graduate credit should contact their major advisers who will forward appropriate requests to the Graduate Dean for approval.

## AUDITS

Students wishing to audit courses must have the approval of their advisers and of the instructors teaching the courses. While auditors receive no course credit, they are expected to attend class regularly. The degree to which auditors must participate in class beyond regular attendance is optional with the instructors; any such requirements should be clearly explained to the auditors in writing at the beginning of the semester. An instructor who feels that an auditor has failed to fulfill the stipulated requirements is justified in marking "NR" (no recognition given for audit) on the grade report roll.

## GRADUATION

There are three official graduations for graduate students per year, occurring at the end of the fall and spring semesters and at the end of the second summer session. Formal commencement exercises are held at the end of spring and fall semesters, but any student who graduated the preceding second summer session is eligible to participate in the December commencement if he or she notifies the Graduate School in writing of such an intent at least four weeks in advance of the actual commencement date. Conversely, any student scheduled to graduate in the spring

or fall semesters but not planning to attend commencement exercises should notify the Graduate School in writing of the desire to have the degree conferred *in absentia*.

**Diploma Order Request Cards**
The diploma order request card is the form used to order a diploma for a student anticipating graduation at the end of a particular semester or second summer session. The cards are normally due to the Graduate School Office by the end of the sixth week of classes during the fall and spring semesters and by the graduation deadline noted in The Calendar for the second summer session graduation. The diplomas for those students graduating at the end of second summer session and those not attending a formal commencement exercise are mailed by the Office of Registration and Records which is also responsible for the ordering of diplomas.

# Tuition and Fees

A statement of tuition and fees is mailed to each preregistered student approximately five weeks before the beginning of any term. The statement must be returned with full payment or complete financial assistance information by the due date appearing on the statement. Normally the due date is approximately two weeks before classes begin. Non-preregistered students are required to pay their tuition and fees at registration.

## SEMESTER RATE SCHEDULE--1993-94 ACADEMIC YEAR
## (ALL RATES ARE SUBJECT TO CHANGE WITHOUT NOTICE)

*(*For definition of in-state and out-of-state rates, see pp. 26-29. **Under certain conditions, nonresident students who have been offered an assistantship, traineeship or fellowship may be eligible for reduced tuition rates; see tuition remission on p. 25.)*

| | RESIDENTS OF NORTH CAROLINA* | NONRESIDENTS** |
|---|---|---|
| *Hours* | *Tuition and Fees* | *Tuition and Fees* |
| 0-Thesis | $215 | $ 731 |
| 0-2 | 215 | 1,095 |
| 3-5 | 321 | 2,081 |
| 6-8 | 535 | 3,176 |
| 9 | 749 | 4,270 |

## SUMMER SESSION RATE SCHEDULE--1994

| | RESIDENTS OF NORTH CAROLINA | NONRESIDENTS |
|---|---|---|
| *Hours* | *Tuition and Fees* | *Tuition and Fees* |
| 0 | $175 | $ 452 |
| 1 | 175 | 452 |
| 2 | 228 | 780 |
| 3 | 281 | 1,106 |
| 4 | 334 | 1,434 |
| 5 | 379 | 1,745 |
| 6 | 425 | 2,057 |
| 7 | 471 | 2,368 |
| 8 | 517 | 2,681 |
| 9 | 562 | 2,992 |

## SPECIAL REGISTRATION AND FEES--1993-94 ACADEMIC YEAR

The following GR courses are assessed the 0-Thesis rate:

| | |
|---|---|
| GR 596S | Master's Summer Research |
| GR 597 | Master's Examination Only |
| GR 598 | Master's Thesis Preparation |
| GR 695 | Doctoral Preliminary Examination Only |
| GR 696S | Doctoral Summer Research |
| GR 697 | Doctoral Dissertation Research |
| GR 698 | Doctoral Dissertation Preparation |

See Graduate School Registrations under the Minor and Other Organized Programs of Study section for descriptions of these courses.

*Audits:* During semester when registered and paying for other course work: One audit free, each additional audit same cost as for credit;
During semester when not registered for other course work: Same cost as for credit;
During any summer session: Same cost as for credit.

*Full-time Faculty or Staff:* $ 7

*Microfilming Doctoral Dissertation:* $57

*Office of International Visitors:* A special administrative management fee of $250 per semester and $150 per summer session is required from a contracting agency sponsoring international students who are programmed and advised by the University's Office of International Visitors.

## TUITION REMISSION

Unless tuition is expressly provided by the terms of an assistantship or fellowship, a recipient must pay tuition at the rate determined by his or her residence status. However, a nonresident graduate student awarded an assistantship or a fellowship may be eligible for a reduced tuition rate (tutition remission) comparable to the in-state rate. Further information may be obtained by contacting the department of major interest.

If a student has been granted tuition remission and that student terminated his/her program or goes off the assistantship which provided him/her with entitlement to tuition remission, the student will be billed for the remainder of the out-of-state tuition by the University Cashier's Office.

## FULL-TIME FACULTY AND EMPLOYEES

Full-time faculty of instructor rank and above and other full-time employees of the University who hold membership in the Teachers' and State Employees' Retirement System may register for credit or as auditors with free tuition privileges for one course in any academic term at any campus of the University of North Carolina. Free tuition privileges do not apply during the summer. Each applicant for free tuition must submit through regular channels a form provided by the University.

## REFUND OF TUITION AND FEES

A student who officially withdraws from school during the first two weeks of a semester or by the end of the fifth day of a summer session will receive a tuition and fees refund of the full amount paid less a $25 registration fee. After the two-week period, no refund will be made.

In some instances, circumstances justify the waiving of rules regarding refunds. An example might be withdrawal because of sickness. Students have the privilege of appeal to the Fee Appeals Committee when they feel special consideration is merited. Applications for such appeals may be obtained from the University Cashier's Office, 1101 Pullen Hall. *(NOTE: No refunds are granted after the first six weeks of classes regardless of the reason for withdrawal or reduction in course load, since the University has already incurred the full enrollment costs.)*

## COOPERATIVE EDUCATION PROGRAM

The Cooperative Education Program (co-op) is designed to give graduate students the option of integrating academic study and related job experience and is available to qualified students in any major. Sponsored, paid work assignments in industry,

business and government complement students' classroom learning. More than 200 employers are partners in this academically relevant design for experiential education. The work experience is selected in terms of its relationship to a student's major and provides for full-time or part-time work. The employer makes the job offer based upon the student's qualifications, resume and interview. Work assignments are supervised by the employer and monitored by the co-op program staff. Participation in co-op entails the cost of registration each term of employment, currently $212 for a full-time co-op job.

For admission to the program, students must meet the following criteria:

- Full-time enrollment during the semester prior to the first work session.
- Completion of at least one semester before applying to the program.
- A minimum grade point average of 3.0.
- Attendance at a co-op orientation session.
- Approval of the graduate advisor or Director of Graduate Programs.
- An interview with a Cooperative Education Program Coordinator or the director.

International students, in addition to meeting the above requirements, must meet visa regulations pertaining to curricular practical training.

For more information, students should attend an orientation session. A recorded message on 515-4427 provides the orientation schedule.

## RESIDENCE STATUS FOR TUITION PURPOSES

The basis for determining the appropriate tuition charge rests upon whether a student is a resident or a nonresident for tuition purposes. Each student must make a statement as to the length of his or her residence in North Carolina with assessment by the institution of that statement to be conditioned by the following:

*Residence*--To qualify as a resident for tuition purposes, a person must become a legal resident and remain a legal resident for at least twelve months immediately prior to classification. Thus, there is a distinction between legal residence and residence for tuition purposes. Furthermore, twelve months' legal residence means more than simple abode in North Carolina. In particular, it means maintaining a domicile (permanent home of indefinite duration) as opposed to "maintaining a mere temporary residence or abode incident to enrollment in an institution of higher education." The burden of establishing facts which justify classification of a student as a resident entitled to in-state tuition rates is on the applicant for each classification, who must show his or her entitlement by the preponderance (the greater part) of the residentiary information.

*Initiative*--Being classified a resident for tuition purposes is contingent on the stu-

dent's seeking such status and providing all information that the institution may require in making the determination.

*Parents' Domicile*--If an individual, irrespective of age, has living parent(s) or court-appointed guardian of the person, the domicile of such parent(s) or guardian is, prima facie, the domicile of the individual; but this prima facie evidence of the individual's domicile may or may not be sustained by other information. Further, nondomiciliary status of parents is not deemed prima facie evidence of the applicant child's status if the applicant has lived (though not necessarily legally resided) in North Carolina for the five years preceding enrollment or re-registration.

*Effect of Marriage*--Marriage alone does not prevent a person from becoming or continuing to be a resident for tuition purposes, nor does marriage in any circumstance insure that a person will become or continue to be a resident for tuition purposes. Marriage and the legal residence of one's spouse are, however, relevant information in determining residentiary intent. Furthermore, if both a husband and his wife are legal residents of North Carolina and if one of them has been a legal resident longer than the other, then the longer duration may be claimed by either spouse in meeting the twelve-month requirement for in-state tuition status.

*Military Personnel*--A North Carolinian who serves outside the State in the armed forces does not lose North Carolina domicile simply by reason of such service. Students from the military may prove retention or establishment of residence by reference, as in other cases, to residentiary acts accompanied by residentiary intent.

In addition, a separate North Carolina statute affords tuition rate benefits to certain military personnel and their dependents even though not qualifying for the in-state tuition rate by reason of twelve months' legal residence in North Carolina. Members of the armed services, while stationed in and concurrently living in North Carolina, may be charged a tuition rate lower than the out-of-state tuition rate to the extent that the total of entitlements for applicable tuition costs available from the federal government, plus certain amounts based under a statutory formula upon the in-state tuition rate, is a sum less than the out-of-state tuition rate for the pertinent enrollment. A dependent relative of a service member stationed in North Carolina is eligible to be charged the in-state tuition rate while the dependent relative is living in North Carolina with the service member and if the dependent relative has met any requirement of the Selective Service System applicable to the dependent relative. These tuition benefits may be enjoyed only if the applicable requirements for admission have been met; these benefits alone do not provide the basis for receiving those derivative benefits under the provisions of the residence classification statute reviewed elsewhere in this summary.

*Grace Period*--If a person (1) has been a bona fide legal resident, (2) has consequently been classified a resident for tuition purposes and (3) has subsequently lost North Carolina legal residence while enrolled at a public institution of higher education, that person may continue to enjoy the in-state tuition rate for a grace period of twelve months measured from the date on which North Carolina legal residence was lost. If the twelve months end during an academic term for which the person is enrolled at a State institution of higher education, the grace period extends, in addition, to the end of that term. The fact of marriage to one who continues domiciled outside North Carolina does not by itself cause loss of legal residence, marking the beginning of the grace period.

*Minors*--Minors (persons under 18 years of age) usually have the domicile of their parents, but certain special cases are recognized by the residence classification statute in determining residence for tuition purposes.

(a) If a minor's parents live apart, the minor's domicile is deemed to be North Carolina for the time period(s) that either parent, as a North Carolina legal resident, may claim and does claim the minor as a tax dependent, even if other law or judicial act assigns the minor's domicile outside North Carolina. A minor thus deemed to be a legal resident will not, upon achieving majority before enrolling at an institution of higher education, lose North Carolina legal residence if that person (1) upon becoming an adult "acts, to the extent that the person's degree of actual emancipation permits, in a manner consistent with bona fide legal residence in North Carolina" and (2) "begins enrollment at an institution of higher education not later than the fall academic term next following completion of education prerequisite to admission at such institution."

(b) If a minor has lived for five or more consecutive years with relatives (other than parents) who are domiciled in North Carolina and if the relatives have functioned during this time as if they were personal guardians, the minor will be deemed a resident for tuition purposes for an enrolled term commencing immediately after at least five years in which these circumstances have existed. If under this consideration a minor is deemed to be a resident for tuition purposes immediately prior to his or her eighteenth birthday, that person on achieving majority will be deemed a legal resident of North Carolina of at least twelve months' duration. This provision acts to confer in-state tuition status even in the face of other provisions of law to the contrary; however, a person deemed a resident of twelve months' duration pursuant to this provision continues to be a legal resident of the State only so long as he or she does not abandon North Carolina domicile.

*Lost but Regained Domicile*--If a student ceases enrollment at or graduates from an institution of higher education while classified a resident for tuition purposes and then both abandons and reacquires North Carolina domicile within a 12-month period, that person, if he or she continues to maintain the reacquired domicile into reenrollment at an institution of higher education, may re-enroll at the in-state tuition

rate without having to meet the usual 12-month durational requirement. However, any one person may receive the benefit of this provision only once.

*Change of Status*--A student admitted to initial enrollment in an institution (or permitted to re-enroll following an absence from the institutional program which involved a formal withdrawal from enrollment) must be classified by the admitting institution either as a resident or as a non-resident for tuition purposes prior to actual enrollment. A residence status classification once assigned (and finalized pursuant to any appeal properly taken) may be changed thereafter (with corresponding change in billing rates) only at intervals corresponding with the established primary divisions of the academic year.

*Transfer Students*--When a student transfers from one North Carolina public institution of higher education to another, he or she is treated as a new student by the institution to which he or she is transferring and must be assigned an initial residence status classification for tuition purposes.

*Prevailing North Carolina Law*--General Statute (G.S.) 116-143.1 is the prevailing statute governing residence status classification. A copy of the applicable law and/or implementing regulations is available for inspection in the Office of Graduate Admissions, 103 Peele Hall. Residence-and-Tuition Status Applications are also available in the same office and questions should be directed to that office.

# Financial Support for Graduate Students

## Fellowships and Graduate Assistantships

Graduate students may receive financial support through fellowships, traineeships and teaching or research assistantships sponsored by federal, state and private agencies. Prospective students may request consideration for financial assistance by completing the appropriate sections of the admissions application form. Applicants for these awards should correspond directly with the department of major interest concerning the availability of awards and related information. Enrolled students should contact the major department. Prospective and enrolled graduate students are encouraged to apply for national, regional and foundation fellowships in addition to awards sponsored through the University. Information on how to apply for this type of financial assistance is available in the Graduate School. Enrolled or prospective students may also consult the Financial Aid Office for information on federal loan programs.

Unless tuition is expressly provided by the terms of the award, an award recipient must pay tuition at the rate determined by his or her residence status. However, a nonresident graduate student awarded an assistantship or a fellowship may be eligible for a reduced tuition rate comparable to the in-state rate. Further information may be obtained by contacting the department of major interest.

A graduate student must be in good academic standing (B or better average) to be eligible for appointment to an assistantship, fellowship or traineeship and must be registered in each semester in which the appointment is in effect. This also means that if an assistantship holder covered by tuition remission terminates his/her studies after the last day to withdraw from the University or to drop a course with a refund (approximately seven days after classes commence), that student will be responsible for the prorated part of tuition and fees.

## RESEARCH AND TEACHING ASSISTANTSHIPS

The University offers approximately 1,900 assistantships each year. Stipend rates for teaching and research assistantships are competitive with other universities. For further information on the availability of assistantships, applicants should contact the program area of interest.

## DEPARTMENTAL FELLOWSHIPS

Several departments or programs offer fellowships. Students are nominated for these fellowships by their departments or programs with selection being made by faculty committees or by the Graduate School. For additional information concerning such fellowships, the applicant should contact the appropriate college, department or program. Examples of such fellowships are listed below:

> PHY Training Grant, USDA National Needs Fellowship, Biotechnology Fellowship and Purina Mills Research Fellowship, all through the College of Agriculture and Life Sciences; Dairyman Inc. Fellowship in the Department of Animal Science; Pioneer Hybred International in the Department of Crop Science; Chemical Industries Institute for Toxicology through the Toxicology Program; Fellowship through the Department of Plant Pathology; E. G. Moss and R. J. Reynolds Fellowships through the N. C. Agricultural Research Service in the College of Agriculture and Life Sciences; Harkema Fellowship in the Department of Zoology; NASA Traineeship, Eastman Scholarship and ARO Fellowships in the Department of Mechanical and Aerospace Engineering; Nuclear Energy Fellow ship, Fusion Technology Fellowship and Murray Fellowship through the Department of Nuclear Engineering; Dupont Manufacturing Systems Fellowship through the Integrated Manufacturing Systems Engineering Insti-

tute; Kimley-Horn Graduate Scholarship and Carolina Asphalt Association, Inc., through the Department of Civil Engineering; ECE Levels I, II and III Supplementary Fellowships, IBM Graduate Fellowship (solid state-electronics), IBM Graduate Fellowship in Manufacturing Research, IBM Graduate Fellowship in Computer Networking and Dupont Graduate Fellowships through the Department of Electrical and Computer Engineering; Dupont Fellowship in Chemical Engineering, Phillips Graduate Fellowship, Southeastern Regional and PIA Supplemental Fellowship in the Department of Chemical Engineering; Dean's Fellowships, Microelectronics Center of N.C. and National Consortium for Minorities in Engineer ing (GEM), all through the College of Engineering; SOHIO Fellowship in the Department of Physics; Gertrude M. Cox Fellowship in the Department of Statistics; Mary Lee and Luther Barnhardt Scholarship in the Depart ment of History; Title IX Fellowship in the Department of Political Science and Public Administration; H. W. Close Fellowship through the College of Textiles.

## NATIONAL, REGIONAL AND FOUNDATION FELLOWSHIPS

These awards are made to an individual rather than to the University. Recipients are chosen through competitions expressive of the terms of each award. Examples of these awards held by currently enrolled graduate students follow:

National Science Fellowship (NSF) Graduate Fellowship
Department of Defense National Defense Science and Engineering Graduate Fellowship (DOD NDSEG)
Department of Defense Office of Naval Research Graduate Fellowship (DOD ONR)
Department of Defense United States Air Force Laboratory Graduate Fellowship (DOD USAF)
Department of Energy Civilian Radioactive Waste Management Fellowship (CRWM)
Department of Energy Environmental Restoration and Waste Management Fellowship (DOE ERWM)
Department of Energy Computational Science Graduate Fellowship
NASA Graduate Student Researchers Program - Underrepresented Minority Focus Award
National Consortium for Graduate Degrees for Minorities in Engineering Inc. (GEM) Fellowship
National Physical Science Consortium: Graduate Fellowships for Minorities and Women in the Physical Sciences

Applications and/or information on the above fellowship programs are available in the Graduate School.

## Graduate School Fellowships

The African-American Graduate Assistance Grant (AAGAG) is a grantsmanship program created by North Carolina State University to aid in the support of African-American graduate students in all graduate programs of the University.

The AAGAG program provides stipends on a financial need basis up to $5,000 for the academic year. Recipients must be full-time, new or continuing students pursuing master's or doctoral degrees at NCSU. The Graduate School should be contacted for further information.

Alumni Association Graduate Fellowship Supplements are funded by the NCSU Alumni Association each year in an effort to recruit outstanding graduate students, with the highly competitive award process being coordinated through the Graduate School office. For the 1993-94 academic year twenty-six Graduate Fellowship Supplements were funded; twenty-four of these were awarded across campus and two were awarded to support the management of University Archives. These supplements are awarded on a one-time-only basis as a financial incentive *and beyond* whatever fellowship or assistantship may be offered. In addition, two Alumni Association Graduate International Fellowships are awarded through the International Student Office.

American Indian Student Legislative Grant Program: The General Assembly of North Carolina has provided funds for the American Indian Student Legislative Grant Program for a number of grants to American Indian students interested in pursuing doctoral degrees at NCSU. The fellowships have a maximum value of $4,000 annually.

To be eligible for a fellowship, interested students must be enrolled full-time and in good standing in a doctoral degree program, meet state residency requirements, have financial need and be an American Indian under the program's definition. This definition states that an eligible individual is one who maintains cultural identification as an American Indian through membership in an Indian tribe recognized by the State of North Carolina or by the federal government or through other tribal affiliation or community recognition.

Graduate Assistance in Areas of National Need: The U.S. Department of Education provides support to expedite completion of the doctoral degree for graduate students committed to a career of teaching and research in an identified area of national need. In addition to an annual stipend of up to $14,000 depending on financial need, the program reimburses educational expenses. To date, NCSU has awarded 51 fellowships to graduate students studying electronic materials in engineering, physics and chemistry. Information is available in the Graduate School.

The Jerry J. Collier Scholarship provides support to an NCSU alumnus(a) who participated in a varsity sport during his/her undergraduate tenure and who is entering a graduate program at NCSU. The criteria for selection include academic credentials and statement of goals and objectives. The scholarship is $3,000 for the academic year and is renewable. Information is available in the Graduate School.

Minority Presence Grant Program: Under the Board of Governors general Minority Presence Grant Program, African-American students may be eligible for special financial assistance if they are residents of North Carolina, enrolled full-time and demonstrate financial need.

The Minority Presence Grant Program for Doctoral Study, Law and Veterinary Medicine provides stipends of up to $4,000 for the academic year, with an option of $500 in additional support for study in the summer sessions, for African-American residents of North Carolina who are selected to participate. Recipients must be full-time students pursuing doctoral degrees, law degrees or degrees in veterinary medicine at East Carolina University, NCSU, University of North Carolina at Chapel Hill or The University of North Carolina at Greensboro.

Patricia Roberts Harris Graduate Fellowships provide funds for minority or women graduate students who demonstrate financial need and who plan to enroll in programs where such students are traditionally underrepresented nationally. Currently, fellowships are offered in engineering, statistics, physics, biochemistry, microbiology, animal science, botany, genetics, management, textile and apparel management, parks, recreation and tourism management, public administration, and counselor education. Thirteen fellowships, each in the amount of up to $14,000/year, were awarded through the Graduate School in 1993-94. Tuition and fees are also paid. Information pertaining to the fellowships is available in the Graduate School.

## Other Financial Aid

### LONG-TERM LOANS

Graduate students who are American citizens or eligible noncitizens may apply for long-term, low interest loans through the Financial Aid Office. To qualify for loans, students must be making satisfactory academic progress towards a degree and must complete the appropriate application materials to demonstrate that all federal eligibility requirements for loan consideration have been met. The *Free Application for Federal Student Aid* is the form required by NCSU to document eligibility for federal loan assistance. In addition, students must complete the university's *Institutional Application*, an *Application and Promissory Note for Federal Stafford Loans (Subsidized and Unsubsidized)*, and have a *Financial Aid Transcript* sent to the NCSU

Financial Aid Office from every institution previously attended (regardless of whether aid was applied for or received at those institutions). Although students are expected to apply for and to accept any available assistantships or fellowships provided by the Graduate School, it is recommended that students not wait for these decisions to be made before applying for financial aid through the Financial Aid Office. If graduate assistantships or fellowships are offered, and borrowing no longer becomes necessary, students have the option to cancel their requests for loan assistance at any point.

*Federal Stafford Loans (Subsidized and Unsubsidized):* Funding for these loans is provided by private lenders. Since they are partially supported by the federal government; however, students must follow federal guidelines in applying for aid to qualify. Information on specific application procedures, loan maximums, interest rates and participating lenders may be obtained from the Financial Aid Office. Students who apply for these loans and demonstrate need by federal definition qualify for Subsidized Stafford Loans, meaning that the federal government pays the interest on the loan while the student is enrolled on at least a half-time basis. If no need is demonstrated, students may still borrow to meet the cost of education (minus other resources, such as scholarships, fellowships and tuition remissions) through the Unsubsidized Stafford Loan Program. Students who receive unsubsidized loans are charged interest while enrolled, although they may elect to capitalize interest payments to repay with principal upon completion of degree. For both subsidized and unsubsidized loans, repayment of principal is deferred until completion of the degree or until termination of at least half-time enrollment status.

*Other Loan Options:* Because of limited institutional funds, graduate students generally are expected to apply for the maximum Federal Subsidized and Unsubsidized Stafford Loans for which they are eligible if funding is needed to assist with educational expenses. Students who need to borrow more than the maximum amounts possible through those loan programs (the combined annual maximum is $18,500) will be considered for other loan funds administered by the Financial Aid Office if sufficient funding is available.

## PART-TIME JOBS

The *Federal Work-Study Program* is a federal program designed to provide part-time jobs to students who apply for financial aid using the *Free Application for Federal Student Aid* and who document need by federal guidelines. Effort is made to assign students to jobs with their special interests and skills. Most of the jobs are on-campus, but limited opportunities for off-campus employment in community service areas are also available. Although priority for these positions is generally given to undergraduate students, graduate students who express a specific interest in being

considered for a work-study job will also be given priority. Other jobs not based on need are listed at the Financial Aid Office and are open to all students.

### SHORT-TERM EMERGENCY LOANS

Loans, usually in amounts of $100 or less, to meet emergency expenses may be obtained on short notice (generally on the day of application) at the Financial Aid Office. These loans, in that they are designed for short-term, emergency use, must be repaid within about 30 days. A loan may not be taken out between semesters or between summer sessions.

## Military Education and Training

The Reserve Officer Training Corps (ROTC) selects interested University students for enrollment in Army ROTC (AROTC) or in Air Force ROTC (AFROTC) for officer education and training leading toward a commission.

The Army and Air Force ROTC departments educate and train University students, graduate and undergraduate, for a commission in their respective military services. These students must have four full semesters (undergraduate or graduate) remaining at the time they enter the ROTC Program (exceptions for Army ROTC are noted below). Uniforms and books for ROTC are provided. Transfer credit is allowed for previous ROTC course work at other institutions.

Graduate students who will be at NCSU for at least two years may, upon successful completion of a six-weeks' summer leadership training period, be enrolled in the ROTC Program. Entry requirements for the AROTC program may also be met by having met any *one* of the following requirements:

1. Completed basic level ROTC courses as an undergraduate.
2. Be an honorably discharged veteran.
3. Have completed military basic training and be a member of a Reserve Component Unit of any branch of the Armed Forces or National Guard.

Air Force ROTC offers a Flight Screening Program for selected cadets which is conducted by an Air Force flying school in Texas during the summer at no expense to the student. Students successfully completing ROTC flight screening may be selected for further flight training as an Air Force pilot.

Graduate students enrolled in the junior and senior years of ROTC receive $100 per month. Scholarships which pay all tuition, fees and costs of required text books in addition to the $100 per month are available on a competitive basis.

Special provisions for veterans are made in Army ROTC whereby they are granted placement credit for their prior service experience and training. Additionally, Army ROTC offers the student several points of entry into the ROTC Program, under a process of granting ROTC placement credit for college courses or other worthwhile experiences that contribute to the requisite skills of a second lieutenant. Army ROTC counselors are available to evaluate the students' prior learning experiences and advise them as to where they can be placed in ROTC. Under the Army's Simultaneous Membership Program, the graduate student may participate in the Army Reserve or National Guard and receive approximately $147 per month in addition to the $100 monthly stipend. The National Guard provides up to $500 tuition costs per year for its members.

Additional information on Army ROTC may be obtained from the Professor of Military Science, Room 154, Reynolds Coliseum (515-2428) and Air Force ROTC from the Professor of Aerospace Studies, Room 145, Reynolds Coliseum (515-2417).

# Health Services

The Student Health Service, located in Clark Hall, offers health care to students in a campus facility staffed by eight full-time physicians, four Nurse Practitioners, a pharmacist, laboratory technicians, registered nurses, health educators and support staff.

During fall and spring semester, the Health Service is open 24 hours weekdays (except during holidays and breaks) and until 11:00 p.m. Saturday and Sunday nights. Appointments are needed to see a health care provider and may be made in person at the Health Service or by calling 515-7107 (8:00 a.m.-4:45 p.m.). Gynecology appointments are made at 515-7762. Urgent medical problems will be seen at the clinic 24 hours a day. Physicians maintain office hours Monday through Friday, 8:30 a.m.-4:15 p.m. and are on call at other times. During summer sessions, Student Health Service is open Monday-Friday, 8:00 a.m.-5:00 p.m.

All currently enrolled students are eligible for medical care. The pre-paid health fee covers professional services such as nurse and M.D. visits, laboratory tests, cold medications and health education. There is a nominal charge for x-rays, prescriptions and specialty clinics. Students are responsible for all services received off-campus, *e.g.*, off-campus M.D. or hospital.

## HEALTH INSURANCE

NCSU strongly encourages each student to have accident and sickness insurance protection, either by their parents' group policy or under the NCSU Student

Insurance Plan. The policy offered by the University helps cover the cost of referrals to off-campus specialists or to hospitals for serious illnesses.

For your protection--with the average hospital charge at $1992 per patient day for the NCSU plan (1992)--do not be uninsured! International students are **required** to have health insurance.

A brochure describing the NCSU student plan is mailed to all students in July. Call (919) 515-2563 for additional information.

# Housing

## OFF-CAMPUS HOUSING

The Housing Assignments Office maintains a self-help facility which makes available listings of off-campus housing accommodations sent to them by private landlords; however, specific arrangements for this housing must be contracted for by those individuals concerned. The listings are not mailed as they change frequently and most landlords and tenants prefer to complete the rental transaction in person rather than by telephone or mail. The Housing Assignments Office, 1112 Pullen Hall, is open from 8:00 a.m. until 5:00 p.m., Monday through Friday only.

The university does not operate a trailer parking area; however, privately owned parks are available within a reasonable distance of the campus.

## EDWARD S. KING VILLAGE

The University also maintains 295 apartments in E. S. King Village for students with families, single parents and graduate students. The monthly rental rates for the 1993-94 year was $240 for a studio, $250 for a one-bedroom apartment and $275 for a two-bedroom apartment including water only (gas is included in studio unites). This rate is subject to change on an annual basis. Information on availability and applications should be requested from Housing Assignments Office, 1112 Pullen Hall, North Carolina State University, Raleigh, NC 27695-7315.

## ON-CAMPUS HOUSING

The University furnishes housing for approximately 7,100 students. The residence halls are grouped in three areas - East, Central and West Campus - with each of the areas providing laundry facilities, convenience stores and recreational grass areas for sports. Living arrangements in the halls vary and include buildings with suites of four or five rooms with a common bathroom and buildings with rooms opening onto a central corridor. Rooms are furnished with a deak, chair, dresser, bed and

mattress, small closet and waste basket, but students must provide bed linen, pillows and towels.

The 1992-93 rental fee for a main campus residence hall double room was $725 per semester per student and is subject to change on an annual basis. New freshmen and continuing residents have priority for a room assignment over new graduate students.

# GRADUATE PROGRAMS

The Graduate School offers programs of study leading to the master's degree in 91 fields and the doctorate in 54. Each student's program is planned with an advisory committee of graduate faculty members to provide the opportunity for gaining advanced knowledge in the particular field of study. Graduate education is the final stage in the development of intellectual independence. It is different from undergraduate education in that the student is encouraged to establish premises, to hypothesize and to defend both the procedure and the conclusions of independent investigation. The burden of proof for the verifiability of knowledge rests on the student, not on the faculty member. Emphasis is placed upon the student's scholarly development through formal course work, seminars, research and independent investigation.

Graduate students are expected to familiarize themselves with the requirements for the degrees for which they are candidates and are held responsible for the fulfillment of these requirements.

## Master's Degrees

The Graduate School offers programs of study leading to the Master of Science degree, the Master of Arts degree and the Master's degree in certain designated fields.

### MASTER OF SCIENCE AND MASTER OF ARTS

For all Master of Science and Master of Arts degrees, the programs are planned with the objective of making possible a reasonable, comprehensive mastery of the subject matter in a chosen field. In most cases, the Master of Science and Master of Arts programs provide training and experience in research in order to familiarize the student with the methods, ideals and goals of independent investigation. In these cases, representative of most Master of Science and Master of Arts degree programs, a thesis is required. A small number of Master of Science and Master of programs do not require a thesis.

### MASTER'S DEGREE IN A DESIGNATED FIELD

A number of departments and programs offer master's degrees in designated fields. These are professional degrees and do not require a thesis.

# REQUIREMENTS FOR MASTER'S DEGREES

All departments and programs offering master's degrees may choose to offer the degree as an "Option B" program which has a different set of requirements from regular master's programs. A small number of departments and programs have chosen Option B. These programs will be identified in the section of this catalog titled "Fields of Instruction." Differences between the requirements of regular programs vs. Option B programs, where appropriate, are identified below.

## GRADUATE ADVISOR AND GRADUATE ADVISORY COMMITTEE

All students in master's programs must have a graduate advisor who is a member of the Graduate Faculty in the student's major department or program. The graduate advisor is appointed by the Director of Graduate Programs. In addition, all students, except those in Option B programs, must have a graduate advisory committee. The advisory committee is composed of at least three members of the Graduate Faculty. The graduate advisor serves as chair or co-chair of the committee. If the student has a minor, then one of the committee members must be from the minor department or program. The graduate advisory committee is appointed by the Director of Graduate Programs in the student's department or program. At the time of the request for a permit to schedule the final oral examination, the Graduate School verifies that the committee is constituted properly.

## PLAN OF GRADUATE WORK

The student's program of study is planned so as to provide a comprehensive view of the major field of interest and in related areas of knowledge, sometime constituting a minor. As great a latitude is permitted in the selection of courses as is compatible with the well-defined major and, in many cases, supporting courses or a minor. In general, it is expected that at least two-thirds of the credits will be in the major. If there are credits in a minor or supporting areas, they normally would not exceed one-third of the total. Since there are many possible combinations of course work, a specific Plan of Graduate Work is developed by the advisory committee with the student. The course work to be taken by the student and the thesis topic, where applicable, must be approved by the student's advisory committee and the Director of Graduate Programs in the student's department or program. This should be done prior to completion of one-half of the credits on the plan.

## CREDITS

A minimum of 30 semester credit hours is required for all master's degrees; however, many programs require more than thirty. Also, many students, in order to gain the breadth desired in their program or to make up deficits in their under-

graduate degree, will actually take more credit hours than the minimum required by the program. At least 20 semester hours must come from 500- and 600-level courses. No more than two credit hours of departmental seminar may be included in the minimum 30-credit program. Programs that require a thesis may include no more than six hours of research credit (699) in the minimum 30- credit-hour program. Research credit is not appropriate in the non-thesis programs. Non-thesis programs may include no more than six hours of independent study credits in the minimum 30-credit program. Courses at the 400 level counted toward the minimal 30-hour requirement may not come from the major field.

**Transfer credit:** No more than six of the minimal 30-hour requirement will be accepted from other institutions. A graduate course which has been completed with a grade of "B" or better may be considered for transfer to a master's program provided that it has been completed in a graduate or post-baccalaureate classification at an accredited graduate school. Exceptions are allowed for transfer from foreign institutions if the department or program provides the Graduate School with adequate documentation that the course is relevant to the degree with appropriate content and level of instruction resulting in student competencies at least comparable to those of students taking the equivalent course at NCSU and that the course was taught by faculty who are qualified to teach at the master's degree level. Transfer credit may not be used to fill the 20-hour 500- and 600-level requirement. Credit accepted by extension reduces the amount of credit that may be transferred from other instititions.

**Transfer of Undergraduate Credit:** Graduate credit may be allowed for up to 6 hours of the minimal 30-hour requirement for courses taken at NCSU provided that it is at the 400 level or higher, that the grade is "B" or better, that it was not counted to fulfill undergraduate requirements, and that it is recommended by the student's undergraduate advisor prior to enrollment in the course. No graduate credit will be allowed for excess credits completed in an undergraduate classification at another institution.

**Credit by Extension:** A maximum of six semester credits taken prior to admission to a graduate program and earned through NCSU extension study may be applied toward the minimal 30-hour requirement provided that the courses are graduate-level and taught by members of the NCSU Graduate Faculty. If a student has been admitted to the Graduate School, six additional semester credits earned through NCSU extension study may be used to meet the minimal 30-hour requirement. No graduate credit will be allowed for courses completed by extension at universities other than NCSU. Credit accepted by extension reduces the amount of credit that may be transferred from other instititions.

**Credit by Examination:** Credit by examination in graduate courses may be awarded for up to six credit hours. Passage of the examination entitles the student to credit only for the course; letter grades are not allowed for credit by examination. Credit by examination may not be obtained for research, seminars, project courses or audits. Residency requirements are not fulfilled by courses in which credit is awarded by examination. Credit by examination is permitted when all of the following conditions exist: a course required on the Plan of Graduate Work is not taught within time periods indicated by the Graduate Catalog or in time periods limited by agreements with outside agencies; the student requesting the examination has not previously registered for the course, either for credit or audit; the academic standards for credit by examination are commensurate with the academic standards for the course; the examination for credit is approved by the Director of Graduate Programs and the examination is prepare by and supervised by appropriate faculty; credit is to be given only when the performance is judged to be equivalent to a "B" grade or higher; only one examination for credit is to be permitted for the same course; the request for credit by examination is approved by the Graduate School.

**Credits from Previous NCSU Master's Degree:** Only six credits from a previous NCSU master's degree may be counted toward the minimal 30-hour requirement.

**Second Master's in the Same Field:** The Graduate School will not admit or transfer a student to a master's program if he/she holds a master's degree in the same discipline without a statement of justification by the student's Director of Graduate Programs.

## MINOR

The Graduate School does not require a minor; however, individual departments and programs may require a minor. All students, except those in Option B programs, have the option of selecting a minor. In most cases, the minor will be in a single department or program. In some cases, an interdisciplinary minor, consisting of related credits from more than one department or program, will be selected. When a student does select a minor, the minor credits on the Plan of Graduate Work must be approved by the graduate advisory committee member, and, in some cases, the Director of Graduate Programs, from the minor department or program.

## CO-MAJOR

Students may co-major at the master's level with the approval of both departments and/or programs and appropriate representation on the advisory committee. Co-majors must be within the same degree area, *i.e.*, Master of Science and Master of Science, Master of Arts and Master of Arts, Master's degree in a designated field and Master's degree in a designated field. Co-majors must meet all requirements of

both departments and/or programs. On degree is awarded, and the co-major is noted on the transcript. Enrolled co-majors will be classified in one program for record purposes.

## LANGUAGE REQUIREMENTS

A reading knowledge of one foreign language (Germanic, Romance or Slavic) is required by some programs for the Master of Arts and the Master of Science degrees. Other departments may designate that the language requirement be filled from among those languages in which the Department of Foreign Languages and Literatures conducts testing. Students should contact the major department for specific language requirements.

Proficiency can be demonstrated in one of two ways:

1. By passing a traditional reading knowledge examination, which can be requested by the student at any time from the Department of Foreign Languages and Literatures.
2. By passing the final examination in a course especially designed for graduate students who have no previous knowledge of a foreign language or who wish to refresh their knowledge of a language. The Department of Foreign Languages and Literatures offers such courses, normally in the fall, for each of the three major foreign languages: French (FLF 401), German (FLG 401) and Spanish (FLS 401). These courses concentrate exclusively on teaching students to understand the written word and do not provide instruction or testing in speaking and original composition. Failure to pass the course carries with it no penalty other than the fact that the student's language requirement will remain unfulfilled. These courses are neither counted for credit nor used in computing the grade point average.

## THESIS

Theses prepared by candidates for the Master of Science and Master of Arts degrees, in programs requiring the thesis, must present an original investigation into a subject which has been approved by the student's advisory committee and the Director of Graduate Programs in the student's major. Three copies of the thesis in final form as approved by the advisory committee, each signed by the members of the advisory committee, must be submitted to the Graduate School by a specific deadline in the semester or summer session in which the degree is to be conferred. Detailed information on the form and organization of the thesis is presented in the Graduate School's *Thesis and Dissertation Guide* which is available at the NCSU Bookstores.

## COMPREHENSIVE WRITTEN EXAMINATIONS

Written examinations covering the subject matter of the major and supporting fields and/or the minor may be required. When required, such examinations must be successfully completed prior to requesting a permit to schedule the comprehensive final oral examination. Information concerning written examination schedules should be obtained from the student's department or program.

## COMPREHENSIVE FINAL ORAL EXAMINATIONS

Candidates for master's degrees, except those in Option B programs, must pass a comprehensive oral examination to demonstrate to the advisory committee that he/she possesses a reasonable mastery of the subject matter of the major and supporting fields and that this knowledge can be used with promptness and accuracy. This examination may not be held until all other requirements, except completion of the course work in current registration during the final semester, are satisfied. A request for a permit to schedule the examination may be filed with the Dean of the Graduate School after the above conditions are met. The Graduate School will check to determine that the advisory committee and the courses taken by the student meet Graduate School requirements. If all requirements are met, the permit to schedule the final examination will be forwarded to the Director of Graduate Programs within 20 days of receipt of the request. Upon receipt of the permit, the student may proceed to schedule the exam at a time that is convenient to all members of the advisory committee. In those programs which require the thesis, the thesis must be submitted in complete form, except for such revisions which may be necessary as a result of the final exam, to all members of the advisory committee at least two weeks prior to the exam.

A unanimous vote of approval of the advisory committee is required for passing the oral examination. Approval of the examination may be conditioned, however, upon completion of additional work to the satisfaction of the advisory committee. A formal reexamination will not be required in this case. Failure of a student to pass the oral examination terminates the student's graduate work at NCSU unless the graduate advisory committee unanimously recommends a reexamination. Only one reexamination will be given. A form giving the date that the exam was conducted and the result of the examination and signed by all members of the advisory committee is forwarded to the Dean of the Graduate School by the Director of Graduate programs in the student's department or program. A student may appeal all committee actions by written application to the Dean of the Graduate School.

Oral examinations for master's degree candidates are open to the Graduate Faculty by right and to the University community by unanimous consent of the advisory

committee and the student being examined. Discussions and decisions regarding the student's performance are private to the advisory committee.

Students in Option B master's programs are not required to take a final oral examination.

### RESIDENCE

Students engaged in a course of study leading to the master's degree are required to be in residence, pursuing graduate work, for a minimum of one full academic year or its equivalent.

### TIME LIMIT

All requirements for the master's degree must be completed within six calendar years, beginning with the date that the student registers for courses carrying graduate credit applicable to the degree program, unless a more restrictive time limit has been has been established by the student's department or program or his/her college or school.

## Summary of Procedures for Master's Degrees

### ALL STUDENTS

- Application materials and required fees received.
- Application materials reviewed by department or programs.
- Department or program forwards recommendation regarding applicant's admissibility to the Graduate Dean.
- The Graduate School reviews the recommendation and the student is notified of the action taken on the request for admission.
- Student arrives, reports to the department or program, is assigned a graduate advisor and develops a roster of courses and credits with the advisor.
- Student complies with requests from Graduate School for updates copies of transcripts from previous colleges or universities.
- Student signs patent agreement and files with Graduate School.
- Student subject to continuous registration policy until graduation.
- Student passes language examination, if required.
- Student passes written examination, if required.
- Student submits diploma order form by end of sixth week of the semester or summer session of anticipated graduation.

- A grade point average of at least 3.00 for the degree requirements as well as on overall graduate course work at NCSU is required for graduation.
- All degree requirements must be completed within six calendar years, beginning with the date the student commences courses carrying graduate credit applicable to the degree program, unless a more restrictive time limit has been established by the department/ program or academic college/school.

## STUDENTS IN OPTION B PROGRAMS

- Plan of Graduate Work prepared by the student, in consultation with and with the approval of his/her graduate advisor and approved by Director of Graduate Programs prior to completion of one-half the credits on the plan.
- Director of Graduate Programs submits requests for graduation checkout to the Graduate Dean no later that 30 working days after the first day of the semester (seven working days after the first day of the summer session) in which the student is taking the last course on his/her Plan of Graduate Work and anticipates graduation.

## STUDENTS IN NON-THESIS PROGRAMS

- Graduate advisory committee of three or more Graduate Faculty members is appointed by the Director of Graduate Programs.
- Plan of Graduate Work prepared by the student, in consultation with and with the approval of his/her graduate advisory committee and approved by the Director of Graduate Programs prior to completion of one-half the credits on the plan.
- When all requirements except completion of the course work in the final semester are satisfied, Director of Graduate Programs requests that the Graduate School issue permit to schedule the final oral examination.
- If Graduate School requirements are met, a permit to schedule the final examination is issued by the Graduate School within 20 working days of receipt of the request.
- Final examination is scheduled and conducted.
- Final examination report, including date and result of the examination, submitted to the Graduate School by the Director of Graduate Programs. Report should be received by the Graduate School within five working days of the examination.
- The deadline date for unconditionally passing the final examination in order for the student to graduate in a given semester or summer session

appears in The Calendar in this catalog as well as other Graduate School calendars.

## STUDENTS IN THESIS PROGRAMS

- Graduate advisory committee of three or more Graduate Faculty members is appointed by the Director of Graduate Programs.
- Plan of Graduate Work prepared by the student, in consultation with and with the approval of his/her graduate advisory committee and approved by the Director of Graduate Programs prior to completion of one-half the credits on the plan.
- A copy of a preliminary draft of the thesis, if required, is submitted to the chair of the student's advisory committee.
- When all requirements except completion of the course work in the final semester are satisfied and after the thesis is complete except for such revisions as may be necessary as a result of the exam, the Director of Graduate Programs requests that the Graduate School issue permit to schedule the final oral examination.
- If Graduate School requirements are met, a permit to schedule the final examination is issued by the Graduate School within 20 working days of receipt of the request.
- At least two weeks prior to the final oral examination, the chair of the student's advisory committee submits the thesis, if required, to the other members of the advisory committee for review.
- Final examination is scheduled and conducted.
- Final examination report, including date and result of the examination, submitted to the Graduate School by the Director of Graduate Programs. Report should be received by the Graduate School within five working days of the examination.
- Student submits three copies of the thesis, signed by each member of his/her advisory committee, to the Graduate School.
- The deadline date for submitting three copies of the thesis to the Graduate School in order for the student to graduate in a given semester or summer session appears in The Calendar in this catalog as well as other Graduate School calendars.
- The thesis is reviewed by the Graduate School to insure that the format conforms with the specifications prescribed in the *Thesis and Dissertation Guide*.

# Doctor of Philosophy and Doctor of Education Degrees

The doctorate symbolizes the ability of the recipient to undertake original research and scholarly work at the highest levels without supervision. The degree is therefore not granted simply upon completion of a stated amount of course work but rather upon demonstration by the student of a comprehensive knowledge and high attainment in scholarship in a specialized field of study. The student must demonstrate this ability by writing a dissertation reporting the results of an original investigation and by passing a series of comprehensive examinations in the field of specialization and related areas of knowledge.

## ADVISORY COMMITTEE AND PLAN OF GRADUATE WORK

An advisory committee of at least four graduate faculty members, one of whom will be designated as chair, will be appointed by the Dean of the Graduate School upon the recommendation of the director of graduate programs of the major department. The committee, which must include at least one representative of the minor field, will, with the student, prepare a Plan of Graduate Work which must be approved by the director of graduate programs of the major department and the Graduate School. In addition to the course work to be undertaken, the subject of the student's dissertation must appear on the plan; and any subsequent changes in committee or subject or in the overall plan must be submitted for approval.

The program of work must be unified, and all constituent parts must contribute to an organized program of study and research. Courses must be selected from groups embracing one principal subject of concentration, the major, and, when appropriate, from a cognate field, the minor. Normally, a student will select the minor work from a single discipline or field which, in the judgment of the advisory committee, provides relevant support to the major field. However, when the advisory committee finds that the needs of the student will best be served by work in an interdisciplinary minor, it has the alternative of developing a special set of courses in lieu of the usual minor.

## CO-MAJOR

Students may co-major at the doctoral level with the approval of both departments and the appointment of a co-chair from each department on the advisory committee. Co-majors must meet all requirements for majors in both departments. One degree is awarded and the co-major is noted on the transcript. Co-majors are not permitted between Doctor of Philosophy and Doctor of Education degree programs. Enrolled co-majors will be classified in only one program for record purposes.

## RESIDENCE REQUIREMENT

For the Doctor of Philosophy and the Doctor of Education degrees, the student is expected to be registered for graduate work at an accredited graduate school for at least six semesters beyond the baccalaureate degree.

The basic University residence requirements are defined below. However, academic colleges/schools have the prerogative of establishing more restrictive requirements within the respective schools. (The College of Education and Psychology requires a minimum of one academic year of full-time resident study).

At least two residence credits, as defined below, must be secured in continuous residence (registration in consecutive semesters) as a graduate student at the University. Failure to take work during the summer does not break continuity; however, summer work may be used in partial fulfillment of this requirement.

Residence credit is determined by the number of semester hours of graduate work carried during a given term. During a regular semester, residence credit is calculated in the following manner:

| *Semester Credits (Hours)* | *Residence Credits* |
|---|---|
| 9 or more | 1 |
| 6-8 | 2/3 |
| less than 6 (including registration for "DR" Dissertation Preparation" or "Dissertation Research") | 1/3 |

The residence credit for a six-week summer term is equal to one-half of the corresponding amount for a regular semester. For example, six semester hours carried during a summer session will earn one-third of a residence credit; less than six credit hours will earn one-sixth of a residence credit.

## LANGUAGE REQUIREMENTS

A reading knowledge of at least one modern foreign language (Romance, Germanic or Slavic) is required by some departments for the Doctor of Philosophy degree. Other departments may designate that the language requirement be filled from among those languages in which the Department of Foreign Languages and Literatures conducts testing. Doctoral students should contact the major department for specific language requirements. For the Doctor of Education degree, the decision as to whether or not there will be a language requirement is left to the student's advisory committee.

The Department of Foreign Languages and Literatures offers courses in French, German and Spanish especially designed for graduate students who have no previous knowledge of a foreign language or who wish to refresh their knowledge of a language. These courses concentrate exclusively on teaching students to understand the written word and do not provide instruction or testing in speaking and original composition. A passing grade on the final examination in one of these courses is sufficient evidence of a reading knowledge of the language.

To demonstrate comprehension in depth of one language, a student must not only prove that one possesses a reading knowledge of the language but also that he or she is proficient in the oral and compositional elements of that language. Students desiring to master one language in depth should consult the head of the Department of Foreign Languages and Literatures concerning the specific courses which will be necessary to achieve this comprehension; specific arrangements will depend upon the student's background in the language.

Students whose native language is other than English may use English as one of the languages when two are required for the Doctor of Philosophy degree. When English is submitted in partial fulfillment of the dual language requirement, the native language may not be used as the other language.

When only one language is required in the student's program, certification for that language must occur on this campus.

## PRELIMINARY COMPREHENSIVE EXAMINATIONS

After completing the language requirement but not earlier than the end of the second year of graduate study and not later than one semester (four months) before the final oral examination, each doctoral student is required to take the preliminary comprehensive examinations. The examinations consist of two parts: written examinations and an oral examination. Requirements for written examinations in the minor field are left to the discretion of the department in which the student is minoring.

The written portion may be conducted in one of two ways. In the first, each member of the advisory committee prepares a set of questions for the student's response, and answers to each set are returned to the appropriate member for grading. This procedure is used by departments which have a relatively small number of doctoral students.

Many of the larger departments have developed departmental written examinations to be used for all students, and scheduled dates are announced well in advance. Where written departmental examinations of this kind are used, the student will be expected to make arrangements to schedule these examinations.

Regardless of the method employed, the questions involved may cover any phase of the course work taken by the student during graduate study or any subject logically related to an understanding of the subject matter in the major and minor areas of study. The questions are designed to measure the student's mastery of the subject matter and the adequacy of preparation for research. Failure to pass the written preliminary examinations terminates the student's work at this institution, subject to departmental and/or school policies with respect to reexamination.

Upon satisfactory completion of the written portion of the preliminary examinations and after completion of all course work relevant to the examination, authorization for the preliminary oral examination is requested from the Graduate School. This examination is conducted by the student's advisory committee and a representative from the Graduate School and is open to all graduate faculty members. The student and the examining committee will be notified by the Graduate School of the arranged time and place. The oral examination is designed to test the student's ability to relate factual knowledge to specific circumstances, to use this knowledge with accuracy and promptness and to demonstrate a comprehensive understanding of the field of specialization and related areas.

A unanimous vote of approval by the members of the advisory committee is required for the student to pass the preliminary oral examination. Approval may be conditioned, however, on the successful completion of additional work in some particular field(s). All committee actions may be appealed by written application to the Graduate Dean.

Failure to pass the preliminary oral examination terminates the student's work at this institution unless the examining committee recommends a reexamination. No reexamination may be given until at least one full semester has elapsed, and only one reexamination is permitted.

## CANDIDACY

A doctoral student is admitted to candidacy upon passing the preliminary examinations without conditions or after fulfilling any conditions specified by the advisory committee.

## FINAL ORAL EXAMINATION

The final oral examination is scheduled after the dissertation is complete except for such revisions as may be necessary as a result of the examination, but not earlier than one semester or its equivalent after admission to candidacy and not before all required course work has been completed or is currently in pro gress. The examination consists of the candidate's defense of the methodology used and the conclusions

reached in the research, as reported in the dissertation. It is conducted by an examining committee, which consists of the student's advisory committee and a Graduate School representative. This examination is open to the University community.

A unanimous vote of approval of the advisory committee is required for passing the final oral examination. Approval may be conditioned, however, on the student's meeting specific requirements prescribed by the student's advisory committee. Failure of a student to pass the examination terminates one's work at this institution unless the advisory committee recommends a reexamination. No reexamination may be given until one full semester has elapsed and only one reexamination is permitted.

## THE DISSERTATION

The doctoral dissertation presents the results of the student's original investigation in the field of major interest. It must represent a contribution to knowledge, be adequately supported by data and be written in a manner consistent with the highest standards of scholarship. Publication is expected.

The dissertation will be reviewed by all members of the advisory committee and must receive their approval prior to submission to the Graduate School. Three copies of the document signed by all members of the student's advisory committee must be submitted to the Graduate School by a specific deadline in the semester or summer session in which the degree is to be conferred. Prior to final approval, the dissertation will be reviewed by the Graduate School to insure that the format conforms to the specifications prescribed in the *Thesis and Dissertation Guide.* Detailed information on form and organization of the dissertation is presented in the University's *Thesis and Dissertation Guide* which is available in the NCSU Bookstores.

The University has a requirement that all doctoral dissertations be microfilmed by University Microfilms International, of Ann Arbor, Michigan, which includes publication of the abstract in *Dissertation Abstracts International.* The student is required to pay for the microfilming service. (See "Special Registration and Fees" under "Tuition and Fees.")

## TIME LIMIT

Doctoral students are allowed a maximum of six calendar years from admission to the doctoral program to attain candidacy for the degree and a maximum of ten calendar years to complete all degree requirements. Academic colleges/schools or departments may have more restrictive requirements than the above stated policy.

## Summary of Procedures for Doctor of Philosophy and Doctor of Education Degrees

- Application materials and required fee received.
- Application materials reviewed by department or program.
- Department or program forwards recommendation regarding applicant's admissibility to Graduate Dean
- Graduate School reviews the recommendation and notifies the student of the action taken on the request for admission.
- Student arrives, reports to the department or program, is assigned a graduate advisor and develops a roster of courses and credits with the advisor.
- Student complies with requests from Graduate School for updated copies of transcripts from previous colleges or universities
- Student signs patent agreement and files with Graduate School
- Student subject to continuous registration policy until graduation.
- Advisory committee of at least four graduate faculty members appointed by the Graduate Dean upon the recommendation of the director of graduate programs.
- Graduate Dean appoints a Graduate School Representative to student's committee.
- A dissertation subject is selected and an outline of the proposed research submitted to the student's advisory committee and the director of graduate programs for review and approval.
- Plan of Graduate Work prepared by the student, in consultation with and with the approval of his/her graduate advisory committee and director of graduate programs, and forwarded to the Graduate School for approval as soon as feasible after completion of 12 hours of course work.
- Student passes language examination(s), if required.
- Written examinations in the major and minor fields are scheduled no earlier than the end of the second year of graduate study and not later than one semester before the final oral examination.
- When all written examinations have been completed satisfactorily, the chairman or the director of graduate programs requests the scheduling of the preliminary oral examination at least two weeks prior to the suggested date. Upon approval of the request, the Graduate School notifies the student and the examining committee of the time and place.
- The report of the examination is sent to the Graduate School and if the examination has been passed without conditions, the student is admitted to candidacy.
- A copy of the preliminary draft of the dissertation is submitted to the chair of the student's advisory committee for review.

- At least two weeks prior to the final oral examination, the chair of the student's advisory committee submits the dissertation to advisory committee members for review. A copy is submitted to the Graduate School Representative at least one week prior to the exam.
- One semester or its equivalent after admission to candidacy or later, after the dissertation is complete except for such revisions as may be necessary as a result of the final examination, and at least two weeks prior to the suggested date, the student's advisory committee chair or director of graduate programs requests the scheduling of the final oral examination. Upon approval of the request, the student and the examining committee, including the Graduate School representative, are notified of the time and place of the examination.
- Results of the final oral examination are forwarded to the Graduate School.
- Upon passing the final oral examination, three copies of the dissertation signed by each member of the student's advisory committee and five copies of the abstract must be submitted to the Graduate School by a specific deadline in the semester or summer session in which the degree is to be conferred. One copy each of the University Microfilms Agreement, the Survey of Earned Doctorate, and the Graduate School Exit Survey forms must be completed and submitted with the dissertation.
- The dissertation is reviewed by the Graduate School to insure that the format conforms with the specifications prescribed in the *Thesis and Dissertation Guide*.
- All course work scheduled in a graduate degree classification must be completed prior to graduation.
- A grade point average of at least 3.0 for the degree requirements as well as on overall graduate course work at NCSU is required for graduation.
- The doctoral residence requirement of 2 residence credits must be satisfied.
- All degree requirements must be completed within ten years from admission to the doctoral program.

# THE NCSU Libraries

The NCSU Libraries is dedicated to offering the fullest information resources and services to its user community. The library system consists of the main D. H. Hill Library; four branches serving the specialized needs of the Schools/Colleges of Design, Forest Resources, Textiles and Veterinary Medicine; and an affiliated library serving the College of Education and Psychology.

The Libraries' collections contain nearly 1.5 million volumes of books and bound journals, 3.7 million microforms, more than 18,000 serials, and about 200 CD-ROMs. The collections are particularly strong in the biological and physical sciences, engineering, agriculture, forestry, textiles and architecture, with the arts, humanities and social sciences also well represented. The NCSU Libraries is a depository for U.S. government documents and holds nearly 850,000 federal government publications. The library is also a U.S. Patent Depository and offers access to U.S. patents from 1790 to date in both microfilm and online. The Media Center has a growing collection of audio, video and multimedia materials and is equipped with equipment for group and individual use.

The new NCSU Libraries Information System extends access to a growing array of online resources, accessible from terminals within the library buildings and from remote locations. Not only can users search the NCSU Libraries' holdings by author, title, subject and key-word, but they can also search the collections of Duke and UNC-Chapel Hill, along with a growing number of other databases such as a journal table-of-contents database and a newspaper index. Moreover, the new system provides gateways to electronic books and journals. The state-of-the art Information Technologies Teaching Center offers instruction in use of the latest information technologies.

As a further aid to graduate and faculty research, the Libraries provides interlibrary loan services to obtain material from other research libraries. Direct borrowing privileges are available with Duke University, UNC-Chapel Hill and other UNC system schools. Other library services include orientation tours for graduate students and faculty and lectures on library use for all new students. In-depth reference service, geared to the individual needs of graduate students, is also available.

# Institutes

**RESEARCH TRIANGLE** - The unique "Research Triangle" in North Carolina has captured national and international attention. It is comprised of the Research Triangle Park, a world-renowned research park, and three major research universities. Because of this wealth of educational and research opportunities, the Triangle area contains the highest total of Ph.D. scientists and engineers on a per capita basis in the nation. The Triangle Universities--NCSU, the University of North Carolina at Chapel Hill and Duke University--have a subsidiary campus in the Research Triangle Park--the Research Triangle Institute. The Institute, which operates as a contract research organization, has an annual research revenue of approximately $122 million.

The Research Triangle Park, founded in 1959, now has more than 59 public and private industrial research facilities, situated on 6,800 acres of land. Over 34,000 people work in the Park and over 30,000 additional jobs have been created outside the Park as a result of its existence. Organizations in the Park include such government facilities as the National Humanities Center, the National Institute of Environmental Health Sciences, the Environmental Protection Agency, and the National Center for Health Statistics. Private companies such as Glaxo Pharmaceuticals, Northern Telecom and Reichhold Chemicals have their North American headquarters in the Park. Two major, state-supported research initiatives in Microelectronics and Biotechnology are located in the Park and North Carolina's Supercomputing Center is housed there as well. Faculty and graduate students from the universities work closely with many of the Park companies. Scientists and researchers from companies like Burroughs Wellcome, IBM and Becton-Dickinson frequently hold adjunct appointments in one or another of the Triangle Universities.

**INSTITUTE OF STATISTICS** - The Institute of Statistics is composed of two sections, one at Raleigh and the other at Chapel Hill. At NCSU, the Institute provides statistical consulting services to all branches of the institution, sponsors research in statistical theory and methodology and coordinates the teaching of statistics at the undergraduate and graduate levels. The instructional and other academic functions are performed by the Department of Statistics, which forms a part of the Institute.

**WATER RESOURCES RESEARCH INSTITUTE** - The Water Resources Institute is a unit of the UNC System and is located on the campus of NCSU. The deans of the College of Engineering and College of Agriculture and Life Sciences, the Vice Chancellor for Research at NCSU and two faculty members from UNC-Chapel Hill serve as a board of directors. The Institute was established to promote a multidisciplinary attack on water problems, to develop and support research in response to the needs of North Carolina, to encourage strengthened educational programs in water resources, to coordinate research and educational programs dealing with water resources and to provide a link between the state and federal water resources agencies and related interests in the university.

Research and educational activities are conducted through established departments and schools of the University System. All senior colleges and universities of North Carolina are eligible to participate in the Institute's research program. Basic support for the Institute's program is provided by appropriations from the State of North Carolina and the U. S. Department of the Interior, under the Water Research and Development Act of 1984. The Institute sponsors research and educational symposia and seminars, encourages the development of specialized training opportunities and provides a means for the continuing evaluation and strengthening of the University System's total water resources program.

# Special Laboratories, Facilities and Centers

**ACADEMIC COMPUTING FACILITIES** - The Computing Center provides computing services and networking services via the University's Computer Communications System.

This system links many computing systems on campus, including the on-line library catalog, and also provides access to the Internet.

The Computing Center facility includes a UNIX-based client/server environment and software, including word processing, electronic mail, spreadsheets and math tools. Several networked public facilities are located on campus. The Computing Center also provides an array of centralized services including consultation, short courses, software licensing, campus electronic information system through World-Wide Web and a library of public domain software.

A number of specialized computing facilities also exist. The Computer Center provides a centralized hardware and software facility for image processing and remote sensing. The Center provides microcomputers and UNIX and VAX computers with image display and manipulation devices, plotters, a color graphics camera system and digitizing tables. Software includes remote sensing, image processing, time series analysis and computer graphics. Other facilities in most colleges/schools provide specialized education and research computing for their students. The University participates in the North Carolina Supercomputing Center and provides high bandwidth communications to the CRAY Y-MP at the Center.

**BIOLOGY FIELD LABORATORY** - The Biology Field Laboratory is located eight miles from the University campus and comprises a 20-acre pond, 180 acres of extremely varied vegetation types and a modern laboratory building. The latter contains two laboratories, one for class use and another principally for research.

The many unique ecological situations found in this area make it ideal for use by advanced classes of most biological science departments. Likewise, the area is well adapted to a variety of research projects by faculty, graduate students and undergraduates because of its habitat diversity. The close proximity of the laboratory facility to the campus makes possible many types of behavioral, physiological, ecological, taxonomic and limnological studies that could be accomplished only with great difficulty at other locations.

**CENTER FOR ADVANCED ELECTRONIC MATERIALS PROCESSING (AEMP)** - The Center for Advanced Electronic Materials Processing was established in 1988 and is one of the 18 NSF Engineering Research Centers in the nation. The center's program is interdisciplinary and involves collaboration among chemists, physicists, materials scientists and electrical, chemical, computer and mechanical engineers. The research focuses on the development of electronic materials processing technologies that will provide the capability of producing submicron electronic devices. The program emphasizes low thermal budget processes using plasma and thermal and optically assisted techniques as well as the automation and control of thoses processes. It is a joint effort with researchers from the University of North Carolina (Chapel Hill and Charlotte), Duke University, North Carolina A&T State University, Research Triangle Institute and MCNC.

**CENTER FOR ASEPTIC PROCESSING AND PACKAGING STUDIES (CAPPS)** - The Center for Aseptic Processing and Packaging Studies was established in October 1987 to promote cooperative research between university and industrial researchers and to further scientific knowledge in areas of food and pharmaceutical aseptic processing and packag-

ing. The center is funded by the National Science Foundation, NCSU and industrial members from food, pharmaceutical and packaging industries. Current members include Fluor Daniel, the Food and Drug Administration, International Paper Company, John Labatt Foods, Kraft General Foods, the North Carolina Biotechnology Center, Nestle, Ross Laboratories and USDA-Agricultural Research Service. The objectives of the center are to support industrially relevant, fundamental research in aseptic processing and packaging, to enhance product quality and improve efficiency, and to communicate information gained from basic research to industry for development and marketing.

Graduate students working on CAPPS projects will be exposed to industrial concerns and given the opportunity to work first-hand with industry in solving problems and making practical application of their research. The research involves faculty, visiting scientists, graduate students and technicians from the Departments of Food Science and Biological and Agricultural Engineering. Other universities participating in the research include Michigan State University, North Carolina A&T State University, The Ohio State University, and Virginia Polytechnic Institute and State University.

**CENTER FOR COMMUNICATIONS AND SIGNAL PROCESSING** - The NCSU Center for Communications and Signal Processing (CCSP) is an Industry/University Cooperative Research Center. It was established in 1982 with a grant from the National Science Foundation. It has been a self-sustaining Center since 1987. The Center is supported by a group of sponsoring industrial members. There is an advisory board comprised of representatives of each member company which meets twice each year to direct the research activities of the Center. Each company also appoints technical monitors who work directly with the university researchers.

The Center does research in the areas of communications networks, digital signal pro cessing, optimization, and ISDN and is currently supported by NSF, IBM, GE, BNR, Bell-South, DEC, AT&T, Kodak and MCNC. During its eight years of operation, the Center has produced an outstanding record of achievement as evidenced by its publications and graduation of outstanding students.

The mission of the Center is education of the highest quality students, performance of basic and applied research and technology transfer. It provides substantial benefits to both the industrial partners and the University. Among these advantages are participation in leading-edge research in a broad range of communications disciplines, development of technical staff through interaction between industry and the university and the exposure of promising students.

**CENTER FOR LEARNING TECHNOLOGIES** - The Center for Learning Technologies (CLT) is a multimedia service facility located in the College of Education and Psychology. Students are instructed through workshops, classes and/or individualized training in the effective delivery of information and the design/production of instructional materials using a variety of computer technologies.

**CENTER FOR RESEARCH AND DEVELOPMENT IN MATHEMATICS AND SCIENCE EDUCATION** - The center, one of ten centers in the North Carolina Mathemat-

ics and Science Education Network, is the only research and development center in the network. Established within the Department of Mathematics and Science Education in 1984, the center conducts research and development activities for precollege students, preservice teachers, in-service teachers and a University faculty. The center identifies areas of need in mathematics and science education and forms partnerships with federal, state, local and private funding agencies to work collaboratively to address the needs. Grants have been obtained from the National Science Foundation, Office of Education, State Department of Public Instruction, Local Education Agencies and IBM to introduce changes that incorporate technology and active learning into the mathematics and science curriculum, K-16. In addition, the center supports graduate students and provides them with opportunities to write grants and to design, conduct and report on educational research.

**CENTER FOR SOUND AND VIBRATION** - The Center for Sound and Vibration, established in 1969 and administered within the Department of Mechanical and Aerospace Engineering, is composed of faculty pursuing the solution of a wide variety of problems such as occur in machinery and aircraft design particularly related to vibration and sound. Graduate programs exist at M.S. and Ph.D. levels in fields such as noise and vibration control, aeroacoustics, hearing conservation, computer-aided machinery design, active control of vibration and sound, and signal processing. Outstanding experimental facilities, which include large anechoic and reverberant rooms and computer graphics equipment, are available. The Center's programs are financed largely by grants and contracts from industry and federal and state agencies.

**DIAGNOSTIC TEACHING CLINIC** - The Diagnostic Teaching Clinic is operated by the graduate program in special education within the College of Education and Psychology for the purposes of providing graduate students with opportunities to gain both observational and applied clinical experience in diagnosing and teaching exceptional students of all ages. The clinic accepts referrals from local school systems and from agencies and individuals within the community. Staff, which includes graduate interns, evaluates the referred clients, develops educational programs for them in conjunction with the referring agency and demonstrates teaching techniques for the benefit of those persons who will work with the children. This clinic is open during the day, late afternoon and early evening hours during the fall and spring semesters and throughout the summer months and is utilized by graduate students from several departments with allied curricula in education and psychology.

**ELECTRIC POWER RESEARCH CENTER** - The Electric Power Research Center is a university/industry cooperative research center recently established within the NCSU College of Engineering. The Center is funded by the university and sponsoring organizations from the various sectors of the electric utility and power industry. The purpose of the Center is to engage in collaborative efforts aimed at enhancing the excellence of research and graduate-level degree programs in electric power systems engineering. This primary purpose is accomplished by providing support for interested faculty and students to be involved in basic and applied research directly relevant to the needs of the multifaceted electric power industry. Motivation to work with the Center derives from the close university/industry interaction, the leverage afforded to an industrial sponsor's membership dues and the enhanced professional and research opportunities provided to faculty and students in electric power engineering.

While the current research program involves faculty from the Department of Electrical and Computer Engineering and the Department of Nuclear Engineering, the Center will facilitate access to all the various resources of the University and for all sectors of the electric power industry.

**ELECTRON MICROSCOPE FACILITIES** - There are three electron microscope facilities at NCSU available to graduate students and faculty for research purposes. The College of Agriculture and Life Sciences (CALS) Center for Electron Microscopy is located in Gardner Hall, the Engineering Research Microscope Facility is in Burlington Engineering Labs and the College of Veterinary Medicine (CVM) Electron Microscopy Laboratory is located in the NCSU College of Vete rinary Medicine on Hillsborough Street.

**The CALS Center for Electron Microscopy** offers complete service support in all areas of Biological Electron Microscopy. The Center has two scanning microscopes: a Philips 505T and a JEOL T-200 and four transmission electron microscopes: an Hitachi HS-8-B, an Hitachi HU-11-B, a JEOL 100-S and a Philips 400T-STEM equipped with a C-400-M computer control system. The Center is also equipped with all of the necessary biological preparatory equipment.

Formal instruction is provided through the biological sciences curriculum for transmission electron microscopy, scanning electron microscopy and ultramicrotomy. Advanced techniques are provided on an individual basis or through workshops.

**The Engineering Research Analytical Instrumentation Facility (AIF)** is equipped with an Hitachi H-800 scanning transmission microscope and a Hitachi S-530 scanning electron microscope, both equipped with energy dispersive x-ray spectrometers (Tracor Northern TN 2000 and TN 5500). The Analytical Instrumentation Facility also has a JEOL 6400F field emission scanning electron microscope and an ISI 002B ultra high resolution TEM's and an ETEC autoscan SEM with full options microscopes.

The H-800 STEM has a maximum accelerating voltage of 200 kV and a lanthanum hexa-boride gun, providing high image brightness and penetration with minimal specimen damage, which is used for ceramic, metallurgical, electronic and textile materials. Computer control of all lenses and a motorized 45-degree double-tilting stage make it easy to use, and a high takeoff angle x-ray detector provides high sensitivity element analysis, including mapping and quantitative capability. The instrument operates in scanning, transmission and STEM modes with full diffraction capability.

Both of the ISI 002B TEM's have the necessary pole pieces and sample holders for UHR imaging or high angle tilting. One is configured for UHR imaging with a Gatan video image intensifier and a MAC II fx for digital image analysis and processing. It has a point to point resolution of 1.8 a. The second 002B is configured with a high resolution pole piece which will allow a maximum sample tilt of 45 degrees for high angle electron diffraction and x-ray analysis.

The S-530 SEM accommodates large (6-inch diameter) specimens, has an ultra-low voltage mode for uncoated non-conductive sample examination and has highly automated focus and

picture-taking controls for routine high-quality images. In addition to 50-a resolution secondary electron images at 25 KeV, the microscope is equipped with a high-resolution backscattered electron detector, a computerized x-ray spectrometer and EBIC systems.

Like the S-530, the JEOL 6400F can handle up to a 6-inch diameter sample through its exchange chamber and operate at very low accelerating voltages. However, the superior brightness and small spot size of the cold cathode field emission electron source on JEOL 6400F enables it to resolve 15 a at an accelerating voltage of 30 KeV and 70 a at 1.0 KeV.

Center personnel teach regular courses covering many of these instrument techniques as well as short courses and offer collaboration with and instruction for graduate students on an individual basis.

**The CVM Electron Laboratory for Advanced Electron and Light Optical Methods (LAELOM)** - The CVM Laboratory for Advanced Electron and Light Optical Methods (LAELOM) is a research/service/teaching facility housing all the optical equipment to examine cytological, histological and gross specimens, and the equipment to perform morphometric analyses, and to prepare material for presentations and publication. Individuals can prepare their own cryosections for light microscopy and immunological staining and can also prepare their own transmission and scanning electron microscopy samples. In addition, the LAELOM can prepare any and all of these materials for investigators. The LAELOM offers individual training in light microscopy, morphometry and darkroom work as well as a formal course in biological transmission and scanning electron microscopy techniques. A course covering photography in scientific illustration is taught in the LAELOM as part of the summer Biotechnology program. A Philips 410LS transmission electron microscope, a JEOL JSM-35 scanning electron microscope, Zeiss and Leitz photomicroscopes and a Wild photomacroscope are available to students and investigators as well as a fully equipped negative processing and print processing darkroom. Equipment is available to make 2 x 2 slides for presentations and to prepare posters and publication prints. The LAELOM offers consultation services for all these techniques in terms of specimen preparation, film selections, and cost determinations for purposes of grant preparation.

**HIGHLANDS BIOLOGICAL STATION** - NCSU is an institutional member of the Highlands Biological Foundation which provides support for the Highlands Biological Station of the University of North Carolina. This is an inland biological field station located at Highlands, North Carolina. The town of Highlands is in the heart of the Southern Appalachians at an elevation of 3,823 feet. The area has an extremely diverse biota and the highest rainfall in the eastern United States.

Facilities are available throughout the year for pre-and post-doctoral research in botany, zoology, soils and geology. The laboratory building with research rooms and cubicles and the library are well equipped for field-oriented research. Also, five cottages and a dining hall are located on the edge of a six-acre lake. In addition to 16 acres surrounding the lake, the station owns several tracts of undisturbed forested land available for research. Research grants available through the Station provide stipends for room, board and research expenses.

**INTEGRATED MANUFACTURING SYSTEMS ENGINEERING INSTITUTE** - The Integrated Manufacturing Systems Engineering Institute was established at North Carolina State University in 1984 to provide interdisciplinary educational, research and technology transfer program in manufacturing systems engineering. The objectives of this program are to educate engineers in the theory and practice of integrated manufacturing systems technology; to conduct basic and applied research on topics in cooperation with industry on problems of contemporary manufacturing system; and to engage in technology transfer with industry.

Central to all aspects of the Institute's operation and activity is in the integration of computer-aided processes in the design and control of manufacturing facilities. Through both internally and externally funded research projects the Institute contributes to the solution of generic design and manufacturing engineering problems and provides a vehicle for technology transfer.

**LEARNING RESOURCES LIBRARY** - The Learning Resources Library, administered by the College of Education and Psychology, is located in Poe Hall. The library maintains a collection of print and audio-visual materials with emphasis on teaching methods, research, administration and psychology. An extensive collection of state-adopted secondary level textbooks includes French, Spanish, Language Arts, Mathematics, Science, Social Studies and Vocational Education. Audio-visual equipment is available for instruction, research and previewing.

**MARS MISSION RESEARCH CENTER** - The Mars Mission Research Center is one of eight University Space Engineering Research Centers established by NASA to broaden the nation's engineering capability to meet the critical needs of the civilian space program. The goal of the center is to focus on educational and research technologies used in the design of spacecraft for planetary exploration with particular emphasis on Mars. It is a cooperative program involving faculty, undergraduate and graduate students at North Carolina State University and N.C. A&T State University. The research is a cross-disciplined program involving (1) hypersonic aerodynamics and propulsion, (2) composite materials and fabrication, (3) light-weight structures and (4) spacecraft controls. Students and faculty conduct part of their research at NASA Centers and participating industries.

**MATERIALS RESEARCH CENTER** - The Materials Research Center was established in 1984 at NCSU as an interdisciplinary program involving persons representing the Department of Chemistry, Electrical and Computer Engineering, Materials Science and Engineering and Physics. The present thrust area of the Center concerning thin films and coatings serves as a focal point for this cooperative research. The experimental efforts are conducted within the four departments noted above.

**MCNC** - NCSU is a participating member of MCNC which conducts research programs in information and electronics technologies in partnership with other North Carolina institutions. Other participating institutions are the UNC-Chapel Hill, Duke University, North Carolina A&T State University, UNC-Charlotte and the Research Triangle Institute.

Faculty and students at NCSU have access to the use of MCNC facilities on sponsored research projects. Areas of interest include systems design, systems engineering, integrated circuit fabrication technology, semiconductor materials, device physics, advanced packaging and interconnection technologies, microelectromechanical systems (MEMS), high performance computing and advanced networking research and development. Departments at NCSU which are actively involved in the program include electrical and computer engineering, computer science, physics, chemistry, and materials science and engineering.

**NUCLEAR REACTOR PROGRAM** - The Nuclear Reactor Program (NRP) provides specialized nuclear facilities to the North Carolina academic and industrial communities. These facilities are used for teaching, research and service. The NRP supports graduate research and undergraduate programs in a wide variety of academic departments. The NRP facilities include the PULSTAR Nuclear Reactor, the Nuclear Services Analytical Laboratories, Health Physics Laborato ries and the Scaled Pressurized Water Reactor Facility (SPWRF). The PULSTAR Reactor is a 1-Megawatt research and training reactor. Irradiation capabilities include wet and dry vertical ports, horizontal beam tubes, a pneumatic transfer system and a graphite thermal column. Neutron radiography, prompt gamma activation analysis and neutron depth profiling facilities are permanently installed.

The Nuclear Services Laboratories are well-equipped to perform routine reactor irradiations, neutron activation analysis, isotope production and low level counting. The laboratories maintain ten high-purity Ge and GeLi detectors, two multi-station Nuclear Data Acquisition and Analysis Systems, a Liquid Scintillation Counting System, an Alpha Spectroscopy System, sample preparation equipment and an extensive set of standards. The SPWRF is a non-nuclear working scale model of a two-loop pressurized water reactor. The SPWRF is used for teaching pressurized water reactor technology and for various research activities.

The Nuclear Reactor Program is part of the Department of Nuclear Engineering and is located in the Burlington Engineering Laboratories on the main NCSU campus.

**ORGANIZATION FOR TROPICAL STUDIES** - NCSU is an institutional member of the Organization for Tropical Studies (OTS), a consortium of North and Central American universities which maintains field research and teaching facilities in Costa Rica. Each year OTS offers a series of courses that are open to NCSU graduate students including tropical biology, agroecology, agroforestry and tropical agricultural biology. These 8-week courses, offered in winter and summer, are taught in Costa Rica and make use of a network of OTS field stations located throughout the country.

The OTS facilities in Costa Rica also provide a unique opportunity for tropical research by NCSU graduate students and faculty. The principal field station, located in the northeastern Atlantic lowlands, has excellent laboratory and housing facilities and provides access to a 3,500-acre tract owned by OTS. Another station is located at mid-elevation in southeastern Costa Rica near the Panamanian border. OTS also utilizes various other sites, including a seasonally dry area in the northwestern part of the country and a high-elevation area at 10,000 feet in the Talamanca range. More information about OTS may be obtained through the International Programs Office.

**PESTICIDE RESIDUE RESEARCH LABORATORY** - The Pesticide Residue Research Laboratory is a facility in the College of Agriculture and Life Sciences devoted to research on pesticide residues in animals, plants, soils, water and other entities of our environment. Although the laboratory is administered through the Department of Toxicology, it serves the total needs of the College in cooperative research projects requiring assistance on pesticide residue analysis.

The laboratory functions as a focal point for residue research involving interdepartmental cooperation, but faculty in the laboratory also conduct independent research on pesticide persistence and decomposition in soils and plants, absorption and translocation in plants, distribution in environment and contamination of streams, estuaries and ground water.

The laboratory is equipped with the latest analytical instruments. Graduate study can be undertaken in any aspect of pesticide residues either in the Pesticide Residue Research Laboratory or in one of the cooperating departments.

**PRECISION ENGINEERING CENTER** - The Precision Engineering Center was established in 1982. The goal is to develop techniques for metrology and manufacturing at tolerances below those attainable with current technology. For example, fabrication of future electro-optical devices will require manufacturing tolerances better than 1 millionth of an inch. This goal requires new methods for measuring and controlling the parts being produced or the process being performed. Specific research objectives involve the study of metrology systems, control algorithms, machine structural dynamics, optics, materials, and microprocessors and the details of many different fabrication processes. An interdisciplinary team of faculty from Mechanical and Aerospace Engineering, Materials Science and Engineering, Computer Science and Physics along with research staff and graduate students are working together to address these research areas. The Center is housed in a state-of-the-art facility on the Centennial Campus.

**PSYCHOEDUCATIONAL CLINIC AND LABORATORIES** - The Department of Psychology operates the Psychoeducational clinic located in Poe Hall. The clinic provides both a service to the public and training for school psychology graduate students. School-age child assessment and program development are the major services provided. Coordination of internships and practica is also administered through this facility.

Each graduate program in psychology also has laboratory facilities, either independently or shared. Thus, the experimental psychology program has laboratories for neuropsychology, auditory and visual perception, cognition and operant behavior. There is also a training and development laboratory as well as facilities for ergonomics, cognitive and social developmental psychology, human resource development, industrial/organizational and vocational psychology and social psychology. The latter facilities include one-way viewing rooms with recording equipment.

**REPRODUCTIVE PHYSIOLOGY RESEARCH LABORATORY** - The Reproductive Physiology Research Laboratory administered through the Department of Animal Science includes environmental control rooms designed to provide constant levels of air temperature, humidity and light for animals involved in studies on reproduction. Facilities and equipment

are available for surgery, *in vitro* growth of embryos, isotope labeling in embryo metabolism and transfer of embryos between females.

Support for research at both the master's and the doctoral levels is available. Students may elect a comparative approach to a specific problem in mammalian reproduction, working with several species, or they may choose to work with a single species. Generally students select a problem associated with the identification of factors influencing early prenatal development, the endocrine control of ovarian function or some aspect of elucidation and control of aberrations in mammalian reproduction.

Cooperative research is possible between the laboratory, the College of Veterinary Medicine and the Medical School or the Environmental Health Sciences Center at the UNC-Chapel Hill for those students desiring a broader training in the general area of reproductive physiology.

Students whose work is concentrated in reproductive physiology can major in either animal science or physiology with a minor in related disciplines.

**SEA GRANT COLLEGE PROGRAM** - North Carolina Sea Grant College Program is a state/federal partnership program involving all campuses of the University of North Carolina system. A majority of its activities, however, are conducted at the NCSU campus. Sea Grant combines the university's expertise in research, extension and education to focus on practical solutions to problems in the area of coastal and marine resource use and conservation. Graduate and undergraduate research opportunities rest with individual project directors on campus via special graduate fellowship program administered through the program office.

**SOUTHEASTERN PLANT ENVIRONMENTAL LABORATORIES - PHYTOTRON** - The Southeastern Plant Environment Laboratory, often referred to as the NCSU Phytotron, is especially designed for research dealing with the response of plants and microorganisms to their environment. A high degree of environmental control makes possible simulation of a wide range of climates found in tropical, temperate and northern zones.

Research in the Phytotron deals with all phases of plant biology. Although the majority of the studies are conducted with agricultural crop species, the Phytotron can accommodate ecological investigations, plant biology problems of the space program, experimental taxonomy and air pollution studies as well as basic physiological and biochemical research. The Phytotron facility is available to the resident research staff, participants in graduate research programs of NCSU and to domestic and foreign visiting scientists.

**TRIANGLE UNIVERSITIES NUCLEAR LABORATORY** - TUNL is a laboratory for nuclear structure research. Located on the campus of Duke University in Durham, the laboratory is staffed by faculty members and graduate students in the Departments of Physics of Duke University, UNC-Chapel Hill and NCSU. There is extensive collaboration with personnel from the other two participating universities and with the many visiting physicists from the United States and abroad. Particle accelerators are used to bombard target nuclei with an assortment of ions of accurately controlled energy spread and spin orientation. The accelerators are a 15-MeV tandem Van de Graaff accelerator and a 4-MeV Van de Graaff accelerator. Polarized and pulsed beams are available as well as polarized targets. In

addition, TUNL physicists perform experiments at major national and international nuclear physics facilities.

# Special Programs

**INTERNATIONAL AREA STUDIES GROUPS** - The International Area Studies Groups, comprising faculty from across the university with common interests in an international studies area, provide a forum for sharing professional experiences; generating and identifying support sources for collaborative scholarly activities; offering seminars for the university; providing a public-service function for the campus and community at large by identifying faculty with expertise in their study area; interacting with visiting scholars and students from the geographic area specific to the study group; and serving an advisory role in institutional linkage development between NCSU and universities in the study area. Additional information is available from the International Programs Office.

**RESEARCH PROGRAM AT THE OAK RIDGE ASSOCIATED UNIVERSITIES** - NCSU has been a sponsoring institution of Oak Ridge Associated Universities (ORAU) since 1949. ORAU is a private, not-for-profit consortium of 65 colleges and universities and a management and operating contractor for the U.S. Department of Energy (DOE) with principal offices located in Oak Ridge, Tennessee. Founded in 1946, ORAU provides and develops capabilities critical to the nation's technology infrastructure, particularly in energy, education, health, and the environment. ORAU works with and for its member institutions to help faculty and students gain access to federal research facilities; to keep members informed about opportunities for fellowship, scholarship, and research appointments; and to organize research alliances among our members in areas where their collective strengths can be focused on issues of national importance.

ORAU manages the Oak Ridge Institute for Science and Education (ORISE) for DOE. ORISE is responsible for national and international programs in science and engineering education, training and management systems, energy and environment systems, and medical sciences. ORISE's competitive programs bring students at all levels, K-12 through postgraduate, and university faculty members into federal and private laboratories.

ORAU's office for University, Industry and Government Alliances (UIGA) seeks out opportunities for collaborative alliances among its member universities, private industry, and federal laboratories. Current alliances include the Southern Association for High Energy Physics (SAHEP) and the Center for Bio-Electromagnetic Interaction Research (CBEIR). Other UIGA activities include the sponsorship of conferences and workshops, the Visiting Scholars program, and the Junior Faculty Enhancement Awards.

Contact Jack H. Britt, (919) 829-4213, for more information about ORAU programs.

# University Patent and Copyright Procedures

North Carolina State University is dedicated to teaching, research and extending knowledge to the public.

It is the policy of the University to carry out its scholarly work in an open and free atmosphere and to publish results obtained therefrom freely, limited only by a short time delay in cases in which this is necessary to prepare and file applications. Patentable inventions sometimes arise out of the research activities of its faculty, staff and students which are carried out wholly or in part with University facilities. As a public service institution, the University has an interest in assuring the utilization of such inventions for the public good. Protection must be provided for at least some of these inventions through patents and the licensing thereof to encourage their development and marketing. Patents and their exploitation, however, represent only a small part of the benefits accruing from either publicly or privately sponsored research.

A portion of the research conducted by the University is supported by government and a portion by private industry. Service to the public, including private industry, is an integral part of the University's mission. As a public institution, the University, in its agreements with private industry or other private organizations, must keep the interests of the general public in view. The rights and privileges set forth in cooperative agreements or contracts, with respect to patents and copyrights developed as a result of research partly or wholly financed by private parties, must be fair and just to the inventor(s), the sponsor and the public. Research should be undertaken by the University under support from private parties only if it is consistent with and complementary to the University's goals and responsibilities to the public.

**SECTION 100–Purposes:**
The North Carolina State University Patent and Copyright Procedures are designed to implement the Patent and Copyright Policies of The University of North Carolina. The procedures incorporate the interests of the faculty, staff, *and students*, the institution, and the sponsors of research, because in many cases those interests are congruent in desiring to encourage innovation and assure broad dissemination of the results of research. These procedures are designed to stimulate and recognize creativity among the faculty, staff, and students, and to establish an institutional process that is flexible enough to accommodate the different types of research and patentable work conducted at a comprehensive research university such as NCSU. Equity and fairness are goals of the procedures in all respects, not only in the distribution of royalty, but also in recognition. Finally, these procedures should provide an efficient and timely mechanism for reaching a decision about patenting with a minimum involvement of the inventor's time so that he or she may continue to be productive in the laboratory and classroom. To this end the University employs a patents administrator whose duties include providing assistance to faculty, staff *and students* in matters related to inventions.

**SECTION 200–Ownership:**

1. As defined by the Patent and Copyright Policies of the Board of Governors of The University of North Carolina, to which these Procedures are expressly subject, North Carolina State University has an interest in all inventions of University personnel, *including students*, that are conceived or first actually reduced to practice as a part of or as a result of: (a) University research; (b) activities within the scope of the inventor's employment by, or official association with, the University; and (c) activities involving the use of University time, facilities, staff, materials, University information not available to the public, or funds administered by the University.

2. Faculty, staff, *and students*, whose inventions are made on their own time, outside the scope of their employment or association with the University and without University facilities, materials, or resources and which inventions are, therefore, their exclusive property as specified by the Patent and Copyright Policies, may submit their invention to the University for possible patenting and/or commercial exploitation and management under terms to be agreed upon by the inventor and the University.

3. The provisions of the NCSU Patent Procedures are subject to any applicable laws, regulations or specific provisions of the grants or contracts which govern the rights in inventions made in connection with sponsored research.

4. Under the terms of certain contracts and agreements between NCSU and various agencies of government, private and public corporations, and private interests, NCSU is or may be required to assign or license all patent rights to the contracting party. NCSU retains the right to enter into such agreements whenever such action is considered to be both in its best interest and in the public interest. Ordinarily, the University will not agree to grant rights in future inventions to private corporations or businesses except as set forth in these procedures.

5. All faculty, staff *and students* engaged in University related or sponsored research shall sign a Patent Agreement.

6. *Students who are pursuing only non-research related studies shall not be obligated to sign an NCSU Patent Agreement. However, if the student should make an invention which is, or may be, subject to University ownership in accordance with the Patent and Copyright Policies, the student shall disclose the invention to the University as provided under these Procedures and the University, together with the student, shall determine an equitable resolution of ownership rights.*

**SECTION 300–Responsibilities of NCSU Personnel (*Including Students*):**

1. NCSU personnel who, either alone or in association with others, make an invention in which NCSU has or may have an interest shall disclose such inventions to the Vice Chancellor for Research. The Vice Chancellor for Research will promptly acknowledge receipt of disclosures and will distribute the disclosures to the Intellectual Property Committee for consideration at its next meeting.

2. For any invention in which the University has an interest, the inventor, upon request of the Vice Chancellor for Research shall execute promptly all contracts, assignments, waivers or other legal documents necessary to vest in the University or its assignees any or all rights to the invention, including complete assignment of any patents or patent applications relating to the invention.

3. NCSU personnel may not: (a) sign patent agreements with outside persons or organizations that may abrogate the University's rights and interests either as stated in the Patent

Policies or as provided in any grant or contract funding the research which led in whole or in part to making the invention, nor (b) without prior authorization, use the name of the University or any of its units in connection with any invention in which the University has an interest.

4. *All faculty teaching courses in which students do work that may lead to patentable inventions should inform the students of the existence of the NCSU Patent and Copyright Policies and of these Procedures.*

**SECTION 400–Suggested Procedures For Record-Keeping:**

1. U.S. patent practice places a premium on witnessed records when two or more parties claim the same invention. The date the idea occurred (the "conception") and the date it was put into practice form ("reduced to practice") are vital. Equally important in the eyes of the U.S. Patent Office is the "diligence" shown by contending inventors. They must prove that they regularly pursued work on the invention, documenting their efforts on a day by-day basis. The intent of U.S. patent laws is to recognize the first inventor; the one who originated the idea. Under these laws, the first to conceive and reduce to practice will receive a patent if his records bear out his claims; the first to conceive and the last to reduce to practice may win if his records show diligence.

2. *The careful recording of ideas and laboratory data is a matter of routine for industrial researchers. Each entry is complete and up-to-date, signed and witnessed; a legal record of the day's work. Record-keeping is not nearly so simple for the academic investigator, for he or she may work at odd hours or on weekends; may be closeted in a laboratory, an office or at home; and often lacks easy accessibility to suitable witnesses. Still, the keeping of a witnessed laboratory notebook is advisable. Additionally, such records can serve as valuable repositories of new ideas.*

**SECTION 500–The Handling of a Disclosure:**

1. When faculty, *students* or staff members make an invention, it shall be their responsibility to discuss their discovery or invention with the Department Head at which time the possibility of exploring patenting should be considered. *Students should first discuss an invention with their instructor, who shall assist them in further discussion within the University.* The Director of Technology Administration is available to discuss possible inventions and to assist faculty, staff and students in the preparation of disclosures. If the invention appears to be a matter that should be considered for patenting, the inventor(s) should prepare a disclosure utilizing guidelines for invention disclosures which can be obtained for the Director of Technology Administration. The Department Head should transmit the disclosure through the Dean of his School to the Vice Chancellor for Research for consideration by the Intellectual Property Committee.

2. Upon receiving a disclosure, the Chairman of the Intellectual Property Committee may refer the disclosure to one of several technical advisory committees to the Intellectual Property Committee. Technical advisory committees will be appointed by the Vice Chancellor for Research and will be composed of faculty and staff who are knowledgable and experienced in broad disciplinary or cross-disciplinary areas. These individuals will be asked to review the disclosure from the point of view of whether or not, based on their knowledge, they believe the invention, if patented, would be a strong, viable, commercial product that would have a large market. The technical advisory committee in each area will meet prior to each Intellectual Property Committee meeting if they have any disclosures presented to

them, and will discuss the disclosures and make to the Intellectual Property Committee, prior to its meeting, one of the following recommendations:

A. That the disclosure has significant commercial possibilities.

B. That the disclosure does not appear to have significant commercial possibilities.

C. That the technical advisory committee could not determine, based on its knowledge, whether or not the disclosure has significant commercial possibilities.

3. The Intellectual Property Committee will review each written disclosure promptly. The inventor or a representative shall be allowed to examine all written materials submitted to the Committee in connection with the disclosure and to make a written and oral presentation to the Committee. The Committee will decide on a disposition of the invention to secure the interests of the University, the inventor, the sponsor, if any, and the public. Its decision may include, but is not limited to, one or a combination of the following:

A. To submit the disclosure for review by a patent or invention management firm or agent;

B. To make inquiries of potential licensees that may have an interest in the invention, including the financing of a patent application, where applicable;

C. To conduct a patent search concerning the patentability of the disclosure;

D. To apply for a patent with University resources (an option with limited application because of financial constraints);

E. To release University rights to the inventor subject to an agreement to protect the interests of the University, the sponsor, if any, and the public, including an obligation to pay to the University a percentage of future royalties or profits in cases where it is necessary to recognize the University's contribution;

F. To dedicate the invention to the public;

G. To waive further University interest in the invention.

4. Normally, within four weeks of the receipt of the disclosure, the inventor will be notified in writing of the decision of the Committee on (a) the equities involved including financial participation, (b) whether the University plans to file a patent application, or (c) whether the University will accept assignment of the invention for patenting, licensing and/or commercial handling as applicable. If the University chooses not to file a patent application for an invention in which it has rights, or not to license the invention, or not to dedicate it to the public, upon the inventor's written request the invention, at the Committee's discretion, may be released in writing to the inventor, with the permission of the sponsor, if any.

5. In those cases in which the University has obtained a patent without obligation to sponsors, if no arrangement has been made for commercial development within five years from the date of the issuance of the patent, the inventor(s) may request in writing an assignment of the University's patent rights. The Intellectual Property Committee will promptly either grant the request or advise the inventor of the University's plans for the development of the invention.

**SECTION 600--Royalty:**

1. NCSU shall share with the inventors revenue it receives from patents or inventions. As noted in Section 200 (4), specific provisions of grants or contracts may govern rights and revenue distribution regarding inventions made in connection with sponsored research; consequently, revenues the University receives from such inventions may be exclusive of payments of royalty shares to sponsors or contractors.

2. The gross royalty revenues (net amount received by the University if there is a specific agreement in a grant or contract with a sponsor) generated by a patent or invention shall be the basis upon which the inventor's royalty is calculated. Unless otherwise agreed, the inventor's share of royalty revenues shall be 25% of the gross revenue. In the case of co-inventors, the 25% of gross revenue shall be subdivided equally among them, unless the inventors, with the concurrence of the Intellectual Property Committee, determine a different share to be appropriate. Applicable laws, regulations or provisions of grants or contracts may, however, require that a lesser share be paid to the inventor. In no event shall the share payable to the inventor or inventors in the aggregate by the University be less than 15% of gross royalties received by the University.

3. To the extent practicable and consistent with State and University budget policies, the remaining revenue received by the University on account of an invention will first be applied to reimburse the University for expenses incurred by it in obtaining and maintaining patents and/or in marketing, licensing and defending patents or licensable inventions and the remainder will be dedicated to research purposes that may include research in the inventor's department or unit, if approved by the Chancellor upon recommendation of the Intellectual Property Committee.

**SECTION 700–Inventor Requests for Waiver of University Rights:**

1. If an inventor believes that the invention was made outside the general scope of his or her University duties, and if the inventor does not choose to assign the rights in the invention to the University, he or she shall, in the invention disclosure, request that the Intellectual Property Committee determine the respective rights of the University and the inventor in the invention and shall also include information on the following points:

A. The circumstances under which the invention was made and developed;

B. The employee's official duties at the time of the making of the invention;

C. The inventor's intention to request an acknowledgment that the University has no claim if such request is deemed appropriate;

D. The extent to which the inventor is willing voluntarily to assign domestic and foreign rights in the invention to the University if it should be determined that an assignment of the invention to the University is not required under the Patent and Copyright Policies;

E. The inventor's intention to request that the University prosecute a patent application if it should be determined that an assignment of the invention to the University is not required under the Patent and Copyright Policies.

**SECTION 800–Publication and Public Use**

1. North Carolina State University strongly encourages scholarly publication of the results of research by faculty and students. Though the Patent and Copyright Policies do not limit the right to publish, except for short periods of time necessary to protect patent rights, publication or public use of an invention constitutes a statutory bar to the granting of a United States patent for the invention unless a patent application is filed within one year of the date of such publication or public use. Publication or public use also can be an immediate bar to patentability in certain foreign countries.

2. In order to preserve rights in unpatented inventions, it shall be the duty of the inventor, or of his or her supervisor if the inventor is not available to make such report, to report immediately to the Vice Chancellor for Research any publication, submission of manuscript for publication, sale, public use, or plans for sale or public use, of an invention, if a

disclosure has previously been filed. If an invention is disclosed to any person who is not employed by the University or working in cooperation with the University upon that invention, a record shall be kept of the date and extent of the disclosure, the name and address of the person to whom the disclosure was made, and the purpose of the disclosure.

After disclosure to the Intellectual Property Committee, the inventor shall immediately notify the Vice Chancellor for Research of the acceptance for publication of any manuscript describing the invention or of any sale or public use made or planned by the inventor.

**SECTION 900–Contractural Arrangements:**

1. North Carolina State University will follow Federal Regulations with respect to election of title in contracts and grants with Federal agencies.

2. The University normally reserves the right to ownership of patents on inventions arising out of research supported in whole or in part by grants or contracts with non-governmental organizations or firms. Contracts or agreements which are entered into between the University and such organizations or agencies should contain clauses setting forth such a reservation unless deviations therefrom are requested by the sponsor and approved by the Vice Chancellor for Research. In the interest of fair treatment to the sponsor in consideration for an investment and in the interest of discharging the University's obligation to the public in the application of its facilities and employee time and talent, special provisions may be negotiated by the Vice Chancellor for Research in such non-government sponsored contracts on options such as the following:

A. The University will retain rights to patents arising out of such sponsored research but, if a significant portion of the research costs are borne by the sponsor, including direct costs, the sponsor may be assured a non-exclusive, non-assignable license at a most favorable royalty rate for the use of the patent.

B. Other patent licensing alternatives may be negotiated in the research contract based on factors which will promote effective and expeditious transfer of the technology. Research sponsors are encouraged to seek guidance from the Office of the Vice Chancellor for Research.

C. In order to protect the potential patent interests of both parties in such contracts in which the sponsor is accorded patent rights, the following procedure may be specified:

"When in the course of the sponsored research project the investigator or investigators conceive or reduce to practice some discovery which appears to be patentable, then the inventor(s) will immediately inform the sponsors and the University of such discovery and will, for a specified period as negotiated (normally three months but in any case not more than twelve months), make available to the sponsor all pertinent information and disclosures which may be required for the development of an appropriate patent application. During this period, the investigators agree not to disclose this material to the public and agree to cooperate in the sponsor's effort to secure the patent. At the end of this agreed period, the investigators and the University will be free to proceed with publications and making public such other documents as they may choose. With the exception of the above mentioned agreed period, the University will operate industry sponsored contracts in the normal manner with no other special considerations being given to the sponsor. Under no circumstances will the sponsor have the right to prevent the publication of material or information derived during the conduct of the program or as a result thereof other than for the agreed period indicated above."

Prior written agreement of the investigators involved in research investigations to be carried out under these conditions must be secured by the University to enable the University to discharge its agreed obligations under such a contract.

**SECTION 1000–Patent Management and Administration:**

1. North Carolina State University recognizes that the evaluation of inventions and discoveries and the administration, development and processing of patents and licensable inventions involves substantial time and expense and requires talents and experience not ordinarily found among its faculty and staff; therefore, it employs the Director of Technology Administration to provide assistance. The University may contract with outside agents for certain services. It may enter into a contract or contracts with an outside organization covering specific inventions or discoveries believed to be patentable and patents developed therefrom or covering all such inventions, discoveries and patents in which the University has an interest. The University may manage an invention using its own resources.

2. The Chancellor shall appoint a Intellectual Property Committee consisting of no fewer than three members. The Vice Chancellor for Research shall serve as Chairman of the Committee. The Committee shall review and recommend to the Chancellor or the Chancellor's delegate changes in these Procedures, decide upon appropriate disposition of invention disclosures, resolve questions of invention ownership, recommend to the Chancellor the expenditure of invention royalties, and make such recommendations as are deemed appropriate to encourage disclosures and to assure prompt and effective handling, evaluation, and prosecution of invention opportunities and to protect the interests of the University and the public. The Director of Technology Administration shall serve as staff for the Committee and shall attend all meetings.

**SECTION 1100–Copyright Procedures:**

1. As a general rule, all rights to copyrightable material are the property of the author. The distribution or royalties, if any, is a matter of arrangement between the author and his or her publishers or licensees. Different treatment may be accorded by the University in case of specific contracts providing for an exception, in cases where the University or sponsor may employ personnel for the purpose of producing a specific work, where differ ent treatment is deemed necessary to reflect the contribution of the institution to the work, as in the case of software or audiovisual material, or where a sponsored agreement requires otherwise. All agreements concerning copyright ownership should be in writing and should be signed by the parties and approved by the Vice Chancellor for Research prior to the commencement of the work.

2. An institute, center, or other unit of the University that is itself a publisher and that engages faculty members and other employees to write for publication by that unit as a part of their professional duty or produce other copyrightable materials, such as audiovisual materials or computer software, may, subject to the approval of the Vice Chancellor for Research, adopt rules providing that copyright on materials prepared by such faculty members and other employees in the course of their professional work for that unit vests in the University and not in the author.

3. Guidelines and procedures for determining faculty, staff *and student* ownership of computer software were adopted by the NCSU Board of Trustees, effective July 1, 1987, and are available from the Office of the Vice Chancellor for Research or the Office of Technology Administration, Room 1 Holladay Hall.

# FIELDS OF INSTRUCTION

This section identifies and gives pertinent information about all the fields of study that participate in graduate education at NCSU. There are a total of 87 different fields that offer graduate degrees. In addition, there are eight fields that offer minors at the graduate level and eleven areas that support graduate support graduate education through offering graduate level courses or in some other capacity. Fields of instruction that offer graduate degrees are listed first. Information given for each field include the faculty, requirements for admission to and completion of the degree program(s), student financial support, courses offered and other relevant information. Following the degree offering fields is a listing other fields of instruction which offer graduate minors, graduate courses or support graduate education in some other way. To avoid duplication, basic Graduate School requirements for admission and completion of graduate degree programs are not duplicated for each field of instruction. Only those requirements that are unique to the field are given in the sections on the individual fields. Graduate School requirements are given in detail on pages 13-14 and pages 40-54 in this catalog and are summarized below.

## Fields Offering Graduate Degrees

The Graduate School offers major programs of study in the following fields. Except where noted by an ◆ or an exception in parentheses, these programs required the Graduate Records Examination (GRE) scores and will not take action on applications unless accompanied by scores for at least the GRE General (Aptitute) Test (verbal, quanititative and analytical):

Accounting - Master of
◆ Adult and Community College Education - Master of Education, M.S., Ed.D.
Aerospace Engineering - M.S., Ph.D.
Agricultural and Resource Economics - M.S. (Exceptions apply; consult program)
Agricultural Education - Master of Education, M.S. (GRE or MAT)
Agriculture - Master of (Consult program of interest)
Animal Science - M.S., Ph.D.
Applied Mathematics - M.S., Ph.D. (and GRE Subject Test)
Architecture - Master of (Exceptions apply; consult program)
Biochemistry - M.S., Ph.D.
Biological and Agricultural Engineering - Master of, M.S., Ph.D. (Exceptions apply; consult program)
Biomathematics - Master of, M.S., Ph.D.
Botany - M.S., Ph.D.
Chemical Engineering - Master of, M.S., Ph.D.
Chemistry - Master of, M.S., Ph.D. (Not required but strongly encouraged)

Civil Engineering - Master of, M.S., Ph.D.
Computer Engineering - M.S., Ph.D.
Computer Science - Master of, M.S., Ph.D. (and GRE Subject Test)
Counselor Education - Master of, M.S., Ph.D. (GRE or MAT)
Crop Science - M.S., Ph.D.
Curriculum and Instruction - Master of Education, M.S., Ed.D. (GRE or MAT)
Ecology -M.S.
Economics - Master of, M.A., Ph.D. (Exceptions apply; consult program)
Educational Administration and Supervision - Master of Education, M.S., Ed.D. (GRE or MAT)
Educational Research and Policy Analysis - Ph.D. (GRE or MAT)
Electrical Engineering - Master of, M.S., Ph.D.
◆ Engineering--Master of (Off-campus program only)
English - M.A.
Entomology - M.S., Ph.D.
Fiber and Polymer Science - Ph.D.
Food Science - M.S., Ph.D.
Forestry - Master of, M.S., Ph.D.
Genetics - M.S., Ph.D.
Graphic Design - Master of (Exceptions apply; consult program)
Health Occupations Teacher Education - Master of Education, M.S. (GRE or MAT)
◆ Higher Education Administration - Master of Education, M.S.
History - M.A.
Horticultural Science - M.S., Ph.D.
Immunology - M.S., Ph.D.
Industrial Design - Master of (Not required but strongly encouraged)
Industrial Engineering - Master of, M.S., Ph.D.
◆ Integrated Manufacturing Systems Engineering - Master of (Exceptions apply; consult program)
International Development, Technology for - Master of
◆ Landscape Architecture - Master of
◆ Liberal Studies - M.A.
◆ Life Sciences - Master of (Consult program of interest)
Management - M.S. (GRE or MAT)
Marine, Earth and Atmospheric Sciences - M.S., Ph.D. (and GRE Subject Test)
Marketing Education - Master of Education
Materials Science and Engineering - Master of, M.S., Ph.D. (Not required by strongly encouraged)
Mathematics - M.S., Ph.D. (and GRE Subject Test)
Mathematics Education - Master of Education, M.S., Ph.D. (MR, GRE or MAT; PhD, GRE only)
Mechanical Engineering - Master of, M.S., Ph.D.
Microbiology - M.S., Ph.D.
Middle Grades Education - Master of Education, M.S. (GRE or MAT)

Natural Resources Administration - Master of, M.S.
Nuclear Engineering - Master of, M.S., Ph.D. (Exceptions apply; contact program)
Nutrition - M.S., Ph.D.
Occupational Education - Master of Education, M.S., Ed.D. (GRE or MAT)
Operations Research - Master of, M.S., Ph.D. (Exceptions apply; contact program)
Parks, Recreation and Tourism Management - Master of, M.S.
Physics - M.S., Ph.D. (and GRE Subject Text)
Physiology - M.S., Ph.D.
Plant Pathology - M.S., Ph.D.
Political Science - M.A. (and GRE Subject Test. Not required but strongly encouraged)
Poultry Science - M.S. (Not required but strongly encouraged)
Psychology - M.S., Ph.D. (and MAT. Not required but strongly encouraged)
Public Administration - Master of
Public History - M.A.
Rural Sociology - M.S.
Science Education - Master of Education, M.S., Ph.D (MR, GRE or MAT; PhD, GRE only)
Sociology - Master of, Ph.D.
◆ Soil Science - M.S., Ph.D.
Special Education - Master of Education, M.S. (GRE and MAT not required but strongly encouraged)
Statistics - Master of, M.S., Ph.D.
Technical Communication - M.S.
Technology Education - Master of Education, M.S. (GRE or MAT)
Textile Chemistry - M.S.
Textile Engineering and Science - Master of, M.S.
Textile Management and Technology - Master of, M.S.
Textile Technology Management - Ph.D. (GRE or GMAT)
Toxicology - Master of, M.S., Ph.D.
◆ Training and Development - Master of Education, M.S.
Veterinary Medical Sciences - M.S., Ph.D.
Wildlife Biology - Master of, M.S. (GRE and GRE Subject Test not required but strongly encouraged)
◆ Wood and Paper Science - Master of, M.S., Ph.D.
Zoology - M.S., Ph.D. (GRE and GRE Subject Test not required but strongly encouraged)

Departments not normally requiring GRE scores may in special instances require their submission as additional information to be used in making a judgment of the student's potential for succes in a graduate program.

The following fields and units, while not offering graduate degrees, support graduate education by offering graduate minors and graduate courses or in some other capacity:

Agricultural Communications
Anthropology
Artificial Intelligence
Biological Sciences
Biomedical Engineering
Biotechnology
Business Management
Communication
Computational Engineering and Sciences
Design
Education
Engineering
Foreign Languages and Literatures
Pest Management
Philosophy
Plant Physiology
Solid State Sciences
Water Resources

## BASIC GRADUATE SCHOOL REQUIREMENTS

### Basic Requirements for Admission

Basic requirements for admission to the Graduate School include two official transcripts from all colleges and universities previously attended, references from at least three people who know of the student's academic record and potential for graduate study, a non-refundable $45.00 application fee, Test of English as a Foreign Language (TOELF) scores for students whose first language is not English, and, in most cases, an official statement of the student's Graduate Record Examination (GRE) scores and/or other standardized tests. The minimum TOEFL score, unless otherwise specified, is 550, with scores of at least 50 on at least two of the sections and no section score below 45. The student's area of special interest may have additional requirements which are included in the individual program descriptions to follow.

### Basic Requirements for Master's Degrees

A minimum of 30 semester credit hours is required for all master's degrees; however, many programs require more than thirty. Also, many students, in order to gain the breadth desired in their program or to make up deficits in their undergraduate degree, will actually take more credit hours than the minimum required by the program. At least 20 semester hours must come from 500- and 600-level courses. No more than two credit hours of departmental seminar may be included in the minimum 30-credit program. Programs that require a thesis may include no more than six hours of research credit (699) in the minimum 30-credit-hour program. Research credit is not appropriate in the non-thesis programs. Non-thesis programs may include no more than six hours of independent study credits in the minimum 30-credit program. Courses at the 400 level counted toward the minimal 30-hour requirement may not come from the major field.

## Basic Requirements for Doctoral Degrees

The doctorate symbolizes the ability of the recipient to undertake original research and scholarly work at the highest levels without supervision. The degree is therefore not granted simply upon completion of a stated amount of course work but rather upon demonstration by the student of a comprehensive knowledge and high attainment in scholarship in a specialized field of study. The student must demonstrate this ability by passing written and oral preliminary comprehensive examinations in the field of specialization and related areas of knowledge, where applicable, and by successfully defending the methodology used and conclusions reached in the research, as reported in the dissertation, in an open oral examination. In addition, the student must meet the residence requirement as described earlier.

# COURSES

The courses listed in this catalog are planned for the academic years 1994-1995 and 1995-1996, unless indicated otherwise. Some listed courses may not be taught, however, if registration for a course is insufficient or if faculty or facilities are not available.

Courses at the 500- and 600-level are graduate courses, but 500-level courses are open to advanced undergraduate students, unless otherwise specified. Graduate standing is a prerequisite for all 600-level courses. Courses at the 400-level are advanced undergraduate course but may be used, with some limitations, in graduate programs of study.

Consent of the department is required for all practicum and individual special topics or special problems courses as well as internships and thesis or dissertation research.

## Course Descriptions

In a typical course description, the semester hours of credit, the number of actual lecture and laboratory/seminar/practicum/studio hours of meeting per week, and the term or terms in which the course is offered are shown in this manner: 4(3-2) F,S,Sum. or 1-3 F,S, Sum. In the first example, the "4" indicates the number of semester hours credit given for satisfactory completion of the course. The "(3-2) indicates that the course meets for three hours of lecture and two hours of laboratory/seminar/practicum/studio work each week. In the second example, the "1-3" indicates that a minimum of one and a maximum of three semester hours' credit can be earned. This is to be arranged with the instructor. The "F" designates that the course is to be given in the fall semester. Likewise, the "S" designates spring and the "Sum.," summer.

For 400-level course prerequisites and descriptions, see the Undergraduate Catalog.

**Abbreviations Used in Course Listings**

Abbreviations used in the course listings are:

alt. yrs. - alternate years
CI - consent of instructor
coreq. - corequisite
grad. standing - admitted to the Graduate School
hrs. - hours
jr. - junior
lab. - laboratory
lect. - lecture
PBS - Post-baccalaureate Studies status
preq. - prerequisite
sem. - semester
sr. - senior
undergrad. - undergraduate.

# MAJOR FIELDS OF STUDY

## Accounting

**Degree Offered: Master of Accounting**

**GRADUATE FACULTY**

*KPMG Peat Marwick Professor* Carl J. Messere, *Head of the Department*
*Associate Professor* Robert L. Peace, *Director of Graduate Programs*
Box 8113, (919) 515-4431, bob_peace@ncsu.edu

*Professors:* J. W. Bartley, K. B. Frazier, P. F. Williams;
*Associate Professor:* G. J. Zuckerman;
*Assistant Professors:* B. C. Branson, F. A. Buckless, Y. A. Chen, K. A. Krawczyk, R. L. McClenny, R. B. Sawyers

The Master of Accounting (MAC) is a professional degree designed to prepare students for careers as public accountants, internal auditors, or tax specialists. Graduates will be prepared to complete the CPA Examination.

### Admission Requirements

Successful applicants typically have a Graduate Management Admissions Test (GMAT) score above 500. The best-qualified applicants will be accepted up to the number of spaces available for new students. Exceptions to the minimum GPA and GMAT score may be made because of the consideration given to other relevant factors. Prerequisite courses for admission to the master's program include accounting and certain other courses that are the equivalent of those required for an undergraduate degree in accounting. Applicants may receive provisional admission prior to completion of the prerequisites, but will not be admitted to 500-level courses until prerequisites are completed. Complete information and application forms can be obtained from the Director of Graduate Programs.

### Master's Degree Requirements

A minimum of 6 (maximum of 9) non-ACC credits are required. There are no required courses, but all programs of study are subject to approval by the Director of Graduate Programs. The curriculum is designed to allow concentrations of course work in either auditing or taxation.

### Other Relevant Information

Master's students must begin the degree program in the fall semester, and they must

carry at least two classes. All course work can be completed in the evening program.

In order to assure that an application will be considered for the next fall semester, all application forms, transcripts, applicable fees, resumes, letters of recommendation and other relevant material must be received no later than March 1. Applicants wishing to receive early notification of the admission decision should submit all required documents prior to December 1 of the year prior to admission.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

ACC 440 ACCOUNTING INFORMATION SYSTEMS.
ACC 450 AUDITING FINANCIAL INFORMATION.
ACC 480 ACCELERATED SURVEY OF FINANCIAL AND MANAGEMENT ACCOUNTING.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ACC 508 ADVANCED COMMERCIAL LAW. Preq: BUS 307. 3(3-0) S.** The principles of statutory law and common law relevant to corporate and public accountants. Legal research.

**ACC 510 ADVANCED FINANCIAL ACCOUNTING. Preq: ACC 312. 3(3-0) F.** Accounting principles and problems related to business combinations, financial reporting for consolidated enterprises, transactions with foreign entities and advanced partnership accounting. Introduction to international accounting practices.

**ACC 515 ACCOUNTING THEORY AND CURRENT ISSUES. Preq: ACC 510. 3(3-0) S.** Accounting theory and current issues related to financial reporting with an emphasis on research methods, database use, written and oral communication skills, ethical issues and team work.

**ACC 519 INTEGRATED ACCOUNTING PRACTICE. Preq: Grad. standing and consent of department. 3(3-0) S.** Integration of financial accounting, managerial accounting, taxation, and auditing. Application of legal and professional standards and analytical methods to accounting problems.

**ACC 521 PRODUCTION COST ANALYSIS AND CONTROL. Preq: ACC 320 or ACC 480; BUS 350. 3(3-0) S.** Advanced managerial accounting practices: cost calculation, cost estimation, cost allocation and control using matrix algebra, statistics and other quantitative techniques.

**ACC 525 ADVANCED MANAGEMENT ACCOUNTING. Preqs: ACC 320 or ACC 480; EC 301 or EC 501; BUS 350. 3(3-0) F.** Uses of accounting data for management decisions within the firm: applications of formal analytical models

including decision theory, statistical analysis of cost behavior and optimization models. Management and control of decentralized operations. The design and evaluation of accounting systems. Designed primarily for students in the Master of Science in Management program.

**ACC 530 ADVANCED INCOME TAX. Preq: ACC 330. 3(3-0) F.** Federal income tax treatment of corporations; partnerships; estates; trusts; and profit and loss distributions to shareholders, partners and beneficiaries. Introduction to wealth transfer taxes and family tax planning.

**ACC 533 TAX RESEARCH, PROCEDURE AND PRACTICE. Preq: ACC 330; grad. standing. 3(3-0) F.** Tax research techniques applicable to federal and state tax laws with an emphasis on legal research techniques, assessing authority, analytical skills, professional judgment, and formal communication of research findings; use and application of traditional and computerized tax research databases; IRS procedure including the tax collection, examination, appeals and assessment functions.

**ACC 534 TAXATION OF CORPORATIONS AND SHAREHOLDERS. Preq: ACC 533; grad. standing. 3(3-0) F.** Selected topics of federal income taxation pertaining to corporations and their shareholders including corporate formation, distributions, liquidations and reorganizations; tax problems of consolidated income tax returns; and tax planning opportunities involving the corporation and its shareholders.

**ACC 535 TAXATION OF PARTNERSHIPS AND S CORPORATIONS. Coreq: ACC 533; grad. standing. 3(3-0) F.** The legal and federal income tax aspects of the partnership as a business entity; the measurement of partnership profits and losses; distributions to partners; and transactions between partners and the partnership. Legal and business aspects of the S Corporation as a business entity and tax planning for S Corporation shareholders.

**ACC 536 TAXATION OF ESTATES, TRUSTS AND GIFTS. Preq: ACC 533; grad. standing. 3(3-0) S.** The examination of federal excise tax levied on transfers of property via gift or from a decedent's estate, including the fundamental concepts of estate planning using planned giving and trusts; income taxation of estates and trusts with an emphasis on the integration of estate, gift and income taxes.

**ACC 537 TAX PLANNING AND BUSINESS STRATEGY. Preq: ACC 533; grad. standing. 3(3-0) S.** Development of a tax planning framework for use in analyzing decision settings including compensation planning, multinational transactions, organizational and capital structure, property transactions, and mergers and acquisitions. Policy implications of existing laws and alternatives.

**ACC 550 AUDITING IN A COMPUTER ENVIRONMENT. Preq: ACC 440, ACC 450, grad. standing. 3(3-0) F.** Application of generally accepted auditing standards in computer-based accounting information systems. The application of audit software tools, including expert systems, in the conduct of an audit.

**ACC 551 ADVANCED AUDITING. Preq: ACC 440, ACC 450; grad. standing. 3(3-0) F.** Current issues and regulation of the auditing profession; application of generally accepted auditing standards and determination of sufficient competent evidential matter including analytical procedures and statistical sampling. Auditor ethics, other auditing services, government auditing, compilation, review and other attestation services.

**ACC 552 ADVANCED AUDITING AND ACCOUNTING CASES. Preq: ACC 450, ACC 510; grad. standing. 3(3-0) S.** Problem identification, analysis, solution and communication in multidimensional settings involving financial reporting, managerial accounting and auditing issues.

**ACC 588 SPECIAL TOPICS IN ACCOUNTING. Preq: Consent of department. 1-6. F,S.** The course objectives dependent upon the unique circumstances that motivate offering the course. Timely curriculum innovation the primary motivation for offering the course.

**ACC 598 INDEPENDENT STUDY IN ACCOUNTING. Preq: Consent of department. 1-6. F,S.** The study of advanced topics not otherwise included in the curriculum by advanced graduate students on a tutorial basis. Determination of credits and content by participating faculty in consultation with the Director of Graduate Programs.

# Adult and Community College Education

**Degrees Offered: Ed.D., M.S., M.Ed.**

## GRADUATE FACULTY

*Professor* J. C. Glass Jr., *Interim Head of the Department*
*Professor* R. W. Shearon, *Associate Head of the Department*
*Associate Professor* E. I. Farmer, *Director of Graduate Programs*
Box 7801, (919) 515-6238, farmer@poe.coe.ncsu.edu

*Joseph D. Moore Distinguished Professor* G. A. Baker III

*Professor:* E. J. Boone, D. C. Locke, W. B. Harvey, R. D. Mustian, G. B. Vaughan;

*Professors Emeriti:* M. P. Burt, G. L. Carter Jr.,M. S. Knowles;
*Associate Professors:* C. J. Killacky, R. T. Liles, L. F. McCutcheon;
*Visiting Associate Professors:* J. L. Burrow, R. Gillett-Karam;
*Associate Professor Emeritus:* E. E. White;
*Assistant Professors:* S. A. J. Colin III, W. Lee, J. R. Valadez;
*Visiting Assistant Professors:* N. E. Hagan, B. I. Mallette, J. M. Pettitt, W. D. Weston

The department offers degrees in adult and community college education, higher education administration, and training and development to meet the professional needs of administrators, supervisors, specialists and instructors in community colleges, four-year colleges and universities, extension systems, business and industry, the professions, and other adult education organizations. Program concentrations include adult and continuing education, community college leadership and higher education, extension education, and training and development.

### Admission Requirements

In addition to Graduate School admission requirements, the Department requires supplemental evidence of qualifications. Specific information regarding admission can be obtained by contacting the Director of Graduate Programs.

### Master's Degree Requirements

The M.S. and M.Ed. programs requires a minimum of 31 or 37 credit hours, respectively. A graduate course in statistics and a thesis are required for the M.S.

### Doctoral Degree Requirements

The Ed.D program requires extensive research work and may include participation in a supervised internship experience. The doctoral program must be completed within seven years from the date of admission. One academic year of full-time residency is required.

### Student Financial Support

A few graduate assistantships may be available to students in this program.

### Other Relevant Information

Students may concentrate in adult and continuing education (continuing professional education, educational gerontology, literacy, and international adult education), extension education, four-year colleges and universities, community and technical colleges, and training and development.

## *SELECTED ADVANCED UNDERGRADUATE COURSE*

**EAC 478 EXTENSION AS NON-FORMAL EDUCATION.**

**EAC 500 COMMUNITY COLLEGE AND TWO-YEAR POSTSECONDARY EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F,S.** Comprehensive community colleges and technical institutes and the state systems of which they are a part: underlying concepts, design of educational needs to be serve, role in meeting these needs, historical development, issues in the establishment and operation of state systems and individual institutions, unresolved issues and emerging trends.

**EAC 503 THE PROGRAMMING PROCESS IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: Grad. standing. 3(3-0) F,S.** The principles and processes in programming, including basic theories and support of the concepts in programming process. Attention to the general programming framework, organizational needs and the program roles of both professional and lay leaders.

**EAC 504 LEADERSHIP IN HIGHER AND COMMUNITY COLLEGE EDUCATION. 3(3-0) S.** Issues and concepts of leadership development and practice in two- and four-year colleges and universities; interpretation and communication of institutional values and understanding of organizational processes. Attention to the role of organizational culture in management improvement and institutional performance in higher education institutions.

**EAC 505 GROUP PROCESS IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) Sum.** Application of research and theory in small group behavior to administration and teaching in adult and community college education settings. Opportunities for participant experience of various aspects of group behavior and practice of group leadership skills applicable to various group situations.

**EAC 510 ADULT EDUCATION: HISTORY, PHILOSOPHY, CONTEMPORARY NATURE. Preqs.: Advanced undergrad., CI. 3(3-0) F,S.** The historical and philosophical foundations of adult education from ancient times to the present, with attention to key figures, issues, institutions, movements and programs, including consideration of the relationship between adult education's historical development and prevailing intellectual, social, economic and political conditions. Consideration of adult education's contemporary nature, present-day schools of thought on its objectives and trends.

**EAC 517 CURRENT ISSUES IN HIGHER EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F. Alt. yrs.** Examination of important social, political and economic issues affecting the present and future operation of colleges and universities in America.

**EAC 537 THE EXTENSION AND PUBLIC SERVICE FUNCTION IN HIGHER EDUCATION. Preq.: EAC 510. 3(3-0) S.** An examination of the background, history, philosophy and contemporary nature of the extension and public service function of institutions of higher education in the United States. Emphasis on the adult education role of public and private universities and colleges. Specific focus on: general extension, industrial extension, engineering extension, cooperative extension and continuing education.

**EAC 538 INSTRUCTIONAL STRATEGIES IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F.** Forms of instruction appropriate for the teaching of adults. Special emphasis upon methods for maximum involvement of the adult learner. Relevant concepts, theories and principles for the selection, utilization and evaluation of instructional strategies with focus on the integration of theory into practice. Development of student proficiency in use of applicable teaching techniques for adult and community college education through participation in classroom exercises.

**EAC 539 EDUCATIONAL GERONTOLOGY. Preq.: Six hrs. in ED, SOC or PSY. 3(3-0) F.** A broad overview of factors relevant to the education of older adults. Various sociological, physiological, psychological and economic aspects of aging and their educational implications. Attention to necessary knowledge and skills for the development of educational programs for the aging population.

**EAC 540 EXTENSION IN DEVELOPING COUNTRIES. Preq.: Grad. standing, PBS status or CI. 3(3-0) F.** Rural extension (agriculture, forestry, development, etc.). Strategies for the enablement of farm/rural people to better usage of science, technology and other types of knowledge in fulfilling their own aspirations within their cultural context. Examination of the practice of rural extension/development in many parts of the world and basic conceptual ideas and processes.

**EAC 543 ADULTHOOD AND LEARNING: THE LATER YEARS. Preq.: EAC 539 or CI. 3(3-0) S.** Occurrence of basic sensory, attitudinal, intellectual and emotional changes in individuals during the process of growing old and the implications of these changes for development, implemention and evaluation of educational programs for and with older adults.

**EAC 545 DEATH AND DYING: A LIFESPAN ISSUE. Preq.: Grad. standing or PBS status. 3(3-0) Sum.** Examination of issues associated with the dying process, death itself and bereavement. Perceptions and responses to these issues at various stages of the lifespan. Implications for students' fields of practice.

**EAC 549 FINANCE IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preqs.: EAC 500, grad. standing. 3(3-0) S.** Examination of theory, research, practices and issues in the development and management of financial resources of the adult and community college enterprise.

**EAC 550 THE ENVIRONMENT FOR LEARNING IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: EAC 500. 3(3-0) S.** Planning and management of the physical environment for effective adult learning. Applicability of concepts and theories of the learning and teaching environment to need analysis, planning, resource development, cooperation with professional designers, and the construction, operations, conservation and maintenance of educational facilities, equipment and grounds.

**EAC 559 THE ADULT LEARNER. Preq.: Six hrs. in educ. 3(3-0) F,S.** Requisite involvement and undergirding of principles in adult education programs including theories and concepts. Emphasis on interrelationship of the nature of adult learning, the nature of the subject matter and the setting for learning occurrence. The applicability of relevant principles and pertinent research findings to adult learning.

**EAC 567 EDUCATION OF SPECIAL ADULT POPULATIONS. 3(3-0) S,Sum.** Analysis and development of adult education responses to the needs and characteristics of special adult populations such as nonliterate, unemployed, handicapped and older adults.

**EAC 578 LAW AND HIGHER EDUCATION. Preq.: Six hrs. grad. credit. 3(3-0) S. Alt. yrs.** Constitutional, statutory and case law in relationship to higher education. Emphasis on faculty, student and staff rights and tort liability.

**EAC 579 CONCEPTS AND PRINCIPLES OF EVALUATION APPLIED TO NON-FORMAL ADULT EDUCATION PROGRAMS. Preq.: EAC 503 or CI. 3(3-0) S.** Introduction to the evaluation of non-formal adult educational programs; course topics include the purposes of evaluation, alternative concepts and techniques, stake holders and their concerns, the specification of evidence, selection of standards for making judgments, gathering and analysis of data, use and dissemination of results and handling problems in evaluation.

**EAC 582 ORGANIZATION AND OPERATION OF TRAINING AND DEVELOPMENT PROGRAMS. 3(3-0) F,S.** Overview of occupational education practice in business and industrial settings. Presentation of roles common to training and development specialists, including managerial concerns related to organization, operation and financial training and development programs.

**EAC 585 QUALITATIVE RESEARCH IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: Grad. standing. 3(3-0) F.** Design of qualitative studies, conduct of field work including open-ended interviews and participant observation, analysis of data and understanding of theoretical and philosophical background of this research approach.

**EAC 586 METHODS AND TECHNIQUES OF TRAINING AND DEVELOPMENT. 3(3-0) F,S.** Methods and techniques common to model occupational education programs in business and industrial settings. Focus on design and evaluation of effective learning programs and instructional methodologies.

**EAC 596 TOPICAL PROBLEMS IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: Grad. standing or PBS status. Credits arranged. F,S, Sum.** Study and scientific analysis of problems in adult education and preparation of a scholarly research type of paper.

**EAC 599 RESEARCH PROJECTS IN EDUCATION. Preqs.: CI; EAC 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. Choice of research on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**EAC 600 ORGANIZATIONAL CONCEPTS AND THEORIES APPLIED TO ADULT AND COMMUNITY COLLEGE EDUCATION. Preqs.: EAC 503, PS 502, SOC 541. 3(3-0) F.** For present and potential administrators interested in increase of their understanding of organization as a basis for administration of effective adult and community college education programs.

**EAC 601 ADMINISTRATIVE CONCEPTS AND THEORIES APPLIED TO ADULT AND COMMUNITY COLLEGE EDUCATION. Preq.: EAC 600 or a comparable course on organizational theory. 3(3-0) S.** For persons interested in the building of a more consistent philosophy of educational administration, extension and strengthening of understanding of administrative concepts and processes, improved comprehension of the theoretical and research foundations upon which administrative processes predicated, and increased ability for application of administrative concepts, theories and principles to the management of the complex education system.

**EAC 607 THE POLITICS OF HIGHER EDUCATION. Preqs.: Grad. standing or Management Development Certificate Program and six sem. hrs. of 500-level course work. 3(3-0).** The differing and changing perceptions of the role of

higher education in American society; the politics of competition for priority of attention and resources; organizational alternatives in its control; relevant elements in the structure and processes of government. References to other societies.

**EAC 616 HISTORY OF HIGHER EDUCATION IN THE UNITED STATES. Preqs.: Six hrs. of grad. educ. courses and CI. 3(3-0) S. Alt. yrs.** The history of higher education from the colonial period to the present. Emphasis on influence of philosophic, political, social and economic forces upon function and structure of higher education.

**EAC 621 INTERNSHIP IN ADULT AND COMMUNITY COLLEGE EDUCATION. Preqs.: Nine hrs. in grad.-level courses and CI. 3-9 F,S,Sum.** Utilization of the participant-observer role with required participation in selected educational situations. Emphasis upon observational skills' development, the recording of relevant observations through written journals, analysis of experiences identifying critical incidents and projection of events and consequences. Student development and selection of possible alternative courses of action in various situations and evaluation of the consequences of the selected course of action.

**EAC 696 SEMINAR IN ADULT AND COMMUNITY COLLEGE EDUCATION. 1-3 F,S.** Identification and scientific analysis of major issues and problems relevant to adult education. Course credit through the active student participation in a formal seminar and scientific appraisal and solution of a selected problem. Student acquisition of a broad perspective of issues confronting adult educators and experiences in the scientific analysis and solution of specific issues.

**EAC 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of educ.; CI. Credits Arranged. F,S,Sum.** Individual research on a thesis or dissertation problem.

# Aerospace Engineering

For a listing of graduate faculty and program informaton, see mechanical and aerospace engineering.

# Agricultural and Resource Economics

For a listing of graduate faculty and program information, see economics.

# Agricultural Education

For a listing of graduate faculty and program information, see occupational education.

# Agriculture

Several departments in the College of Agriculture and Life Sciences offer programs leading to the Master of Agriculture and/or the Master of Life Sciences. These are non-thesis degrees that are designed for students who wish to emphasize course work in a graduate program. As such they require a total of 36 semester hours. A minimum of four semester hours in special problems is required and not more than six semester hours will be allowed. A minimum of 20 credit hours of 500- or 600-level course work is required.

# Animal Science

**Degrees Offered: Ph.D., M.S., Master of Agriculture**

GRADUATE FACULTY

*Professor* L. S. Bull, ***Head of the Department***
***William Neal Reynolds Professor*** E. J. Eisen, ***Director of Graduate Programs***
Box 7621, (919) 515-4017, gene_eisen@ncsu.edu

***Professors:*** K. R. Butcher, E. V. Caruolo, R. G. Crickenberger, W. J. Croom Jr., D. G. Davenport, K. L. Esbenshade, R. W. Harvey, W. L. Johnson, E. E. Jones, J. R. Jones, R. L. McCraw, B. T. McDaniel, R. M. Petters, K. R. Pond, A. H. Rakes, O. W. Robison, J. W. Spears, D. P. Wesen, L. W. Whitlow, J. C. Wilk;
***Visiting Professor:*** R. E. McDowell;
***Professors Emeriti:*** E. R. Barrick, R. F. Behlow, L. Goode, C. A. Lassiter, J. M. Leatherwood, J. G. Lecce, J. E. Legates, C. L. Markert, R. D. Mochrie, R. M. Myers, I. D. Porterfield, H. A. Ramsey, F. D. Sargent, F. H. Smith, L. C. Ulberg, G. H. Wise;
***Associate Professors:*** B. Alston-Mills, J. D. Armstrong, J. H. Eisemann;
***Visiting Associate Professor:*** G. G. Gomez;
***Adjunct Associate Professor:*** M. T. Coffey;
***Associate Professors Emeriti:*** E. U. Dillard, J. J. McNeill;
***Assistant Professors:*** C. E. Farin, W. L. Flowers, J. A. Hansen, B. A. Hopkins, W. E. Morgan Morrow, M. H. Poore, S. P. Washburn;
***Visiting Assistant Professors:*** S. L. Ash, J. A. Moore

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* J. H. Britt, W. M. Hagler Jr.;
*Professor (USDA):* J. C. Burns;
*Associate Professors:* D. K. Larick, M. D. Whitacre

Animal science offers an opportunity for training in a diversity of basic sciences and the integration of such knowledge into the framework of a living system. Students may major or co-major in animal science or one of the following disciplines: biochemistry, genetics, microbiology, nutrition, physiology or statistics. Students may also concentrate in management and production areas.

### Admission Requirements

Factors considered for admission include: grade point average, scores on the GRE (for M.S. and Ph.D. applicants), undergraduate courses, letters of recommendation and a member of the Animal Science Department faculty willing to serve as the applicant's advisor.

### Master of Science

The minor is optional but external faculty representation is required on the advisory committee.

### Ph.D.

Majors in Animal Science do not have specific course requirements. Each student's course program is developed in consultation with the Ph.D. advisory committee. The minor is optional but external faculty representation is required on the advisory committee.

### Student Financial Support

The department offers a limited number of half-time research assistantships on a competitive basis. To be eligible for support, applicants must have a minimum grade point average of 3.2.

### Other Relevant Information

To provide an opportunity for students to develop their teaching skills, all graduate students are required to assist in the departmental teaching program, regardless of source of financial support.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

ANS 402 BEEF CATTLE MANAGEMENT.
ANS 403 SWINE MANAGEMENT.
ANS 404 DAIRY CATTLE MANAGEMENT.

ANS 406 SHEEP MANAGEMENT.
ANS 410 EQUINE MANAGEMENT.
ANS 412 APPLIED ANIMAL BREEDING.
ANS(PO,NTR) 415 COMPARATIVE NUTRITION.
ANS(NTR) 419 HUMAN NUTRITION IN HEALTH AND DISEASE.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ANS 500 ADVANCED RUMINANT NUTRITION. Preq.: ANS 204 or ANS 415. 3(3-0) Sum. Alt. yrs.** Advanced concepts in ruminant nutrition for the practicing agricultural professional. Protein, energy, vitamin and mineral nutrition in relationship to the nutritional needs and practical feeding of beef cattle, dairy cattle, sheep and goats. New developments in feeding systems, feed additives and the prevention and treatment of metabolic disorders.

**ANS(PHY) 502 REPRODUCTIVE PHYSIOLOGY OF MAMMALS. Preq.: ZO 421. 3(3-0) F.** Survey of reproductive strategies among vertebrates; in-depth coverage of mammalian reproductive physiology; gametogenesis, fertilization, embryonic and fetal development, parturition, puberty, neuroendrocrine control mechanisms in male and female mammals.

**ANS(GN) 508 GENETICS OF ANIMAL IMPROVEMENT. Preqs.: GN 411, ST 511. 3(3-0) S.** Emphasis on the utilization of basic principles of population and quantitative genetics in animal improvement. Factors affecting genic and genotypic frequencies and methods of estimating genetic and nongenetic variance, heritabilities and breeding values. The roles of mating systems and selection procedures in producing superior genetic populations.

**ANS 510 ADVANCED LIVESTOCK MANAGEMENT. Preq.: ANS 402 or ANS 403 or ANS 404. 3(3-0) S.** An advanced study of beef cattle, dairy cattle and swine management practices with particular emphasis on input-output relationships and the consequences of alternative management decisions. Problem. (Offered on-campus in even-numbered years.)

**ANS(NTR) 516A,B,C,D ANIMAL NUTRITION RESEARCH METHODS. 1-4 S.** (See nutrition.)

**ANS 520 LIVESTOCK PRODUCTION IN WARM CLIMATES. Preq.: CI. 3(3-0) F. Alt. yrs.** Analysis of constraints of warm climates to livestock; interdependence of crop and animal agriculture in farmer decisions; roles of animals in sustainable agriculture and economic development; application of principles through case studies and independent study.

**ANS(PHY) 580 MAMMALIAN ENDOCRINOLOGY. Preqs.: BCH 451, ZO 421. 3(3-0) S. Alt. yrs.** Mammalian endocrine system with emphasis on ontogeny and anatomy of key organs; synthesis and action of hormones. Role of hormones in regulation of physiological processes such as metabolism, exocrine function, digestion, ion balance, behavior, lactation, growth and reproduction.

**ANS 590 TOPICAL PROBLEMS IN ANIMAL SCIENCE. Credits arranged. Max. 6 F,S.** Selection or assignment of special problems in various phases of animal science.

*FOR GRADUATES ONLY*

**ANS(GN) 603 QUANTITATIVE GENETICS AND BREEDING. Preqs.: GN 509, GN 510; ST 512. 3(3-0) F.** Quantitative and population genetic theory of breeding problems; partitioning of genetic variance, maternal effects, genotype by environment interaction and genetic correlation; selection indexes; design and analysis of selection experiments; marker-assisted selection.

**ANS(NTR,PO) 605 MINERAL METABOLISM. Preqs.: ANS(NTR,PO) 415 or BCH 551, BCH 451 and ZO 421. 3(3-0) F.** Requirements, function, distribution, absorption, excretion and toxicity of minerals in humans and domestic animals. Interactions between minerals and other factors affecting mineral metabolism or availability. Emphasis on mechanisms associated with mineral functions and the metabolic bases for the development of signs of deficiency.

**ANS 606 MAMMALIAN EMBRYO MANIPULATION. Preq.: ANS 502. 4(1-8) S. Alt. yrs.** Advanced training and experience in mammalian embryo manipulation; techniques of superovulation and embryo recovery, in vitro culture, parthenogenetic activation, in vitro fertilization, embryo transfer, embryo aggregation and DNA micro-injection.

**ANS(NTR,PHY,VMS) 632 COMPARATIVE PHYSIOLOGY OF THE DIGESTIVE SYSTEM. 3(3-0) Every yr.** (See veterinary medical sciences.)

**ANS 699 RESEARCH IN ANIMAL SCIENCE. Credits Arranged. F,S.** A maximum of six hours allowed toward the master's degree; no limitation on credits in doctorate program.

# Applied Mathematics

For a listing of graduate faculty and program information, see mathematics.

# Architecture

**Degrees Offered: Master of Architecture**

## GRADUATE FACULTY

*Professor* Christos A. Saccopoulos, ***Head of the Department***
***Associate Professor*** F. A. Rifki, ***Associate Head of the Department***
***Professor*** P. Tesar, ***Director of Graduate Programs***
Box 7701, (919) 515-2204

***Professors:*** P. Batchelor, G. Bizios, R. P. Burns Jr., R. H. Clark, J. T. Regan, J. P. Reuer, H. Sanoff, E. W. Taylor;
***Visiting Professor:*** E. F. Harris Jr.;
***Professor Emeritus:*** V. F. Shogren;
***Associate Professors:*** F. C. Harmon, J. W. Place, J. P. Rand, J. O. Tector;
***Associate Professor Emeritus:*** D. W. Barnes Jr.;
***Assistant Professors:*** S. L. Roe, R. L. Spears

The Department of Architecture offers three tracks to the Master of Architecture degree: Track 1 is for applicants with a four-year undergraduate degree in architecture and may be completed in two years of full-time study. Track 2 is for applicants holding a five-year NAAB-accredited Bachelor of Architecture degree and normally requires three semesters in residence. Track 3 is for students with degrees in fields other than architecture. This track normally requires four semesters of preparatory work before entering the final two-year program of graduate study. Some applicants with design-related academic or professional experience may be able to complete the preparatory work in less than four semesters. Curriculum requirements for the M.Arch. degree are held to a minimum in order to permit students the necessary flexibility to achieve individual educational and professional goals.

A variety of courses are available within the Department of Architecture in urban and community design, architectural history and theory, methods and programming, architectural conservation, professional practice, building technology and environmental systems.

### Admission Requirements

In addition to documents required by the Graduate School, students apply to the Master of Architecture program by submitting the following documents by January 15: 1. Personal Data form; 2. GRE scores (Track 3 applicants only); 3. Portfolio; 4. Statement of purpose. Applicants will be considered on an individual basis. Ex-

ceptions to Graduate School policy may be made for students indicating other qualifications and professional experience.

### Master's Degree Requirements

The department stipulates the minimum course credits based on educational and professional goals to individualize a plan of study.

### Student Financial Support

There are limited provisions for tuition remission permitting out-of-state students to pay in-state tuition. The department awards a number of teaching and research assistantships on the basis of ability and need, and applications are available from the graduate secretary. Students are also encouraged to apply for competitive national fellowships.

## *SELECTED ADVANCED UNDERGRADUATE COURSE*

ARC 400 ARCHITECTURAL DESIGN.
ARC 402 ARCHITECTURAL DESIGN: HISTORY.
ARC 403 PRE-GRADUATE ARCHITECTURAL DESIGN (SERIES).
ARC 414 ENVIRONMENTAL CONTROL SYSTEMS.
ARC 441 HISTORY OF CONTEMPORARY ARCHITECTURE.
ARC 442 HISTORY OF NORTH CAROLINA ARCHITECTURE.
ARC 445 AESTHETICS AND DESIGN.
ARC 457 ARCHITECTURAL CONSTRUCTION SYSTEMS.
ARC 494 PRACTICUM IN ARCHITECTURE.
ARC 495 INDEPENDENT STUDY IN ARCHITECTURE.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ARC 543 ANALYSIS OF PRECEDENT. Preq.: Grad. standing. 3(0-3) S.** Investigation of architectural elements, relationships and ordering ideas through comparative graphic analysis of buildings designed by architects. Emphasis on buildings as physical artifacts.

**ARC 544 ARCHITECTURAL CONSERVATION. Preq.: Advanced undergrad. in Sch. of Design or grad. standing. 3(3-0) S. Alt. yrs.** An examination of the many dimensions of architectural conservation and/or preservation as a significant aspect of architectural practice. Exploration of historical evolution, regulatory and economic factors, technology and pertinent design issues as foundations for individual case studies by class members of selected adaptive use, rehabilitation and restoration projects.

**ARC 546 THEORY OF BUILDING TYPES. Preq.: Two ARC studios. 3(3-0) F.** Theoretical implications and practical applications of typology in architec-

ture. Analysis and documentation of selected building types in their historical evolution. Graphic identification of type characteristics.

**ARC 551 DESIGN METHODS AND PROGRAMMING. Preq.: Grad. standing or CI. 3(3-0) F.** An intensive study of a part of the design process involving the social and behavioral needs of the users through disciplined methods of data collection, analysis, organization, communication and evaluation. Emphasis upon the role of programming in the environmental design field and variety of applications used in the profession.

**ARC 561 THE PRACTICE OF ARCHITECTURE. 3(3-0) F,S.** Examination of the practice of architecture, with emphasis upon both normative and emerging procedures in the private architectural firm. Special attention upon the role and function of the practicing architect, legal and regulatory conditions, the nature of professional services, office management and project management processes.

**ARC 570 ANATOMY OF THE CITY. 3(3-0) F. Alt. yrs.** A morphological investigation of cities throughout urban history, with emphasis on formal principles of spatial organization. Part one: examination of the descriptive properties of cities in terms of interdisciplinary concepts and principles. Part two: examination of the organizational characteristics of urban space.

**ARC 571 URBAN HOUSING. Preq.: Advanced undergrad. 3(3-0) S.** Interrelationships between housing and the form and structure of cities. Housing design as a function of economic, public policy, social and technological influences. Emphasis on the physical form of housing in the latter half of the twentieth century.

**ARC 573 ENVIRONMENTAL PERCEPTION. Preq.: Grad. standing or CI. 3(3-0) S.** An intensive review of the design research literature with emphasis upon people's interaction with the physical environment. Exploration of various techniques for measuring human response to the environment to permit student development and analysis of their own research projects.

**ARC 574 PLACE AND PLACE MAKING. Preq.: Grad. standing or CI. 3(3-0) F.** Examination of the definitions, concepts and emergent research findings useful in explaining the human sense of place through seminar-lecture course. Particular emphasis upon those physical aspects and relationships influencing this sense of place and affording some designer control.

**ARC 575 PARTICIPATORY DESIGN IN ARCHITECTURE. Preq.: Grad. standing or CI. 3(3-0) S. Alt. yrs.** The theories and methods pertaining to the participatory design process. A probe of the nature of advocacy design and examination of successful projects in the U. S. and abroad defining a social role for architects.

**ARC 580 SPECIAL TOPICS IN ARCHITECTURE. Preq.: Grad. standing or CI. 2-3 As needed.** Topics of current interest by faculty in the Dept. of Architecture. Subjects under this number normally to test and develop new courses.

**ARC 591 SPECIAL PROJECT IN ARCHITECTURE. Preq.: Grad. standing. 1-3 F,S.** Presentation of seminars on subjects of current interest in design by persons not part of the regular faculty.

**ARC 595 INDEPENDENT STUDY. Preq.: Grad. standing. 1-3 Max. 6. F,S, Sum.** Development of special problems and projects in various aspects of architecture under the direction of an architecture faculty member on a tutorial basis.

*FOR GRADUATES ONLY*

**ARC 600 ADVANCED ARCHITECTURAL DESIGN (SERIES). 6(0-12) F,S.** Advanced studies in architectural design. Projects concerning various aspects of building design, urban design and community design in a comprehensive and integrative manner.

**ARC 681 FINAL PROJECT RESEARCH IN ARCHITECTURE. 1-6 As needed.** Investigation of selected problems and projects in architecture of particular interest to graduate students under the direction of a faculty member on a tutorial basis. Credits and content vary to meet the scope of the project proposal.

**ARC 688 FINAL PROJECT STUDIO IN ARCHITECTURE. Preqs.: 18 hrs. of ARC 600 and ARC 681. 6(0-12) F,S.** Final project for graduate students supervised by members of their graduate advisory committee.

# Biochemistry

**Degrees Offered: Ph.D., M.S.**

GRADUATE FACULTY

*William Neal Reynolds Professor* W. L. Miller, *Interim Head of the Department* Box 7622, 919-515-2581, wlmiller@bchserver.bch.ncsu.edu

*University Professor:* E. C. Theil
*William Neal Reynolds Professor:* H. R. Horton

*Professors:* P. F. Agris, H. M. Hassan, J. D. Otvos, E. C. Sisler;
*Adjunct Professor:* K. S. Korach;

*Professors Emeriti:* F. B. Armstrong, L. W. Aurand, J. S. Kahn, I. S. Longmuir, S. B. Tove;
*Associate Professors:* J. A. Knopp, E. S. Maxwell, P. L. Wollenzien;
*Assistant Professors:* J. C. Hall, L. K. Hanley-Bowdoin, C. C. Hardin, C. L. Hemenway;

## ASSOCIATED FACULTY OF THE PROGRAM

*Professors:* D. E. Sayers, R. R. Sederoff, H. E. Swaisgood

The graduate program in biochemistry is designed to prepare individuals for careers in research and teaching. Emphasis is primarily focused on laboratory research, where graduate students work closely with faculty. The department is well equipped to conduct research in biochemistry, biophysics, molecular biology, and molecular genetics.

### Admission Requirements

Students entering the graduate program in biochemistry should have a bachelor's degree in biochemistry, chemistry or a related physical or biological science, including undergraduate courses in organic chemistry, calculus, physics, and one year of physical chemistry, as well as biochemistry/molecular biology.

### Master of Science Degree Requirements

Up to 6 of the 30 credits required may be earned in laboratory rotations (BCH 692) and thesis research (BCH 699). On average, completion of the M.S. degree requires 2 to 3 years.

### Doctoral Degree Requirements

Requirements for the Ph.D. degree include a minimum of 30 credit hours in course work and thesis research, including at least two advanced courses in biochemistry/ molecular biology; teaching experience. Formal coursework may be completed with-within three semesters; on average, completion of the Ph.D. degree requires 5 years.

### Student Financial Support

The department endeavors to meet the financial needs of students accepted into its doctoral program. Essentially all admitted students are offered the opportunity to apply for graduate teaching and research assistanships.

### Other Relevant Information

The Department of Biochemistry is jointly administered by the Colleges of Agriculture and Life Sciences and Physical and Mathematical Sciences. The department, committed to a strong research environment, interacts with other life science depart-

ments on campus as well with the other research universities and institutes of the Research Triangle area.

*SELECTED ADVANCED UNDERGRADUATE COURSE*

**BCH 451 PRINCIPLES OF BIOCHEMISTRY.**

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**BCH 552 EXPERIMENTAL BIOCHEMISTRY. Preq.: BCH 452; Coreq.: BCH 553. 3(1-6) F.** An advanced laboratory to give students practical experiences in purification and quantitative characterization of enzymes and nucleic acids. Studies with carbohydrates and membrane lipids. Credit may be applied toward biotechnology minor.

**BCH 553 METABOLISM AND MOLECULAR BIOLOGY. Preq.: BCH 451. Credit in both BCH 453 and BCH 553 is not allowed. 3(3-0) F,S.** Metabolic relationships including nitrogen and lipid metabolism, photosynthesis, molecular biology and methodologies of recombinant DNA research.

**BCH 590 SPECIAL TOPICS IN BIOCHEMISTRY. Preq.: BCH 451 or equivalent. Credits arranged, Max. 3 F,S,Sum.** The study of topics of special interest by small groups of students instructed by members of the faculty.

*FOR GRADUATES ONLY*

**BCH 601 MACROMOLECULAR STRUCTURE. Preqs.: BCH 453 or BCH 553; a course in physical chemistry highly recommended. 3(3-0) F.** Introduction to the current understanding and methods used for the study of structures, thermodynamics and conformational dynamics of proteins, nucleic acids and membranes.

**BCH 603 MACROMOLECULAR SYNTHESIS AND REGULATION. Preq.: BCH 453 or BCH 553. 3(3-0) F.** Biochemistry of DNA replication, transcription, RNA processing and translation. Development of key concepts, techniques and applications relating to mechanisms and regulation of these processes by analysis of primary literature.

**BCH 605 MOLECULAR BIOLOGY OF THE CELL. Preq.: BCH 601 or BCH 603. 3(3-0) S.** Regulation of cellular processes, membrane structure and function, signal transduction, protein trafficking/sorting, secretion, photosynthesis and nitrogen fixation.

**BCH 651 BIOPHYSICAL CHEMISTRY. Preq.: BCH 451 or equivalent; one sem. of physical chemistry. 3(3-0) F. Alt. yrs.** Fundamental and practical aspects of biological macromolecular structure, thermodynamics, hydrodynamics, kinetics and spectroscopy with emphasis on mechanisms in functionally important structural transformations.

**BCH 653 BIOCHEMISTRY OF HORMONE ACTION. Preq.: BCH 605 or GN GN 560. 3(3-0) S. Alt. yrs.** Study of well-defined models of steroid and protein hormone action via lectures, assigned readings and discussions. Students add breadth to the course and depth to their own understanding by searching the literature and writing *or* lecturing about a particular hormone of their own choosing.

**BCH(GN) 658 NUCLEIC ACIDS: STRUCTURE AND FUNCTION. Preqs.: BCH 601 and 603. 3(3-0) S. Alt. yrs.** Structure-function relationships of nucleic acids and nucleic acid-protein complexes, including the physical biochemistry of nucleotides, polynucleotides, DNA, RNA and protein as related to the biological processes of replication, transcription and translation. Usage of current techniques to analyze nucleic acid structure and function.

**BCH(GN) 661 ADVANCED MOLECULAR BIOLOGY OF THE CELL. Preqs.: BCH 603 and 605. 3(3-0) S. Alt. yrs.** An advanced treatment involving integrated approaches to biological problems at the molecular level, encompassing biochemistry, cell biology and molecular genetics. Broad, multidisciplinary approaches to solving research problems in biology and the critical study of primary scientific literature, the development of a research proposal, oral presentations and class discussions.

**BCH 691 SEMINAR IN BIOCHEMISTRY. 1(1-0) F,S.**

**BCH 692 LABORATORY ROTATIONS. Preq.: BCH 451 or equivalent. 1(0-3) F,S,Sum.** Performance of highly directed research by biochemistry students in one or more laboratories of student's choice prior to beginning thesis research. Each laboratory experience lasts 5 weeks and given 1 hr. of credit. Not more than 4 credits earned in BCH 692. Required permission of instructor.

**BCH 695 SPECIAL TOPICS IN BIOCHEMISTRY. Preq.: Grad. standing in BCH. Credits Arranged. F,S,Sum.** Critical study of special problems and selected topics of current interest in biochemistry and related fields.

**BCH 699 BIOCHEMICAL RESEARCH. Credits Arranged, F,S,Sum.**

# Biological and Agricultural Engineering

**Degrees Conferred: Ph.D., M.S., Master of Biological and Agricultural Engineering**

## GRADUATE FACULTY

*Professor* D. B. Beasley, ***Head of the Department***
*Professor* C. F. Abrams Jr., ***Director of Graduate Programs***
Box 7625, (919) 515-6714, frank_abrams@ncsu.edu

***Distinguished University Professor, William Neal Reynolds Professor and Graduate Alumni Distinguished Professor:*** R. W. Skaggs

***Professors:*** J. C. Barker, F. J. Humenik, E. G. Humphries, W. H. Johnson, G. J. Kriz, W. F. McClure, R. P. Rohrbach, R. S. Sowell, L. F. Stikeleather, P. W. Westerman, D. H. Willits, J. H. Young;
***Professor (USDA):*** T. B. Whitaker;
***Professors Emeriti:*** H. D. Bowen, J. W. Dickens, L. B. Driggers, F. J. Hassler, D. H. Howells, F. M. Richardson, R. E. Sneed, C. W. Suggs, E. H. Wiser;
***Associate Professors:*** G. R. Baughman, S. M. Blanchard, R. W. Bottcher, C. G. Bowers Jr., A. R. Rubin;
***Adjunct Associate Professor:*** D. C. Richardson;
***Assistant Professors:*** M. D. Boyette, R. O. Evans Jr., S. A. Hale, R. L. Huffman, G. D. Jennings, J. E. Parsons;
***Visiting Assistant Professors:*** D. W. Donahue, G. T. Roberson, J. D. Spooner;
***Senior Researcher:*** S. C. Mohapatra

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** D. D. Hamann, A. E. Hassan, K. R. Swartzel;
***Assistant Professors:*** T. M. Losordo, S. C. Roe

Course offerings or research facilities are available in the following areas: bioinstrumentation, biomechanics, human engineering, bioprocessing, food packaging and processing, biological systems modeling, aquaculture, hydrology, water table management, ground water management, animal waste management, non-point source pollution, power and machinery, soil and water, structures and environment, food and process engineering, electrical and electronic systems, forest mechanization, robotics, and machine vision.

### Admission Requirements

A baccalaureate in biological or agricultural engineering or the equivalent is the preferred prerequisite for admission. Those with strong academic background in the physical or biological sciences may also be admissible with a requirement for certain additional background undergraduate work. In the case of applicants with master's degrees, a master's GPA of at least 3.2 is required for admission. Exceptions to the overall undergraduate GPA requirements may be made for cases where performance in the major or during the last two years was at or above the 3.00 level.

GRE scores are recommended for those with academic performance records near the minimal level. Applicants without engineering degree from domestic accredited institutions must submit GRE scores to be considered for admission. Admission decisions are made by a faculty review committee. The best-qualified applicants will be accepted up to the number of spaces available for new students.

### Master's Degree Requirements

(M.BAE): This non-thesis degree requires 33 hours of approved graduate course work and a directed special project which must comprise from 3-6 hours credit. A minor is required. (M.S.): A minor is required.

### Doctoral Degree Requirements

Course hour requirements are flexible but typically include at least 36 hours beyond a master's degree. Direct admission without a master's is possible in exceptional cases. A minor is required.

### Student Financial Support

Graduate assistantships are available to students in this program on a competitive basis.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

BAE 411 FARM POWER AND MACHINERY.
BAE 441 AGRICULTURAL SYSTEMS IV: MODELLING AND ANALYSIS.
BAE 462 FUNCTIONAL DESIGN OF FIELD MACHINES.
BAE(CHE) 465 INTRODUCTION TO BIOMEDICAL ENGINEERING.
BAE 471 SOIL AND WATER ENGINEERING.
BAE 481 AGRICULTURAL STRUCTURES AND ENVIRONMENT.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**BAE 501 INSTRUMENTATION AND CONTROL FOR BIOLOGICAL SYSTEMS. Preqs.: ECE 211, MA 242, MA 341. Credit for both BAE 401 and BAE 501 is not allowed. 3(2-3) F.** Basic concepts of instrumentation for monitoring and control of biological systems. Study of transducers and control circuits

utilized in biological and agricultural engineering work. Demonstration of concepts of errors, accuracy and precision, linearity and other instrument characteristics by electronic models. Provision of hands-on experience for reinforcing lecture concepts in laboratories.

**BAE(VMS) 522 MECHANICS OF BIOLOGICAL MATERIALS. Preqs.: BS 100, MA 242, PY 205. 3(2-2) F. Alt. yrs.** The structure and composition of biological materials, both animal and plant, as related to the ability of the materials to withstand mechanical loading. Emphasis on the measurement of mechanical properties and the development and understanding of models of biological material mechanical behavior.

**BAE 552 INSTRUMENTATION FOR AGRICULTURAL RESEARCH AND PROCESSING. Preqs.: EE 331, MA 301. 2(1-3) F.** Theory and application of primary sensing elements and transducers. Generalized performance characteristics and the use of standards. Use of specialized measurement systems for agricultural research and processing including an introduction to correlation and power spectral density measurements.

**BAE 572 IRRIGATION AND DRAINAGE. Preqs.: BAE 471, SSC 200 or CI. Credit for both BAE 472 and BAE 572 is not allowed. 3(3-0) S. Alt. yrs.** Design, management and evaluation of irrigation and drainage systems; concepts and processes of system design.

**BAE(SSC) 573 HYDROLOGIC AND WATER QUALITY MODELING. Preqs.: BAE 471, SSC 200 or CI. Credit for both BAE 473 and BAE(SSC) 573 is not allowed. 3(2-2) S. Alt yrs.** Concepts in basic hydrologic, erosion and chemical transport used in modeling. Evaluation of typical hydrologic/water quality models on watershed systems. Usage of "state-of-the-art models" in project examples.

**BAE(CE) 578 AGRICULTURAL WASTE MANAGEMENT. Preq.: Grad. or advanced undergrad. standing. 3(2-3) F. Alt. yrs.** Principles of managing, handling, treating and applying agricultural and organic industrial and municipal waste materials. Waste characterization of systems and technology, land application, waste management plans, permits, biochemical/biological processes, anaerobic digestion, irrigation, and water quality. Emphasis on problem solving and development of waste management.

**BAE(FS) 585 FOOD RHEOLOGY. 3(2-3) F. Alt. yrs.** (See food science.)

**BAE 590 SPECIAL PROBLEMS. Preq.: Sr. or grad. standing in biological and agricultural engineering. Credits Arranged.** Selection of a subject by each student on which to do research and write a technical report on the results. The

individual may choose a subject pertaining to his or her particular interest in any area of study in biological and agricultural engineering.

*FOR GRADUATES ONLY*

**BAE(SSC) 671 THEORY OF DRAINAGE–SATURATED FLOW. Preq.: MA 301. 3(3-0) F. Alt. yrs.** Discussion of physical concepts and properties of fluids and porous media in relation to soil-water movement. Derivation and discussion of the fundamental laws and equations governing saturated flow in porous media. Analysis of mathematical solutions of steady-state and transient flow equations to determine their applicability to drainage problems. Consideration of analogs and models of particular drainage problems.

**BAE(SSC) 674 THEORY OF DRAINAGE–UNSATURATED FLOW. Preq.: BAE 671 or equivalent. 3(3-0) S. Alt. yrs.** Involvement of forces and utilization of theories in unsaturated flow of porous media in relation to soil-water movement. Development and solution of steady-state and transient unsaturated flow equations for horizontal and vertical moisture movement. Application of solutions to present day laboratory and field technology. Consideration of molecular diffusion and hydrodynamic dispersion considered in light of current tracing techniques.

**BAE 690 SPECIAL TOPICS. 1-4.** A study of topics in the special fields of interest of graduate students under the direction of the graduate faculty.

**BAE 695 SEMINAR. Preq.: Grad. standing in BAE. 1(1-0) F,S.** Elaboration of the subject areas, techniques and methods peculiar to professional interest through presentations of personal and published works; opportunity for students to present and critically defend ideas, concepts and inferences. Discussions to point up analytical solutions and analogies between problems in biological and agricultural engineering and other technologies, and to present the relationship of biological and agricultural engineering to the socio-economic enterprise.

**BAE 699 RESEARCH IN BIOLOGICAL AND AGRICULTURAL ENGINEERING. Preq.: Grad. standing in BAE. Credits Arranged.** Performance of a particular investigation of concern to biological and agricultural engineering. The study will begin with the selection of a problem and culminate with the presentation of a thesis.

# Biomathematics

**Degrees Offered: Ph.D., M.S., Master of Biomathematics**

## GRADUATE FACULTY

*Associate Professor* S. P. Ellner, *Director of Graduate Programs*
Box 8203, (919) 515-1908, ellner@stat.ncsu.edu

*Professors:* H. J. Gold, K. H. Pollock;
*Adjunct Professor:* P. H. Morgan;
*Professors Emeriti:* R. J. Monroe, H. R. van der Vaart;
*Associate Professor:* C. E. Smith;
*Assistant Professor:* T. B. Kepler;
*Adjunct Assistant Professors:* P. M. Dixon, M. W. Lutz, M. V. Smith

## ASSOCIATE MEMBERS OF THE PROGRAM COMMITTEE

*Professors:* J. W. Bishir, L. B. Crowder, T. Johnson, H. E. Schaffer, J. F. Selgrade, R. E. Stinner;
*Professor (USDA):* G. Namkoong;
*Associate Professors:* J. F. Gilliam, G. G. Wilkerson;
*Associate Professor (USDA):* S. M. Schneider

Biomathematics is an interdisciplinary graduate program offering courses and research opportunities in basic and applied mathematical biology. Degree programs are flexible, to accommodate students with backgrounds in the biological, mathematical or physical sciences. The program also offers Ph.D. and master's-level minors. A brochure with additional information on requirements, courses, faculty and rrent research can be obtained by writing the program director.

### Admission Requirements

Applicants should have either a bachelor's degree in biology with evidence of aptitude and interest in mathematics, or a bachelor's in a mathematical science with evidence of aptitude and interest in biology. Advanced (multivariate) calculus, linear algebra and general biology are prerequisites for all BMA courses, and deficiencies in these should be remedied during the first year of graduate study. The application must include a narrative statement (1-2 pages) of the applicant's goals and reasons for interest in the BMA program.

### Master's Degree Requirements

The M.S. and M.BMA. degrees require BMA 567 or 611, 571-572; 2 upper-level

biology courses; and 3 courses from mathematical sciences (ST 511 or 512; ST 521 or 541; and numerical analysis, *e.g.*, MA 427). The M.S. degree requires a thesis, and the M.BMA. requires two additional courses and a written project.

### Doctoral Degree Requirements

Course requirements consist of a "core" and a "concentration" in some area of biology or mathematical sciences. Core requirements are: BMA 571-572, 610 and 611; 3 upper level biology courses from at least two areas (*e.g.*, physiology and evolution); ST 511 and 512, ST 521 or 541, and one course each in numerical analysis and in time series or stochastic processes. Concentration consists of either a Ph.D. co-major in a biological or mathematical science, or a coherent series of 5 graduate courses approved by the student's committee, which must include a two-semester sequence and at least one 600-level course.

### Financial Assistance

TAs (generally in the Department of Statistics), RAs and internships are available. Awards are based on GRE scores, transcripts, and letters of recommendation. RAs usually are held by continuing students. To receive full consideration for financial aid, the completed application must be received by March 1.

### Other Relevant Information

All students are required to participate in the BMA Graduate Seminar. Course requirements can be met by examination or by demonstrating that an equivalent course was completed at another university.

### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**BMA 567 MODELING OF BIOLOGICAL SYSTEMS. Preq.: MA 112. 4(3-2) F.** An introduction to quantitative modeling in biology. Use of Forrester diagrams, probabilistic and deterministic description of dynamic processes, development of model equations, simulation methods and criteria for model evaluation. Examination of current literature dealing with application of models and simulation in biology. Individual and class modeling projects.

**BMA(MA,ST) 571 BIOMATHEMATICS I. Preq.: Advanced calculus, reasonable back ground in biology or CI. 3(3-0) F.** The role of theory construction and model building in the development of experimental science. The historical development of mathematical theories and models for the growth of one-species populations. Mathematical theories of two and more species systems and discussion of some similar models for chemical kinetics. Mathematical treatment of the differential equations in these models stresses qualitative and graphical aspects, as well as certain aspects of discretization. Difference equation models.

**BMA(MA,ST) 572 BIOMATHEMATICS II. Preqs.: BMA 571, elementary probability theory. 3(3-0) S.** Continuation of topics of BMA 571. Advanced mathematical techniques concerning nonlinear differential equations of the types encountered in BMA 571: concepts of stability, asymptotic directions, Liapunov functions; different time-scales. Comparison of deterministic and stochastic models for biological problems including birth and death processes. Discussion of various other applications of mathematics to biology, some recent research.

**BMA(OR,ST) 575 DECISION ANALYTIC MODELING. 4(3-2) F. Alt. yrs.** (See statistics.)

**BMA 591 SPECIAL TOPICS. Preq.: CI. Maximum 3. F,S,Sum.** Directed readings, problem sets, written and oral reports as dictated by need and interest of student, *e.g.*, cellular, molecular and physiological modeling; new 500-level courses during the developmental phase.

*FOR GRADUATES ONLY*

**BMA(MA,OR,ST) 610 STOCHASTIC MODELING. Preq.: BMA 572 or ST (MA) 542. 3(3-0) S. Alt. yrs.** Survey of modeling approaches and analysis methods for data from continuous state random processes. Emphasis on differential and difference equations with noisy input. Doob-Meyer decomposition of process into its signal and noise components. Examples from biological and physical sciences, and engineering. Student project.

**BMA(OR) 611 SYSTEM MODELING THEORY. Preqs.: MA 405; MA 421 or ST 421; linear systems (*e.g.*, BMA 572 or IE 522 or OR 531). 3(3-0) F. Alt. yrs.** System concepts and modeling processes. Objectives include the following: development of understanding of the modeling process; development and improvement of skills in system modeling; provision of basis for accessing research literature. Graph theory and system structure; system morphisms and representation of system dynamics; sensitivity and model validation; models in scientific theory compared with decision-related modeling. Examples from a broad spectrum of application areas.

**BMA 691 ADVANCED SPECIAL TOPICS. Preq.: CI. 1-3 F,S,Sum.** Directed readings, problem sets, written and oral reports as dictated by need and interest of student; new 600-level courses during the development phase.

**BMA 694 SEMINAR. 1(1-0) F,S.** Graduate students in biomathematics are expected to attend through most of their residence period.

**BMA 699 RESEARCH. Credits Arranged. F,S,Sum.**

# Botany

**Degrees Offered: Ph.D., M.S., Master of Life Sciences**

## GRADUATE FACULTY

*Professor* E. D. Seneca, ***Head of the Department***
*Professor* C. G. Van Dyke, ***Director of Graduate Programs***
Box 7612, (919) 515-2727, gerald_vandyke@ncsu.edu

*University Research Professor:* W. F. Thompson

*Professors:* C. E. Anderson, U. Blum, W. F. Boss, R. C. Fites, J. W. Hardin, J. R. Troyer, T. R. Wentworth;
*Professors (USDA):* W. W. Heck, H. E. Pattee;
*Visiting Professor:* W. S. Chilton;
*Professors Emeriti:* R. J. Downs, R. L. Mott, G. R. Noggle, L. A. Whitford, A. M. Witherspoon;
*Associate Professors:* R. L. Beckmann, R. S. Boston, J. M. Burkholder, J. E. Mickle, J. M. Stucky;
*Assistant Professor:* D. Robertson

## ASSOCIATED MEMBERS OF THE PROGRAM

*Professors:* L. B. Crowder, M. M. Goodman, E. C. Sisler;
*Professors (USDA):* S. C. Huber, D. E. Moreland, H. Seltmann;
*Associate Professor:* H. V. Amerson;
*Associate Professors (USDA):* K. O. Burkey, T. W. Rufty Jr.

Course offerings or research facilities are available in the following areas: molecular genetics and physiology of development and signal transduction; biochemistry of crown gall, fungal phytotoxins and biocontrol of weeds; physiological ecology of freshwater, marine and terrestrial plants; community ecology; composite plant systematics; ultrastructure and anatomy.

### Admission Requirements

In special situations, students with an undergraduate GPA of less than 3.00 (on a 4.00 scale) may be admitted provisionally. If students lack certain prerequisites (*i.e.* in mathematical, chemical, biological or other areas), additional courses may be required that do not qualify for graduate credit. The best qualified students will be accepted when spaces are available for new students.

**Master's and Doctoral Degree Requirements**
Courses from each of the four botany subdisciplines (ecology, physiology, anatomy and systematics) are required. Students must earn a letter grade of at least a "B" in these courses. Other requirements include: a graduate statistics course, a thesis (for the Ph.D. and M.S., but not the M.LS.), a comprehensive examination (Ph.D.), oral thesis defense and a one-semester teaching responsibility per degree.

**Other Relevant Information**
Graduate research and teaching assistantships and tuition remission information is available from the department. Graduate students are expected to attend and participate in the seminar program every semester they are in residence.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

BO 400 PLANT DIVERSITY.
BO 403 SYSTEMATIC BOTANY.
BO 413 INTRODUCTORY PLANT ANATOMY.
BO(ZO) 414 CELL BIOLOGY.
BO 421 PLANT PHYSIOLOGY.
BO 480 INTRODUCTION TO PLANT BIOTECHNOLOGY.
BO 495 SPECIAL TOPICS IN BOTANY.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**BO 510 PLANT ANATOMY. Preq.: BO 200. 4(2-6) F.** A study of plant cells, ultrastructure, cell types, tissues, organs and patterns of growth and differentiation.

**BO(CS,HS) 518 BIOLOGICAL CONTROL OF WEEDS. 1(1-0) F.** (See crop science.)

**BO 522 ADVANCED MORPHOLOGY AND PHYLOGENY OF SEED PLANTS. Preq.: BO 403. 4(3-3) F. Alt. yrs.** A comprehensive survey of the morphology and evolution of angiosperms and gymnosperms. Special emphasis upon vegetative and reproductive morphology of fossil and living forms and their presumed evolutionary relationships.

**BO 544 PLANT GEOGRAPHY. Preqs.: BO 403, BO(ZO) 360, GN 411 or equivalent. 3(3-0) S. Alt. yrs.** Descriptive and interpretive plant geography, synthesizing data from the fields of ecology, genetics, geography, paleobotany and taxonomy. A survey of the present distribution of major vegetation types throughout the world, a discussion of the history and development of this present pattern of vegetation, and a discussion of the principles and theories of plant geography.

**BO 545 PALEOBOTANY. Preqs.: BO 400, BO 403, BO 413, BO 544 or MEA 423. 4(3-3) S. Alt. yrs.** Morphologic, taxonomic, geologic and evolutionary relationships of fossil plants; emphasis on vascular plants; discussions of taphonomy, biogeography and palynology. Required field trips.

**BO(CS,GN,HS) 547 CELL AND TISSUE TECHNIQUES IN PLANT BREEDING. 3(1-4) F. Alt. yrs.** (See crop science.)

**BO 551 ADVANCED PLANT PHYSIOLOGY I. Preq.: BO 421 or equivalent. 3(3-0) F.** The first half of a two-semester sequence covering the field of plant physiology. Topics include cellular transport, water relations, mineral relations, vascular transport and temperature relations.

**BO 552 ADVANCED PLANT PHYSIOLOGY II. Preqs.: BO 421 or equivalent and biochemistry. 3(3-0) S.** The second half of a two-semester sequence covering the field of plant physiology. Topics include respiration, photosynthesis, nitrogen metabolism, growth and development.

**BO 554 LABORATORY IN ADVANCED PLANT PHYSIOLOGY II. Preq. or coreq.: BO 552. 1(0-3) S.** Laboratory to accompany BO 552 Advanced Plant Physiology II.

**BO(ZO) 560 PRINCIPLES OF ECOLOGY. Preq.: Three semesters of college-level biology courses. 4(3-3) F.** A consideration of the principles of ecology at the graduate level. Development of each of major subject areas of ecology in sufficient depth to provide a factual and philosophical framework for the understanding of ecology.

**BO 561 PHYSIOLOGICAL ECOLOGY. Preqs.: BO 421 and BO(ZO) 560 or equivalent. 4(3-3) S. Alt. yrs.** The plant community approached from a physiological standpoint. Emphasis upon the individual in the community and how it responds to its immediate environment on short- and long-term bases.

**BO 565 PLANT COMMUNITY ECOLOGY. Preq.: BO(ZO) 560 or BO(ZO) 360 or equivalent. 4(3-3) F.** Consideration of the structure and function of terrestrial vascular plant communities, with emphasis on both classical and recent research. Topics include measurement and description of community properties, classification, ordination, vegetation pattern in relation to environment, ecological succession and a survey of the vegetation of North America.

**BO(MB) 574 PHYCOLOGY. Preq.: BS 100 or BO 200. 3(1-4) S. Alt. yrs.** An introduction to the taxonomy, morphology, reproduction and ecological importance of organisms which may be included in the algae. Attention to the local freshwater

flow and the physiology of selected species in relation to algal blooms, water quality and nutrient loading in aquatic habitats.

**BO(MB,PP) 575 THE FUNGI. Preq.: BO 200 or equivalent. 3(3-0) F.** An overview of the fungi within the framework of a survey of the major classes.

**BO(MB,PP) 576 THE FUNGI--LAB. Coreq.: BO 575. 1(0-3) F.** Illustrative material of the fungal assemblages discussed in BO 575.

**BO 580 PLANT MOLECULAR BIOLOGY. Preqs.: BCH 451, GN 411. 3(3-0) F.** Molecular analysis of plant growth and development. Molecular techniques and their application to understanding the control of gene expression in plants.

**BO 590 TOPICAL PROBLEMS. Preq.: CI. 1-3 F,S.** Discussions and readings on problems of current interest in the fields of ecology, anatomy and morphology, taxonomy, plant physiology and cell biology. May be repeated with a change in topic for a maximum of six credits.

*FOR GRADUATES ONLY*

**BO 612 PLANT MORPHOGENESIS. Preq.: Six hrs. of botany equivalent to BO 400 and BO 421. 4(3-3) F. Alt. yrs.** A review and synthesis of the factors involved in the development of plant form. Demonstration of levels of control from the molecular to the whole organism by tissue culture experiments.

**BO(PP) 625 ADVANCED MYCOLOGY. 4(2-6) F.** (See plant pathology.)

**BO(GN,MB,PP) 627 FUNGAL GENETICS AND PHYSIOLOGY. 3(2-3).** (See plant pathology.)

**BO 631 WATER RELATIONS OF PLANTS. Preq.: BO 551 or equivalent. 3(3-0) S. Alt. yrs.** A discussion of the physiological water relations of plants with emphasis on theoretical principles and quantitative description.

**BO 633 PLANT GROWTH AND DEVELOPMENT. Preqs.: BO(ZO) 414 or BO 421, organic chemistry. 3(3-0) S.** An advanced course in plant physiology covering plant growth, development, differentiation, senescence and biological control mechanisms.

**BO(ZO) 660 ADVANCED TOPICS IN ECOLOGY I. Preq.: BO(ZO) 560. 3(3-0) S.** Development of subject matter in the major fields of ecology through seminars and lectures and principles illustrated by laboratory exercises and field trips. Topics

include microenvironment, population biology, community ecology, ecosystems and nutrient cycling.

**BO 662 APPLIED COASTAL ECOLOGY. Preq.: BO(ZO) 360 or BO(ZO) 560. 3(3-0) S. Alt. yrs.** The environmental factors, the vegetative communities and man's influence on the ecology of the Coastal Plain of North Carolina. Emphasis on the coastal fringe (Outer Banks) and the problems involved in Coastal Zone Management. Course is field- and problem-oriented and designed primarily for graduate students in environmentally oriented programs. Two field trips mandatory.

**BO 691 Botany Seminar. 1(1-0) F,S.**

**BO 693 SPECIAL PROBLEMS IN BOTANY. Credits Arranged.** Directed research in some phase of botany other than a thesis problem, but designed to provide experience and training in research.

**BO 699 RESEARCH. Credits Arranged. F,S.** Original research preliminary to writing a master's thesis or a doctoral dissertation.

# Chemical Engineering

**Degrees Offered: Ph.D, M.S., Master of Chemical Engineering**

**GRADUATE FACULTY**

*Professor* G. W. Roberts, ***Head of the Department***
*Professor* C. K.Hall, ***Director of Graduate Programs***
Box 7905, (919) 515-2324

***Camille Dreyfus Professor:*** H. B.Hopfenberg
***Distinguished University Professor:*** D. F. Ollis
***Hoechst-Celanese Professors:*** R. G. Carbonell, R. M. Felder

***Professors:*** K. J. Bachmann, P. S. Fedkiw, H. Jameel, T. W. Joyce, R. M. Kelly, M. R. Overcash, C. J. Setzer, R. M. Thorogood;
***Adjunct Professor:*** P. M. Schlosser;
***Professors Emeriti:*** J. K. Ferrell, D. B. Marsland, A. S. Michaels, V. T. Stannett;
***Associate Professors:*** C. M. Balik, S. A. Khan, P. K. Kilpatrick, P. K. Lim, S. W. Peretti, H. M. Winston;
***Adjunct Associate Professor:*** J. L. Williams;
***Assistant Professors:*** B. D. Freeman, C. S. Grant, H. H. Lamb, G. N. Parsons;
***Adjunct Assistant Professor:*** R. T. Chern;

Research activities in the department include: biochemical engineering, catalysis and reaction engineering, computer-aided design and manufacturing, electronic materials, electrochemical engineering, environmental engineering; polymer science and engineering, thermodynamics and computer simulation, and transport phenomena.

**Admissions Requirements**
Students admitted to the graduate program normally have a bachelor's degree in chemical engineering or its equivalent. Students with undergraduate degrees in chemistry, physics or other engineering disciplines may be admitted but will be required to make up undergraduate coursework deficiencies in chemical engineering without graduate credit. The most promising candidates will be accepted up to the number of spaces available.

**Master of Science Degree Requirements**
A set of 5 core courses is strongly recommended. The thesis must be defended in a final public oral examination.

**Master of Chemical Engineering Degree Requirements**
A 3-credit project is required. A set of 5 core courses is strongly recommended.

**Doctor of Philosophy Degree Requirements**
Students normally take a set of 5 core courses, two advanced chemical engineering courses and at least 6 credits of dissertation research. A thesis is required; this must be defended in a final public oral examination. In addition, the candidate must: (1) submit and defend an original written proposition in any area of chemical engineering, and (2) submit and defend a proposal to perform his/her thesis research.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

CHE 425 PROCESS SYSTEM ANALYSIS AND CONTROL.
CHE 446 DESIGN AND ANALYSIS OF CHEMICAL REACTORS.
CHE 451 CHEMICAL ENGINEERING DESIGN.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**CHE 511 CHEMICAL ENGINEERING PROCESS MODELING. Preqs.: CHE 311, CHE 312, MA 301. 3(3-0) F.** Applications of the methods of mathematical analysis to the formulation and solution of problems in transport phenomena, process dynamics and chemical reaction engineering.

**CHE 513 THERMODYNAMICS I. Preqs.: CHE 315, 316. 3(3-0) F.** In-depth coverage of chemical engineering thermodynamics principles. Application of non-ideal fluid-phase chemical potentials to problems in phase and chemical reaction

equilibria. Relations of molecular structure and intermolecular forces to macroscopic thermodynamic properties.

**CHE 515 TRANSPORT PHENOMENA. Preq.: CHE 311. 3(3-0) F.** A theoretical unified study of transport of momentum, energy and matter. Introduction to diffusional operations including coupled heat and mass transfer in light of the theory.

**CHE 516 TRANSPORT PHENOMENA II. Preq.: CHE 515. 3(3-0) S.** Applications of the principles introduced in CHE 515. The applications include multiphase flow and sedimentation, non-Newtonian and porous media flows, transport through membranes and in electrochemical systems, and thermal instabilities.

**CHE 517 CHEMICAL REACTION ENGINEERING. Preq.: CHE 446. 3(3-0) S.** Rates and mechanisms of homogeneous and heterogeneous reactions. Design, analysis and scale-up of batch and continuous chemical reactors.

**CHE 521 SEPARATION PROCESSES. Preq.: CHE 312. 3(3-0) S.** The theory and practice of staged multicomponent mass transfer operations and continuous rate processes. Problems unique to specific operations such as extractive and azeotropic distillation.

**CHE(OR) 527 OPTIMIZATION OF ENGINEERING PROCESSES. Preqs.: CHE 451 or OR 501, FORTRAN programming. 3(3-0) Alt. yrs.** The formulation and solution of process optimization problems, with emphasis on nonlinear programming techniques. Computer implementation of optimization algorithms, on-line optimization, simulation methods and structuring of process models to increase computational efficiency.

**CHE 543 POLYMER SCIENCE AND TECHNOLOGY. Preqs.: CHE 223, CHE 316. 3(3-0) Alt. yrs.** Concepts and techniques for the polymerization of macromolecules. Structure, properties, and applications of commercially important polymers.

**CHE 551 BIOCHEMICAL ENGINEERING. Preqs.: CHE 312, 446. 3(3-0) S.** Enzyme and microbial kinetics and reactor designs for processes involving enzymes and single and mixed cultures. Samples drawn from the full range of applications: food processing, single cell proteins, tissue culture and vaccines, monoclonal antibodies, recombinant DNA and hybridomas, artificial organs, biological waste treatment and environmental processes.

**CHE 552 SEPARATION PROCESSES FOR BIOLOGICAL MATERIALS. Preq.: CHE 521 or CHE 551 or CI. 3(3-0) Alt. yrs.** Definition and engineering analysis of major bioseparation techniques useful in product isolation and purifica-

tion. Topics include solid-liquid separation, crystallization, filtration, extraction, chromatography, membrane processes, distillation, drying, combined operations and process economics.

**CHE(TC) 569 POLYMERS, SURFACTANTS AND COLLOIDAL MATERIALS. Preqs.: CHE 316, CH 223. 3(3-0) Alt. yrs.** Relationships between molecular structure and bulk properties of nonmetallic materials applied to commercial products and chemical engineering processes. Applications of surface and colloid chemistry and polymer science to product development and process improvement.

**CHE 597 CHEMICAL ENGINEERING PROJECTS. Preq.: Grad. standing. 1-3 F,S.** Independent study of some phase of chemical engineering or a related field.

**CHE 598 SPECIAL TOPICS IN CHEMICAL ENGINEERING. Preq.: Grad. standing. 1-3 F,S.** Directed reading of the chemical engineering literature, introduction to research methodology, and lectures and seminar discussion on topics which vary from term to term.

*FOR GRADUATES ONLY*

**CHE 613 THERMODYNAMICS II. Preq.: CHE 513. 3(3-0) Alt. yrs.** Topics in chemical engineering thermodynamics. Perturbation theories, critical phenomena, multi-component phase equilibria, supercritical extraction, irreversible thermodynamics and thermodynamics of macromolecules are representative topics.

**CHE 617 ADVANCED CHEMICAL REACTION ENGINEERING. Preq.: CHE 517. 3(3-0) Alt. yrs.** Topics relating to the design, analysis and operation of homogeneous and heterogeneous chemical reactors.

**CHE 619 ELECTROCHEMICAL SYSTEMS ANALYSIS. Preqs.: CHE 515, 517 or CI. 3(3-0) S. Alt. yrs.** Electrochemical thermodynamics, electrochemical kinetics and catalysis, coupled charge and material transport in an electric field and electrophoretic effects. Design and analysis of electrochemical reactors. Survey of electrochemical industry.

**CHE 660 PHOTOCHEMICAL ENGINEERING: FUNDAMENTALS AND APPLICATIONS. Preq.: Grad. standing in engineering or physical or life sciences. 3(3-0) Alt. yrs.** Fundamentals and applications of photochemical processing: photoexcitation and deexcitation kinetics, illumination sources, radiation fields and photoreactor configurations, and engineering kinetics. Design applications include air pollution photochemical models, grafting and curing of polymers, microlithography, water treatment processes, photography and imaging processes.

**CHE(TC) 669 DIFFUSION IN POLYMERS. Preq.: CHE 569 or CI. 2(2-0) Alt. yrs.** Theory of small molecule transport in polymers; applications of membrane transport processes in the chemical, polymer, textile, coatings and natural fiber industries.

**CHE(TC) 671 SPECIAL TOPICS IN POLYMER SCIENCE. Preq.: CI. 1-3 Alt. yrs.** An intensive treatment of topics in polymer science and technology selected in accord with the state of the art.

**CHE 695 SEMINAR. 1(1-0) F,S.** Weekly seminars on topics of current interest given by resident faculty members, graduate students and visiting lecturers.

**CHE 697 ADVANCED CHEMICAL ENGINEERING PROJECTS. Preq.: Grad. standing in CHE. 1-3 F,S, Sum.** Independent study of some phase of chemical engineering or a related field.

**CHE 699 RESEARCH. Credits Arranged. F,S,Sum.** Individual research in chemical engineering. A report on this research is required as a graduate thesis.

# Chemistry

## GRADUATE FACULTY

**Degrees Offered: Ph.D., M.S., Master of Chemistry**

*Professor* J. G. Osteryoung, *Head of the Department*
*Associate Professor* R. J. Linderman, *Director of Graduate Programs*
Box 8204, (919) 515-2548, russell_linderman@ncsu.edu

*Professors:* R. D. Bereman, L. H. Bowen, C. L. Bumgardner, H. H. Carmichael, D. L. Comins, F. W. Getzen, K. W. Hanck, F. C. Hentz Jr., S. G. Levine, G. G. Long, M. L. Miles, C. G. Moreland, R. A. Osteryoung, A. F. Schreiner, E. O. Stejskal, W. P. Tucker, G. H. Wahl Jr., M. H. Whangbo, J. L. Whitten;
*Professors Emeriti:* G. O. Doak, L. D. Freedman, Z Z. Hugus Jr., L. A. Jones, R. H. Loeppert, R. C. White;
*Associate Professors:* C. B. Boss, E. F. Bowden, T. C. Caves, Y. Ebisuzaki, M. G. Khaledi, S. T. Purrington, W. L. Switzer, D. W. Wertz;
*Associate Professors Emeriti:* A. F. Coots, T. M. Ward;
*Assistant Professors:* C. R. Cornman, D. A. Shultz

The Department of Chemistry offers programs of study leading to the Doctor of Philosophy, Master of Science, and Master of Chemistry degrees. The Ph.D. and

M.S. degrees are based on original research, while the Master of Chemistry degree is a non-research degree. Many research projects merge disciplines such as biochemistry, computational science, materials science, physics, statistics, and toxicology with chemistry. General courses as well as advanced and special topics courses are offered.

### Admission Requirements

Applicants should have an undergraduate degree in chemistry or in a closely related field with a strong chemistry background. A GPA of at least 3.0 in the sciences is needed for consideration. GRE General Test scores are required, and the Subject Test is recommended. Admission decisions are made as completed applications are received. For most favorable consideration for the fall term, all application materials should be received by March 1; for spring admission, by August 15.

### Master's Degree Requirements

The requirements for a Master of Chemistry degree are 27 hours of course work, 3 hours of a critical review paper and an oral examination on the review paper. Students in this program should have present or past experience in a research laboratory.

### Doctoral Degree Requirements

In the doctoral program, emphasis is placed on original research and a comprehensive knowledge of one's chosen field. There are no definite credit hour requirements for the doctoral degree.

### Student Financial Support

Incoming graduate students are supported by departmental teaching assistantships. Outstanding applicants are eligible for supplemental fellowships during their first year of study. Research assistantships are normally available to second-, third-, and fourth-year students. The department also has fellowships for students interested in the area of electronic materials and fellowships for students interested in pharmaceutical and synthetic organic chemistry.

### Other Relevant Information

The Department of Chemistry is one of five academic departments in the College of Physical and Mathematical Sciences. Several new faculty have been added in the last few years, thereby enhancing opportunities for graduate research.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

CH 401 SYSTEMATIC INORGANIC CHEMISTRY.
CH 411 ANALYTICAL CHEMISTRY I.
CH 413 ANALYTICAL CHEMISTRY II.
CH 428 QUALITATIVE ORGANIC ANALYSIS.

CH 431 PHYSICAL CHEMISTRY I.
CH 433 PHYSICAL CHEMISTRY II.
CH 434 PHYSICAL CHEMISTRY II LABORATORY.
CH(TC) 461 INTRODUCTION TO FIBER-FORMING POLYMERS.
CH 499 SENIOR RESEARCH IN CHEMISTRY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**CH 501 ADVANCED INORGANIC CHEMISTRY I. Preq.: CH 433. 3(3-0) F.** The major emphasis of this course on the complexes of the transition metals (3d, 4d and 5d). Topics include the structure, stability, synthesis and reaction mechanisms of these complexes. The consideration of organometallic compounds and of species containing metal-metal bonds.

**CH 503 ADVANCED INORGANIC CHEMISTRY II. Preq.: CH 501. 3(3-0) S.** This course, a continuation of CH 501, deals with the use of photochemical reactions as applied to inorganic complexes, metal cluster complexes and organometallic systems. Other topics treated at length: solid-state chemistry and bioinorganic chemistry. Discussion of structure, synthesis, energetics, reactions and applications presented. In addition, other topics of current research interest in inorganic chemistry briefly discussed.

**CH 505 PHYSICAL METHODS IN INORGANIC CHEMISTRY. Preqs.: Grad. standing and CH 501 or CI. 3(3-0) S.** The use of group, molecular orbital and ligand field theories for spectroscopy and bonding; measurement methodology and the significance of experimental parameters, including electronic, photoluminescence, photoelectron, vibrational spectroscopies, magnetic susceptibility, Mössbauer, esr, nmr, nqr and x-ray structure determinations.

**CH(MAT) 507 CHEMICAL CONCEPTS IN MATERIALS SCIENCE AND ENGINEERING. 3(3-0) F.** (See materials science and engineering.)

**CH 511 ADVANCED ANALYTICAL CHEMISTRY I. Preqs.: CH 433; CH 413 or CH 415. 3(3-0) F.** First semester of a two-semester integrated sequence covering advanced methods for extraction and interpretation of chemical information from electronic/optical signals in chemical analysis. Digital and analog electronics, signal acquisition and processing, chemometrics, and instrumentation.

**CH 513 ADVANCED ANALYTICAL CHEMISTRY II. PREQ.: CH 511. 2(2-0) S.** Second semester of a two-semester integrated sequence covering advanced methods for extracting and interpreting chemical information from electronic/optical signals in chemical analysis. Digital and analog electronics, signal acquisition and processing, chemometrics, and instrumentation.

**CH 514 ELECTRONICS AND INSTRUMENTATION LABORATORY. Preq.: CH 511; Coreq.: CH 513. 1(0-3) S.** A laboratory course covering the operation and application of analog and digital electronics in the context of chemical instrumentation. Circuit elements, integrated circuits, microprocessors and computers, data acquisition systems, and signal processing.

**CH 515 CHEMICAL INSTRUMENTATION. Preq.: CH 431; Coreq.: CH 411. 3(3-0) S.** Basic electronic components and circuits, the response of laboratory instruments, design and modification of typical electronic control and measurement systems. Emphasis on the utilization of transducers and control elements in chemical research.

**CH 517 PHYSICAL METHODS OF ELEMENTAL TRACE ANALYSIS. Preq.: CH 315 or 331 or CI. 3(3-0) F.** The principles and applications of currently used methods of trace analysis. Designed for students with little or no experience in trace analysis but with a strong interest in or need for analytical data at the trace level. Topics include pulse polarography, potentiometry, UV-Vis spectrophotometry, atomic absorption, emission spectrometry, fluorescence, neutron activation analysis and spark source mass spectrometry.

**CH 518 TRACE ANALYSIS LABORATORY. Coreq.: CH 517 or CI. 2(0-6) F.** The trace element content of samples determined by a variety of instrumental techniques including UV-Vis spectrophotometry, fluorescence, emission spectrometry, atomic absorption, pulse polarography and neutron activation analysis.

**CH 521 ADVANCED ORGANIC CHEMISTRY I. Preqs.: CH 223, 433 or 435. 3(3-0) F.** Structure stereochemistry and reactions of the various classes of hydrocarbons. Emphasis upon molecular orbital treatment of bonding and reactivity of alkenes, the conformational interpretation of cycloalkene and cycloaklene reactivity and the application of optical isomerism to the study of reaction mechanisms.

**CH 523 ADVANCED ORGANIC CHEMISTRY II. Preq.: CH 521. 3(3-0) S.** An introduction to acid-base theory and mechanistic organic chemistry as applied to synthetically useful organic reactions.

**CH 525 PHYSICAL METHODS IN ORGANIC CHEMISTRY. Preqs.: CH 223 and 433 or 435. 3(3-0) S.** Application of physical methods to the solution of structural problems in organic chemistry. Emphasis on spectral methods including infrared, ultraviolet, nuclear magnetic resonance, mass spectrometry, electron paramagnetic resonance, X-ray and electron diffraction and optical rotatory dispersion.

**CH 527 MASS SPECTROMETRY. Preq.: CH 223. 3(3-0) F. Alt. yrs.** Interpretation of mass spectra emphasizing characterization of organic molecules. Instru-

mentation topics: types of mass analyzers such as magnetic sector, quadrupole and time-of-flight; hybrid instruments such as GC/MS, LC/MS and MS/MS; and ionization methods including EI, CI, laser desorption and fast atom bombardment. Applications: quantitation, environmental analysis, and peptide and DNA sequencing.

**CH 530 ADVANCED PHYSICAL CHEMISTRY. Preq.: Grad. standing or CI. 3(3-0) F.** A survey of chemical thermodynamics and kinetics, with emphasis on reactions in the liquid phase. Problem solving an important part of the course. Designed for review and expansion on materials usually covered in a one-year undergraduate physical chemistry course.

**CH 531 CHEMICAL THERMODYNAMICS I. Preqs.: CH 433, MA 301. 3(3-0) F.** An extension of elementary principles to the treatment of ideal and real gases, ideal solutions, electrolytic solutions, galvanic cells, surface systems and irreversible processes. An introduction to statistical thermodynamics and the estimation of thermodynamic functions from spectroscopic data.

**CH 533 CHEMICAL KINETICS. Preqs.: CH 433, MA 301. 3(3-0) S. Alt. yrs.** An intensive survey of the basic principles of chemical kinetics with emphasis on experimental and mathematical techniques, elements of the kinetic theory and theory of the transition state. Applications to gas reactions, reactions in solution and mechanism studies.

**CH 536 CHEMICAL SPECTROSCOPY. Preq.: CH 435. 3(3-0) S. Alt. yrs.** Introduction to rotational, vibrational and electronic molecular spectroscopy from a quantum mechanical viewpoint. Emphasis on the elucidation of structure, bonding and excited state properties of organic and inorganic molecules.

**CH 537 QUANTUM CHEMISTRY. Preqs.: MA 301, CH 435 or PY 407. 3(3-0) S.** The elements of wave mechanics applied to stationary energy states and time-dependent phenomena. Applications of quantum theory to chemistry, particularly chemical bonds.

**CH 539 COLLOID CHEMISTRY. Preqs.: CH 220, 315 or 331, or CI. 3(2-3) S. Alt. yrs.** Theories, basic principles and fundamental concepts including preparation and behavior of sols, gels, emulsions, foams and aerosols and topics in areas of adsorption, Donnan equilibrium dialysis and small-particle dynamics. Laboratory includes independent project studies in specialized areas.

**CH(MAT,TC) 562 PHYSICAL CHEMISTRY OF HIGH POLYMERS--BULK PROPERTIES. 3(3-0) F.** (See textile chemistry.)

**CH 595 SPECIAL TOPICS IN CHEMISTRY. Preq.: CI. 1-3 F,S.** Detailed study of a particular problem or technique pertaining to chemistry.

FOR GRADUATES ONLY

**CH 611 ANALYTICAL SPECTROSCOPY. Preq.: CH 413 or 433. 3(3-0) S. Alt. yrs.** Presentation of the quantitative laws of spectroscopic analysis and discussion of deviations. Discussion of experimental methods for spectroscopic observation.

**CH 613 ELECTROCHEMISTRY. Preq.: CH 433. 3(3-0) S. Alt. yrs.** The thermodynamics and kinetics of electrode reactions presented as well as the experimental methods for studying them. Particular emphasis on the measurement of standard potential and establishing the number of electrons transferred. Applications of electrochemistry in the production/storage of energy and in chemical analysis.

**CH 615 CHEMICAL SEPARATION. Preqs.: CH 415, CH 416; Coreq.: CH 595. 3(3-0) F.** Basic principles of methods in chemical separation including gas chromatography, liquid chromatography, etc. Theory, instrumentation and applications of various chromatographic and electrophoretic techniques.

**CH 625 ORGANIC REACTION MECHANISMS. Preqs.: CH 523, CH 433. 3(3-0) S.** A study of the effects of structure and substituents on the direction and rates of organic reactions.

**CH 627 CHEMISTRY OF METAL-ORGANIC COMPOUNDS. Preq.: CH 521. 3(3-0) F. Alt. yrs.** Preparation, properties and reactions of compounds containing the carbon-metal bond with a brief description of their uses.

**CH 659 NATURAL PRODUCTS. Preqs.: CH 523 and CH 525. 3(3-0) F.** Illustrative studies of structure determination, synthesis and biosynthesis of natural substances. Stress upon modern physical methods and fundamental chemical concepts. Examples from such classes as alkaloids, terpenes, steroids and antibiotics.

**CH(MAT,TC) 662 PHYSICAL CHEMISTRY OF HIGH POLYMERS--SOLUTION PROPERTIES. 3(3-0) S. Alt. yrs.** (See textile chemistry.)

**CH 691 SEMINAR. Preq.: Grad. standing in CH. 1(1-0) F,S.** Review and discussion of scientific articles, progress reports on research and special problems of interest to chemists.

**CH 695 ADVANCED TOPICS IN CHEMISTRY. Preq.: CI. Maximum 3 F,S.** Critical study in one of the branches of chemistry.

**CH 697 ADVANCED CHEMISTRY PROJECTS. Preq.: Grad. standing in CH. 1-3. F,S,Sum.** Independent literature study of a current subject in chemistry. A critical review paper of the selected subject must be written.

**CH 699 CHEMICAL RESEARCH. Preq.: Grad. standing in CH. Credits Arranged. F,S.** Special problems furnishing material for a thesis. A maximum of six semester credits allowed toward a master's degree; no limitation on credits in the doctoral program.

# Civil Engineering

**Degrees Offered: Ph.D., M. S., Master of Civil Engineering**

## GRADUATE FACULTY

*Professor* E. D. Brill Jr., *Head of the Department*
*Professor* H. E. Wahls, *Director of Graduate Programs*
Box 7908, (919) 515-7344, wahls@eos.ncsu.edu

*Distinguished Professor:* J. M. Hanson
*Distinguished University Professor and Graduate Alumni Distinguished Professor:* P. Z. Zia
*Harrelson Professor:* P. H. McDonald Jr.

*Professors:* S. H. Ahmad, J. F. Ely, J. S. Fisher, W. S. Galler, C. G. Gilbert, A. K. Gupta, K. S. Havner, Y. Horie, D. W. Johnston, N. P. Khosla, N. M. Rouphail, C. C. Tung;
*Adjunct Professors:* R. C. Heath, L. E. King;
*Professors Emeriti:* M. Amein, P. D. Cribbins, R. A. Douglas, R. E. Fadum, C. L. Heimbach, J. W. Horn, A. I. Kashef, S. W. Nunnally, C. J. Smallwood, M. E. Uyanik;
*Associate Professors:* L. E. Bernold, W. L. Bingham, R. C. Borden, R. H. Borden, A. C. Chao, E. D. Gurley, P. C. Lambe, H. R. Malcom Jr., V. C. Matzen, J. M. Nau, M. F. Overton, M. S. Rahman, W. J. Rasdorf, J. C. Smith, J. R. Stone;
*Assistant Professors:* M. A. Barlaz, J. W. Baugh Jr., F. Farid, H. C. Frey, J. E. Hummer, Y. R. Kim, S. K. Liehr, A. E. Schultz, A. A. Tayebali;
*Visiting Assistant Professor:* R. Navon

## INTERINSTITUTIONAL FACULTY OF THE PROGRAM

S. Chang, L. E. King, C. J. Poran, H. D. Robertson, J. S. Wu

Graduate programs are offered in coastal and ocean engineering, computer-aided engineering, construction engineering and management, environmental and water resources engineering, geotechnical engineering, public works engineering/administration, structures and mechanics, transportation engineering and materials.

### Admission Requirements

Provisional admission may be granted to applicants who do not satisfy normal admission criteria but have other special qualifications. Applicants without academic experience in civil engineering may be required to take undergraduate courses to remove deficiencies, without graduate credit. The Graduate Record Examination normally is required of all applicants.

### Master's Degree Requirements

**(M.CE.):** The M.CE. is an Option B non-thesis degree with other requirements, such as independent projects or core courses, specified in some areas of specialization. At least two-thirds of a master's program should be in a well-defined major area of concentration. A formal minor is not permitted. **(M.S.):** A thesis is required and a formal minor is optional.

### Doctoral Degree Requirements

The Ph.D. typically requires one year of full-time course work beyond the master's degree. The program must develop a well-defined major area of concentration and may include supporting courses outside the major or a formal minor in a related field.

### Student Financial Support

Departmental teaching and research assistantships are available. Full and partial fellowships, which may include tuition and fees, are available for exceptional U. S. applicants. All financial aid recipients are selected on merit-based competition with other applicants. Applications requesting financial aid should be received by March 1 for Fall admission and by September 1 for Spring admission.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

**CE 406 TRANSPORTATION SYSTEMS ENGINEERING.**
**CE 425 INTERMEDIATE STRUCTURAL ANALYSIS.**
**CE 426 STRUCTURAL STEEL DESIGN.**
**CE 428 STRUCTURAL DESIGN IN WOOD.**
**CE 443 SEEPAGE, EARTH EMBANKMENTS AND RETAINING STRUCTURES.**
**CE 463 COST ANALYSIS AND CONTROL.**
**CE 464 LEGAL ASPECTS OF CONTRACTING.**
**CE 466 BUILDING CONSTRUCTION ENGINEERING.**
**CE 487 INTRODUCTION TO COASTAL AND OCEAN ENGINEERING.**
**CE 484 WATER SUPPLY AND WASTE WATER SYSTEMS.**

**CE 501 TRANSPORTATION SYSTEMS ENGINEERING. Preq.: CE 305. Credit for both CE 401 and CE 501 is not allowed. 3(3-0) F.** Planning and analysis of multi-modal transportation systems including railroads, airports, highways and other modes. Supply, demand, flows, impacts and network optimization. Completion of term papers and projects for students taking the course for graduate credit.

**CE 502 TRAFFIC OPERATIONS. Preq.: CE 305. 3(3-0) F. Alt. yrs.** Highway capacity; traffic control systems; intelligent vehicle/highway systems; and other advanced topics.

**CE 503 HIGHWAY DESIGN. Preq.: CE 305. 3(3-0) S. Alt. yrs.** Corridor selection; highway alignment; design of roadsides, intersections and interchanges.

**CE 504 WATER TRANSPORTATION. Preq.: CE 305. 3(3-0) S Alt. yrs.** The planning, design and operation of waterways, ports, harbors and related marine facilities. Development of analytical techniques for evaluating maritime commodity flows and infrastructure feasibility.

**CE 508 PUBLIC WORKS ENGINEERING--OPERATIONS AND ADMINISTRATION. Preq.: CE 406 or CE 484. 3(3-0) F.** Organization, operational management-management and engineering responsibilities of a municipal and/or public works engineering department.

**CE 509 PUBLIC WORKS ENGINEERING--ANALYSIS AND DESIGN. Preq.: CE 508. 3(1-4) S.** Modular design-oriented public works topics, including implication, policies, illustrations and case studies.

**CE 510 AIRPORT PLANNING AND DESIGN. Preq.: CE 305. 3(3-0) F.** The analysis, planning and design of air transportation facilities.

**CE 511, 512 CONTINUUM MECHANICS I, II. Preqs.: CE 313 or MAE 314, CE 382 or MAE 308, MAE 301, MA 405. [511] 3(3-0) F; [512] 3(3-0) S. Alt. yrs.** The concepts of stress and strain in generalized tensor form. Emphasis on the discussion and relative comparisons of the analytical models for elastic, plastic, fluid, viscoelastic, granular and porous media. Presentation of underlying thermodynamic principles, formulation of associated boundary value problems and illustration of the theory by selected examples.

**CE 513 THEORY OF ELASTICITY I. Preq.: CE 313 or MAE 314. 3(3-0) S.** Development of fundamental equations governing the behavior of an elastic solid in various curvilinear coordinate systems. Plane problems, as well as the St. Venant

problem of bending, torsion and extension of bars. Usage of displacement fields, stress fields, Airy and complex stress functions among methods to obtain solutions.

**CE 514 STRESS WAVES. Preqs.: MA 301; CE 313 or PY 411 or MA 401 or MEA 351. 3(3-0) F. Alt. yrs.** Introduction to theory of stress waves in solids. Origins and nature of longitudinal transverse and surface waves originating at an impact site or from other transient disturbances. Determination of stresses, particle velocities, wave velocities. Wave interaction with other waves and with boundaries and dissimilar materials. Modern instrumentation and seismic refraction exploration.

**CE 520 MATRIX AND FINITE ELEMENT STRUCTURAL ANALYSIS I. Preq.: CE 425. 3(3-0) F.** Development of the stiffness method of analysis using bar and bean elements; solution of symmetric-banded simultaneous equations; displacement and shape functions for bar and beam elements; introduction to the finite element method using the constant strain triangle and 4- and 8-node isoparametic elements. Development of computer programs at each stage.

**CE 521 ADVANCED STRENGTH OF MATERIALS. Preq.: CE 313 or MAE 314. 3(3-0) F.** Stresses and strains at a point: rosette analysis; strength theories, stress concentration and fatigue; torsion and unsymmetrical bending of open and closed sections; inelastic, composite and curved beams; energy methods; shear deflections; and membrane stresses in shells.

**CE 522 ELASTIC STABILITY. Preqs.: CE 521, MA 301, 405. 3(3-0) S.** Study of elastic and plastic stability. Stability criterion as a determinant. The energy method and theorem of stationary potential energy. Solution of buckling problems by finite differences and the calculus of variations. Application of successive approximations to stability problems.

**CE 524 ANALYSIS AND DESIGN OF MASONRY STRUCTURES. Coreq.: CE 427. 3(3-0) F. Alt. yrs.** Theory and design of masonry arches, culverts, dams, foundations and masonry walls subjected to lateral loads.

**CE 527 ANALYSIS AND DESIGN OF STRUCTURES FOR DYNAMIC LOADS. Preq. or coreq.: CE 525. 3(3-0) F.** Analysis and design of single and multi-degree-of-freedom structures subjected to various types of excitations and initial conditions. Computational aspects of dynamic analysis. Introduction to nonlinear analysis techniques and to approximate methods of analysis. Consideration of strong motion earthquakes. Study of earthquake regulations in building codes.

**CE 531 STRUCTURAL MODELS. Preq.: CE 427. 3(2-3) F.** Dimensional analysis and structural similitude, indirect and direct models, model materials and experimental techniques, individual project in structural model analysis.

**CE 534 PLASTIC ANALYSIS AND DESIGN. Preq.: CE 427. 3(3-0) S.** Theory of plastic behavior of steel structures; concept of design for ultimate load and the use of load factors. Analysis and design of components of steel frames including bracings and connections.

**CE 536 THEORY AND DESIGN OF PRESTRESSED CONCRETE. Coreq.: CE 427. 3(3-0) F.** The principles and concepts of design in prestressed concrete including elastic and ultimate strength analyses for flexure, shear, torsion, bond and deflection. Principles of concordancy and linear transformation for indeterminate prestressed structures. Application of prestressing to tanks and shells.

**CE(MEA) 541 GRAVITY WAVE THEORY I. 3(3-0) S.** (See marine, earth and atmospheric sciences.)

**CE 544 FOUNDATION ENGINEERING. Preq.: CE 342. 3(3-0) S.** Subsoil investigations; excavations; design of sheeting and bracing systems; control of water; footing, grillage and pile foundations; caisson and cofferdam methods of construction.

**CE 548 ENGINEERING PROPERTIES OF SOILS I. Preq.: CE 342. 3(2-3) F.** Study of soil properties significant in earthwork engineering, including properties of soil solids, basic physiochemical concepts, classification, identification, plasticity; permeability, capillarity and stabilization. Laboratory work includes classification, permeability and compaction tests.

**CE 551 THEORY OF CONCRETE MIXTURES. Preq.: CE 332. 3(3-0) F.** An in-depth study of the theory of portland cement concrete mixtures including types and properties of portland special cements; chemical reactions; brief examination of history of mixture design; detailed study of current design methods; properties of fresh and hardened concretes; strength-age-curing relationships; durability; admixtures; special concretes; production and quality control.

**CE 553 ASPHALT AND BITUMINOUS MATERIALS. Preq.: CE 332. 3(2-3) S.** An in-depth study of properties of asphalts and tars for use in waterproofing and bituminous materials and theories of design of bituminous mixtures for construction and paving uses including types and properties of asphalt cements, cutbacks, emulsions, blown asphalts and tars; brief examination of historical developments; detailed study of properties and design of bitumi nous mixtures; and current research. Laboratory work includes standard tests on asphalts, tars and road oils; design, manufacture and testing of trial batches; and current research techniques.

**CE 555 HIGHWAY PAVEMENT DESIGN. Preq.: CE 342. 3(3-0) F.** Theoretical analysis and design of highway pavements with critical evaluation of current

design practices. Pavement materials characterization; stresses and strains in pavements; traffic consideration; pavement performance models; and actual thickness design of pavements using different methodologies.

**CE 557 PAVEMENT MANAGEMENT SYSTEMS. Preq.: CE 555. 3(3-0) S. Alt. yrs.** Fundamental concepts in the process of pavement management at both network level and project level. Distress identification and evaluation; concepts and methods for rehabilitation and maintenance techniques; nondestructive testing of pavements; performance prediction models; and principles of prioritization/optimization.

**CE 559 INELASTIC BEHAVIOR OF CONSTRUCTION MATERIALS. Preq.: CE 513 or CE 521. 3(3-0) S. Alt. yrs.** Application of the principles of linear and nonlinear viscoelasticity, fracture mechanics and damage mechanics to modeling inelastic behavior of construction materials. Mechanical analog of time-dependent response; linear and nonlinear elastic-viscoelastic correpondence principles; time-temperature superposition; stress intensity factor; energy release rate; J-integral; and continuum damage mechanics.

**CE 561 CONSTRUCTION PLANNING AND SCHEDULING. Preq.: CE 463. 3(3-0) F or S.** Construction project planning, scheduling and control utilizing network methods. Application of both manual and computer techniques. Introduction to other quantitative management methods in construction. Utilizing the principles developed, students bid, plan, schedule and manage a construction project under competitive conditions in a computer-simulated environment.

**CE 562 CONSTRUCTION PRODUCTIVITY. Preq.: CE 463 or equivalent. 3(3-0) F or S.** Methods of collecting, assembling and analyzing construction productivity data in order to increase construction productivity. Applications of methods improvement techniques such as time-lapse photography, flow charts, process charts and time standards to the improvement of construction productivity. Safety and human factors in construction and their relation to construction productivity.

**CE 563 MATERIALS MANAGEMENT IN CONSTRUCTION. Preqs.: CE 463, CE 465. 3(3-0) Every 3rd sem.** Fundamental concepts and methods; construction specific models for integrated materials management; computer usage; vendor analysis and "best-buy;" materials requirement planning and control; management of material waste; automated materials tracking; materials handling; study of current issues; development of a practical solution to a real-world problem.

**CE 564 LEGAL ASPECTS OF CONTRACTING. Preq.: Grad. standing. Credit for both CE 464 and CE 564 is not allowed. 3(3-0) F.** Legal aspects of contract documents, drawings and specifications; owner-engineer-constructor rela-

tionship and responsibilities; bids and contract performance; labor laws; governmental administrative and regulatory agencies; torts; business organizations; ethics and professionalism; analysis of current topics and issues. Investigation of recent statute and case implications.

**CE 566 BUILDING CONSTRUCTION SYSTEMS. Preq.: CE 466 or CE 427 or grad. standing in ARC. 3(3-0) F or S.** Construction engineering of conventional and industrialized building systems. Emphasis in the areas of structural systems utilizing cast-in-place concrete, precast concrete, prestressed concrete, structural steel, cold-formed steel, masonry, timber, composite and mixed materials. Topics include mechanisms for resisting and transmitting loads, detailing, fabrication, transportation, erection, stability, shoring, quality control and integration of service systems.

**CE 571 THEORY OF WATER AND WASTE TREATMENT. Preq.: CE 574. 3(3-0) F.** Basic physical and chemical processes underlying water and waste treatment, including mass transfer, equilibria, kinetics and flow through porous media.

**CE 572 DESIGN OF WATER AND WASTEWATER FACILITIES. Preq.: CE 571. 3(3-0) S.** Theory and design of water and wastewater treatment plants.

**CE 574 CHEMISTRY AND MICROBIOLOGY FOR ENGINEERS I. Preq.: CE 384. 3(3-0) F.** Fundamental aspects of inorganic chemistry, biochemistry and microbiology presented and related to problems of surface and groundwater pollution, refuse decomposition and water and wastewater treatment. Buffering, alkalinity, solubility, oxidation reduction, microbial diversity and ecology, and energy conservation and growth requirements in bacteria.

**CE 575 MODELING AND ANALYSIS OF ENVIRONMENTAL SYSTEMS. Preqs.: CE 375 and CE 382 or equivalent. 3(3-0) F.** Movement and fate of pollutant discharges. Development and application of analytical solutions and numerical models. The role of these models in planning and management. Mathematical programming models. Alternative management strategies: direct regulation, charges and transferable discharge permits. Multiple objectives: cost, equity and certainty of outcome.

**CE 577 ENGINEERING PRINCIPLES OF SOLID WASTE MANAGEMENT. Preq.: CE 384. 3(3-0) F.** Solid waste management including generation, storage, transportation, processing, land disposal and regulation. Processing alternatives including incineration and composting. Integration of policy alternatives with evaluation of engineering decisions. Investigation of current research.

**CE(BAE) 578 AGRICULTURAL WASTE MANAGEMENT. 3(2-3) F.** (See biological and agricultural engineering.)

**CE 580 FLOW IN OPEN CHANNELS. Preq.: CE 382. 3(3-0) F.** Theory and applications of flow in open channels, including dimensional analysis, momentum-energy principle, gradually varied flow, high-velocity flow, energy dissipators, spillways, waves, channel transitions and model studies.

**CE 582 COASTAL HYDRODYNAMICS. Preq.: CE 382 or equivalent. 3(3-0) F.** Surface gravity waves, solitary waves, longwaves, impulsively generated waves, flow in inlets and estuaries, storm surge, wave refraction and diffraction, harbor oscillations.

**CE 583 ENGINEERING ASPECTS OF COASTAL PROCESSES. Preq.: CE 382 or equivalent; Coreq.: MEA (CE) 541. 3(3-0) S.** Coastal environment, engineering aspects of the mechanics of sediment movement, littoral drift, beach profiles, beach stability, meteorological effects, tidal inlets, inlet stability, shoaling, deltas, beach nourishment, mixing processes, pollution of coastal waters, interaction between shore processes and man-made structures, case studies.

**CE 584 HYDRAULICS OF GROUND WATER. Preq.: CE 382. 3(3-0) F.** Introduction to ground water hydraulics and hydrology. Hydrologic cycle, basic ground water hydraulics, numerical solution of governing equations, ground water hydrology of North Carolina, well design and construction, flow new development, and ground water contamination sources.

**CE 585 URBAN STORMWATER MANAGEMENT. Preq.: CE 383. 3(3-0) F.** Studies of storm water management in urban areas emphasizing quantitative problems in flooding, sedimentation and water quality. Review and extension of design concepts involving channels and impoundments. Survey of hydrographic formation techniques and examination of common hydrologic models. Case studies of urbanizing watersheds.

**CE 586 ENGINEERING HYDROLOGY. Preq.: CE 383. 3(3-0) F. Alt. yrs.** A study of hydrologic principles underlying procedures for surface water modeling; applications of common hydrologic models to actual watersheds.

**CE 589 SPECIAL TOPICS IN CIVIL ENGINEERING. 1-3 F,S.** New or special course on recent developments in some phase of civil engineering. Specific topics and prerequisites identified for each section and will vary from term to term.

**CE 591, 592 CIVIL ENGINEERING SEMINAR. 1(1-0) F,S.** Discussions and reports of subjects in civil engineering and allied fields.

**CE 598 CIVIL ENGINEERING PROJECTS. 1-6 F,S.** Research- or design-oriented independent study and investigation of a specific civil engineering topic, culminating in a final written report.

*FOR GRADUATES ONLY*

**CE 601 TRANSPORTATION PLANNING. Preq.: CE 502. 3(3-0) F. Alt. yrs.** The planning, administration and evaluation of various transportation engineering facilities.

**CE 603 ADVANCED AIRPORT SYSTEMS DESIGN. Preq.: CE 510. 3(3-0) S. Alt. yrs.** The planning, design and operation of the components of the U. S. air transportation system with special emphasis on the forecasting and analysis techniques used at major airports.

**CE 604 URBAN TRANSPORTATION PLANNING. Preq.: CE 501. 3(3-0) S. Alt. yrs.** Planning and design of urban transportation systems as related to comprehensive urban planning; principles of land use planning, urban thoroughfare planning and regional planning.

**CE 614 PLASTICITY AND LIMIT ANALYSIS. Preq.: CE 513 or 521. 3(3-0) S. Alt. yrs.** Stress-strain rate relationships and theorems of limit analysis and shakedown in plastic solids. Application to collapse load calculations in arches, rings, plates and axisymmetric shells. Introduction to slip-line field theory of plane plastic flow and to dynamic limit analysis.

**CE 615 FINITE DEFORMATION OF MATERIALS I. Preqs.: CE 511 or 513, MA 512. 3(3-0) F. Alt. yrs.** Application of the principles of classical continuum mechanics to the study of large deformation of solid materials. Finite strain geometry and kinematics, work-conjugate stress and stress-rate measures, rotating reference frames, local balance laws and jump conditions. Constitutive equations of nonlinearly elastic and inelastic behavior, general theorems for rate-type boundary value problems, conditions for bifurcation of solution.

**CE 620 MATRIX AND FINITE ELEMENT STRUCTURAL ANALYSIS. Preqs.: CE 520. 3(3-0) S.** Advanced topics in matrix structural analysis and finite element method. Introductory review of the method, isoparametric quadrilateral element and three-dimensional elements. Energy methods and convergence criteria. Higher order elements. Isoparametric beam and plant elements, shear locking. Isoparametric curved beam and shell elements. Axisymmetric elements, Fourier series load and displacement representation. Analysis of systems with geometric and material nonlinearities.

**CE 623 THEORY OF PLATES AND SHELLS. Preq.: CE 513 or CE 521. 3(3-0) F.** Small and large deflection theories of thin plates; membrane analysis of shells. Discussion and illustration of various methods of analysis by problems of practical interest.

**CE 625, 626 ADVANCED STRUCTURAL DESIGN I, II. Preqs.: [625]: CE 427, CE 525; [626] CE 427; Coreqs.: [626] CE 525, 526. [625] 3(3-0) S. [626] (2-3) F. Alt. yrs.** Complete structural design of a variety of projects including comparative study of alternative solutions. Discussions of long-span structural systems.

**CE 627 ADVANCED ANALYSIS AND DESIGN OF STRUCTURES FOR DYNAMIC LOADS. Preq.: CE 527. 3(3-0) F. Alt. yrs.** Consideration of following advanced topics in the analysis and design of structures for dynamic loads: eigenvalue routines and numerical integration techniques; response analysis through the frequency domain; investigation of damping; variational formulation of the equations of motion; analysis and design of continuous systems; approximate methods of analysis; and special topics.

**CE 628 EARTHQUAKE STRUCTURAL ENGINEERING. Preq.: CE 527. 3(3-0) S.** Study of the effects of earthquakes on structures and of the design of structures to resist earthquake motions; earthquake mechanisms and ground motions; response of structures to earthquake motions; behavior of materials, structural elements and assemblages subjected to earthquakes; principles of earthquake-resistant design practice; soil-structure interactions; and special topics.

**CE 632 PROBABILISTIC METHODS OF STRUCTURAL ENGINEERING. Preqs.: CE 525 and MA 421. 3(3-0) F. Alt. yrs.** Application of probability theory and stochastic processes to the study of safety of structures. Fundamentals of probability theory and stochastic processes; probabilistic modelings of structural loadings, material properties and risk. Reliability analysis of structures; reliability-based design criteria. Random vibration of simple structures; safety analysis of structures under dynamic loads.

**CE 635 ADVANCED THEORY OF CONCRETE STRUCTURES. Preq.: CE 536. 3(3-0) S.** Inelastic theory of structural concrete members under flexure, axial load, combined flexure and axial compression, shear and torsion. Yield line theory of slabs. Limit analysis of beams and frames of reinforced and prestressed concrete.

**CE 641, 642 ADVANCED SOIL MECHANICS. 3(3-0) F,S.** Theories of soil mechanics; failure conditions; mechanical interaction between solids and water, and problems in elasticity and plasticity pertaining to earthwork engineering.

**CE 644 GROUND WATER CONTAMINANT TRANSPORT. Preq.: CE 584. 3(3-0) F.** Introduction to the movement and attenuation of contaminants in the subsurface. Topics include common contaminant sources; advection and dispersion; numerical modeling of contaminant transport; chemical and biological processes in the subsurface; and ground water restoration technology.

**CE 646 Dynamics of Soils and Foundations. Preq.: CE 641. 3(3-0) S. Alt. yrs.** The application of vibration and wave propagation theories to soil media; the review of existing experimental data and empirical procedures for analysis of foundation vibrations, the prediction of soil responses to impulse loads, dynamic properties of soils and methods for their determination, design procedures for foundation subjected to dynamic forces.

**CE 661 DESIGN OF TEMPORARY STRUCTURES. Preq.: CE 536 or CE 544 or CE 566 or equivalent. 3(3-0) Every 3rd sem.** Computer-based analysis of temporary structures in construction and their design, safety and control. Emphasis on concrete formwork, falsework, earth support, cofferdams, underpinning, lifting and rigging.

**CE 669 AUTOMATION AND ROBOTICS IN CIVIL ENGINEERING. Preq.: CE 563 or equivalent. 3(3-0) Every 3rd sem.** Concepts of automation in design, planning, construction and maintenance of civil structures. Design office automation as a tool to create a computer-integrated engineering system. Intelligent process planning to link design with fabrication and construction. Critical robot technologies. Pattern recognition and architectures for adaptive control.

**CE 671 ADVANCED WATER MANAGEMENT SYSTEMS. Preqs.: CE 375, CE 571. 3(3-0) S. Alt. yrs.** The application of systems analysis methods to the design, analysis and management of water and waste systems.

**CE 673 INDUSTRIAL WATER SUPPLY AND WASTE DISPOSAL. Coreq.: CE 571. 3(3-0) F.** Water requirements of industry and disposal of industries waste.

**CE 674 CHEMISTRY AND MICROBIOLOGY FOR ENGINEERS II. Coreq.: CE 574. 3(3-0) S.** Microbiological and chemical principles, including applications of energetics, stoichiometry, genetics, biodegradation mechanisms, kinetics models, attached growth, coordination chemistry, solubility and adsorption.

**CE 681 BEHAVIOR AND ANALYSIS OF OCEAN STRUCTURES. Preq.: CE 527. 3(3-0) S. Alt. yrs.** Introduction to linear and random water waves, analysis of wave forces on small bodies, analysis of wave forces on large bodies, response of offshore structures to waves and earthquake loadings, mooring dynamics.

**CE 685 DESIGN OF COASTAL FACILITIES. Preqs.: CE 582 and CE 583. 3(3-0) F.** Types and functions of coastal structures, computation of wave forces on coastal structures, wave uprush, shore protection against waves and storms, planning and design of navigation channels, port development, harbor design, dredging technology, planning and design of offshore platforms, technology of disposal of wastes and heated discharge, consideration of environmental effects of waste disposal.

**CE 689 ADVANCED TOPICS IN CIVIL ENGINEERING. 1-3 F,S.** New or special course on advanced developments in some phase of civil engineering. Specific topics and prerequisites are identified for each section and will vary from term to term.

**CE 698 ADVANCED READING IN CIVIL ENGINEERING. 1-3 F,S.** Directed reading of advanced topics in some phase of civil engineering.

**CE 699 CIVIL ENGINEERING RESEARCH. Credits Arranged. F,S.** Independent investigation of an advanced civil engineering problem; a report of such an investigation is required as a graduate thesis.

# Computer Engineering

For a listing of graduate faculty and program information, see electrical and computer engineering.

# Computer Science

**Degrees Offered: Ph.D., M.S., Master of Computer Science**

**GRADUATE FACULTY**

*Professor* A. L. Tharp, *Head of the Department*
*Professor* W. E. Robbins, *Director of Graduate Programs*
Box 8206, (919) 515-2654, robbins@adm.csc.ncsu.edu

*Distinguished University Research Professor:* D. L. Bitzer

*Professors:* W. Chou, R. J. Fornaro, R. E. Funderlic, D. C. Martin, D. F. McAllister, H. G. Perros, W. J. Stewart, K. C. Tai;
*Adjunct Professor:* R. J. Plemmons;
*Associate Professors:* D. R. Bahler, E. W. Davis Jr., E. F. Gehringer, T. L.

Honeycutt, W. J. Rasdorf, D. S. Reeves, R. D. Rodman, C. D. Savage, M. F. M. Stallmann, M. A. V. Vouk;
*Assistant Professors:* J. W. Baugh Jr., W. R. Cleaveland II, R. A. Dwyer, S. P. Iyer, A. Ola;
*Adjunct Assistant Professors:* K. D. Clark, G. Q. Kenney, J. Mauney, A. O. Zaghloul;
*Assistant Professors Emeriti:* J. W. Hanson, N. F. Williamson

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professor:* C. D. Meyer;
*Associate Professor:* T. K. Miller III;
*Assistant Professors:* J. W. Baugh Jr., I. Viniotis

The department has developed an international reputation for its research endeavors. Faculty are at the leading edge of research in software systems (includes software engineering, software specification and verification, real-time systems, object-oriented systems, artificial intelligence, computer graphics, and database), communications and performance analysis, architecture, and theory and algorithms (includes scientific computing).

### Admission Requirements

Applicants must have a bachelor's degree from an accredited institution, ideally, in computer science. Applicants must have an extensive knowledge of high-level programming, assembly language programming, computer organization and logic, and data structures. Additional requirements include a three-semester calculus sequence and knowledge of probability and statistics. All applicants must take the GRE General and Subject Tests.

### Master's Degree Requirements

The master's degree with thesis requires six hours of research. At least two core courses chosen from CSC 501, 505, 506, and 522 must be taken. The non-thesis degree requires nine hours from a designated area of interest and must include three core courses and at least three hours at the 600-level. Neither CSC 693 nor CSC 695 can be used to satisfy the 600-level requirement.

### Doctoral Degree Requirements

There is no prescribed minimum number of courses for the Ph.D. degree. Normally a student will take approximately 60 semester hours of course credits, including the four core courses mentioned under the master's requirements above, beyond the BS degree. Students must pass a written qualifying examination within one year of admission to the Ph.D. program in addition to the examination required required by all Ph.D. programs.

### Student Financial Support

The department offers a number of graduate teaching, research, and industrial assistantships to qualified applicants which require, on average, 20 hours of work per week. Current stipends are competitive on a national basis. A TA's duties usually involve grading programs and homework and, in general, assisting a professor in the academic program. A limited number of teaching positions are available to Ph.D. candidates. An RA's duties are to assist a professor in a research program generally in the student's area of interest. An IA works at a local company in an environment which matches the student's academic strengths with a company's needs. The College of Engineering offers fellowships which are in addition to other stipends.

### Other Relevant Information

In addition to College of Engineering computing resources, the department has numerous laboratories which support both education and research. Current laboratories include: artificial intelligence, communications, computer graphics, multimedia, real-time systems, software engineering and voice I/O systems. The department was a co-founder, with mathematics, of the Center for Research in Scientific Computation (CRSC) and offers a concentration in scientific computation. Students make use of high-performance computers on campus and at the North Carolina Supercomputing Center.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

CSC 401 DATA AND COMPUTER COMMUNICATIONS NETWORKS.
CSC(MA) 416 INTRODUCTION TO COMBINATORICS.
CSC 417 THEORY OF PROGRAMMING LANGUAGES.
CSC 421 INTRODUCTION TO MANAGEMENT INFORMATION SYSTEMS.
CSC 422 MANAGEMENT INFORMATION SYSTEMS.
CSC 423 INFORMATION RESOURCES MANAGEMENT.
CSC(MA) 427 INTRODUCTION TO NUMERICAL ANALYSIS I.
CSC(MA) 428 INTRODUCTION TO NUMERICAL ANALYSIS II.
CSC 431 FILE ORGANIZATION AND PROCESSING.
CSC 432 DATABASE MANAGEMENT SYSTEMS.
CSC(ECE) 440 DIGITAL SYSTEMS INTERFACING.
CSC(IE) 441 INTRODUCTION TO SIMULATION.
CSC 451 OPERATING SYSTEMS.
CSC 452 OPERATING SYSTEMS PROJECTS.
CSC 461 COMPUTER GRAPHICS.
CSC 462 COMPUTER GRAPHICS PROJECTS.
CSC 471 PROGRAMMING ENVIRONMENTS.
CSC 472 SOFTWARE ENGINEERING PROJECT.
CSC 481 SOFTWARE ENGINEERING WITH ADA.
CSC 495 SPECIAL TOPICS IN COMPUTER SCIENCE.
CSC 499 INDEPENDENT RESEARCH IN COMPUTER SCIENCE.

**CSC(ECE) 501 OPERATING SYSTEMS PRINCIPLES. Preqs.: CSC 202, CSC 311 and MA 421. 3(3-0) F,S.** Fundamental issues related to the design of operating systems. Process scheduling and coordination, deadlock, memory management and elements of distributed systems.

**CSC 502 COMPUTATIONAL LINGUISTICS. Preq.: CI. 3(3-0) F.** Natural language processing by computer. Finite-state, context-free, context-sensitive and transformational grammars. Parsing mechanisms including augmented transition networks. Analysis of complex English sentences. Question-answering systems.

**CSC (ECE) 505 DESIGN AND ANALYSIS OF ALGORITHMS. Preq.: CSC 311 and CSC 222. 3(3-0) F,S.** Algorithm design techniques: use of data structures, divide and conquer, dynamic programming, greedy techniques, local and global search. Complexity and analysis of algorithms: asymptotic analysis, worst case and average case, recurrences, lower bounds, NP-completeness. Algorithms for classical problems including sorting, searching and graph problems (connectivity, shortest paths, minimum spanning trees).

**CSC(ECE) 506 ARCHITECTURE OF PARALLEL COMPUTERS. Preq.: CSC 312 or ECE 342. 3(3-0) F.** The need for parallel computers and their potential performance. Taxonomy of parallel computer architecture. Arithmetic pipeline design and vector processes. Single and multi-stage interconnection networks, massively parallel computing with array machines shared memory and distributed memory multi-processor computers. Memory system, design issues, applications/ algorithms for parallel computers.

**CSC(ECE) 510 SOFTWARE ENGINEERING. Preqs.: CSC 311 and CSC 222. 3(3-0) F.** Introduction to the principles, methods and tools for the design, coding and validation of software systems. Topics include software planning, cost estimation, software design techniques, programming methodology, program testing, proofs of program correctness, software reliability and software management.

**CSC 511 ARTIFICIAL INTELLIGENCE I. Preq.: CSC 311 and either CSC 222 or PHI 201 or PHI 335 or background in symbolic logic. 3(3-0) F,S.** Introduction to and overview of artificial intelligence. Study of an AI programming language such as LISP or PROLOG. Elements of AI problem-solving technique. State spaces and search techniques. Logic, theorem proving and associative databases. Introduction to knowledge representation, expert systems and selected topics including natural language processing, vision and robotics.

**CSC(ECE) 512 COMPILER CONSTRUCTION. Preq.: CSC 311. 3(3-0) S.**

A detailed understanding of the techniques used in the design and implementation of compilers. Formal grammars and algorithms for lexical scanners, top-down recog nizers, bottom-up recognizers for simple precedence grammars, operator precedence grammars, high order precedence grammars and bounded-context grammars. Run-time storage organization for a compiler including symbol tables, internal forms for source programs, semantic routines, error recovery and diagnostics, code generation and optimization and interpreters.

**CSC 517 OBJECT-ORIENTED LANGUAGES AND SYSTEMS. Preq.: CSC 417. 3(3-0) F.** Object-oriented languages and the systems built with object-oriented software components. Systems concepts, including inheritance, dynamic binding, type systems and genericity; implementation in specific languages, *e.g.*, Smalltalk, C++ and Eiffel. Object-oriented programming environments and object-oriented databases. Project required.

**CSC(ECE) 518 COMPUTER GRAPHICS. Preqs.: MA 405, knowledge of FORTRAN or PASCAL. 3(3-0) F.** Clipping, windowing, transformations, projections, hiddenline and surface removal, smooth shading, shadowing, translucence, reflection, refraction, curve and surface representation.

**CSC(ECE) 520 FUNDAMENTALS OF LOGIC SYSTEMS. 3(3-0) F.** (See electrical and computer engineering.)

**CSC(ECE) 521 DIGITAL COMPUTER TECHNOLOGY AND DESIGN. 3(3-0) F.** (See electrical and computer engineering.)

**CSC 522 AUTOMATA, LANGUAGES AND COMPUTABILITY THEORY. Preq.: CSC 222 required, CSC 333 recommended. 3(3-0) S.** Formal models of language and computation; finite automata and regular languages, pushdown automata and context-free languages, Turing machines. Relative power of models, Chomsky hierarchy. Inherent complexity of problems: undecidability, computational complexity, intractable problems.

**CSC(MA) 529, 530 NUMERICAL ANALYSIS I, II. 3(3-0) F,S.** (See mathematics.)

**CSC 541 ADVANCED DATA STRUCTURES. Preq.: CSC 311. 3(3-0) F.** Complex and specialized data structures relevant to the design and development of effective and efficient software. Hardware characteristics of storage media. Primary file organizations. Hashing functions and collision resolution techniques. Low level and bit level structures including signatures, superimposed coding, disjoint coding and Bloom filters. Tree and related structures including AVL trees, B*trees, tries and dynamic hashing techniques.

**CSC(ECE) 542 DATABASE MANAGEMENT. Preq.: CSC 431 or CSC(ECE) 501. 3(3-0) S.** The fundamentals of database management. Basic topics include: general architecture for database management systems; current data models such as network, relational, hierarchical; security and integrity; discussion of current implemented systems.

**CSC(ECE,OR,IE) 562 COMPUTER SIMULATION TECHNIQUES. Preqs.: ST 516 and a scientific programming language. 3(3-0) F.** Basic discrete event simulation methodology: random number generators, simulation designs, validation, analysis of simulation output. Applications to various areas of scientific modeling. Simulation language such as SLAM and GPSS. Computer assignments and projects.

**CSC(ECE) 571 COMPUTER NETWORKS. Preqs.: CSC 312 or ECE 318. 3(3-0) F,S.** Detailed description and related performance issues of OSI layers two and three for wide-area networks, well-known standards for metropolitan area networks such as FDII and DQDB, and basic random access mechanisms for local area networks.

**CSC(ECE) 572 INTRODUCTION TO COMPUTER COMMUNICATIONS. Preq.: CSC 312 or ECE 318. 3(3-0) F,S.** Computer communications including local area networks (LANs), metropolitan area networks (MANs), wide area networks (WANs), standard organizations, open system architecture (OSI), IBM's system network architecture (SNA), network performance and topological optimization.

**CSC(ECE) 573 INTRODUCTION TO COMPUTER PERFORMANCE MODELING. Preqs.: CSC 312 and MA 421; Coreq.: CSC 501. 3(3-0) F.** Workload characterization, collection and analysis of performance data, instrumentation, tuning, analytic models including queueing network models and operational analysis, economic considerations.

**CSC(ECE) 574 REAL TIME COMPUTER SYSTEMS. Preq.: CSC 451 or CSC(ECE) 501. 3(3-0) S.** Hardware and software characteristics of computer systems designed to meet specific response time requirements studied. Topics include allocation of system resources including processor memory, disk, support I/O devices; synchronous and asynchronous event scheduling; effect of interrupts; static and dynamic priorities; implementation of queues; measurement of performance, especially scheduling and response accuracy.

**CSC(ECE,IE) 575 VOICE INPUT/OUTPUT COMMUNICATION SYSTEMS. Preq.: IE 307 or CSC 312. 3(3-0) F.** Introduction to the physical, linguistic and computational principles underlying speech synthesis and speech recognition. Human factors of speech I/O. Advantages and disadvantages of implementing

voice applications. Hands-on use of voice I/O equipment through class projects. Case studies of current applications of speech I/O technology.

**CSC(MA,OR) 585 GRAPH THEORY. Preq.: MA 405 and CSC 222. 3(3-0) F.** Basic concepts of graph theory. Trees and forests. Vector spaces associated with a graph. Representation of graphs by binary matrices and list structures. Traversability, connectivity, matching and assignment problems. Planar graphs. Colorability. Directed graphs. Applications of graph theory with emphasis on organizing problems for computer solutions.

**CSC 591 SPECIAL TOPICS IN COMPUTER SCIENCE. Preqs.: B average in technical subjects and CI. 3(3-0) F,S.** Topics of current interest in computer science not covered in existing courses.

*FOR GRADUATES ONLY*

**CSC 602 COMPUTATIONAL SEMANTICS. Preqs.: CSC 502 and CSC 222. 3(3-0) S.** An examination of how to represent meaning in natural language to a computer. Logical systems for representing meaning. Other systems for representing meaning such as conceptual dependencies. Generating natural language output from data bases representing knowledge. Reading of advanced material in such areas as natural language dialogue processing.

**CSC(ECE) 606 CONCURRENT SOFTWARE SYSTEMS. Preq.: CSC(ECE) 501. 3(3-0) S.** Concepts, techniques and tools for the development of concurrent (parallel or distributed) software systems. Topics include specification of concurrency, design of concurrent software systems, concurrent languages and validation of concurrent programs.

**CSC 611 ARTIFICIAL INTELLIGENCE II. Preq.: CSC 511. 3(3-0) S.** Advanced concepts of AI including logic programming, automatic programming, natural language understanding, visual perception by machine, learning and inference, intelligent computer-aided instruction, knowledge representation, robotics and other topics to be chosen by the instructor. Students asked to write programs in an AI programming language such as LISP and PROLOG.

**CSC(ECE) 640 ADVANCED LOGIC SYSTEMS. 3(3-0) S.** (See electrical and computer engineering.)

**CSC(ECE) 671 ADVANCED COMPUTER PERFORMANCE MODELING. Preqs.: CSC (ECE) 573 or OR (IE) 561. 3(3-0) S. Alt. yrs.** In-depth study of computer performance modeling techniques such as exact and approximate analysis

of queueing networks and direct and iterative numerical solutions of queueing systems.

**CSC(MA) 673 PARALLEL ALGORITHMS AND SCIENTIFIC COMPUTATION. 3(3-0) S.** (See mathematics.)

**CSC(ECE,IE) 675 ADVANCES IN VOICE INPUT/OUTPUT COMMUNICATIONS SYSTEMS. Preq.: CSC 575. 3(2-3) S.** Selected topics from the current literature in voice input/output research, technology and applications. Execution of a significant experiment or project by each student.

**CSC(ECE) 676 PERFORMANCE EVALUATION OF COMPUTER NETWORKS. 3(3-0) S.** (See electrical and computer engineering.)

**CSC(ECE) 677 TELECOMMUNICATIONS NETWORK DESIGN. 3(3-0) S.** (See electrical and computer engineering.)

**CSC 691 ADVANCED TOPICS IN COMPUTER SCIENCE. Preq.: CI. 3(3-0) F,S.** Advanced topics of current interest in computer science not covered by existing courses.

**CSC 693 INDIVIDUAL TOPICS IN COMPUTER SCIENCE. Preq.: CI. 1-3 F,S.** An opportunity for an individual graduate student to investigate special topics of interest under the direction of members of the graduate faculty.

**CSC 695 SEMINAR IN COMPUTER SCIENCE. Preq.: CI. 1(1-0) F,S.** Seminar discussion of problems of current research interests in computer science. Seminar speakers consist of advanced graduate students, faculty and invited speakers.

**CSC 699 COMPUTER SCIENCE RESEARCH. Preq.: CI. Credits Arranged. F,S.** Individual research by graduate students minoring and majoring in computer science. Research may be done under the supervision of CSC faculty members meeting the interest and need of the student.

# Counselor Education

**Degrees Offered: Ph.D., M.S., M.Ed.**

**GRADUATE FACULTY**

*Professor* E. R. Gerler Jr., ***Interim Head of the Department***
Box 7801, (919) 515-2244, edwin@poe.coe.ncsu.edu

*Professors:* J. Anderson, L. K. Jones, D. C. Locke, N. A. Sprinthall;
*Professors Emeriti:* W. E. Hopke;
*Associate Professor:* H. A. Exum;
*Visiting Associate Professor:* T. H. Stafford Jr.;
*Associate Professors Emeriti:* J. G. McVay, B. C. Talley Jr.;
*Assistant Professors:* T. L. Robinson, D. D. Saidla;

**Admission Requirements**
Requirements include a 3.00 average (4.00 scale) in the junior and senior years of the undergraduate program and one year of work experience in a human services capacity. The best-qualified applicants will be accepted up to the number of spaces that are available for new students. Exceptions to the minimum grade-point average may be made for students with special backgrounds, abilities and interests.

Admission requirements for the Ph.D. program include, in addition to the general admission requirements, a 48 semester hour master's degree, the completion of a work sample and a personal interview.

**Master's Degree Requirements**
A minimum of 45 semester hours are required in the school counseling and agency counseling programs. The program in student development has a minimum requirement of 51 semester hours.

**Doctoral Degree Requirements**
A minimum of 60 semester hours is required in the Ph.D. program in counselor education and must include courses in research, behavioral sciences foundation, counselor education theory and professional application.

**Other Relevant Information**
The Council for Accreditation of Counseling and Related Educational Programs (CACREP), a specialized accrediting body recognized by the Council on Post-secondary Accreditation (COPA), has conferred accreditation to the following program areas in the Department of Counselor Education: student development in higher education (M.S., M.Ed.) and the Ph.D. program in counselor education. These program area have admission and curriculum requirements that conform to CACREP standards.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ECD 520 INTRODUCTION TO COUNSELING. Preq.: Six hrs. in educ. or psy. 3(3-0) F,S,Sum.** An introduction to counseling with a focus on three settings-schools, college and community agencies. The exploration of issues of theory, practice and research with regard to children, adolescents, college students and

adults. Personal and professional exploration encouraged through the use of psychological tests.

**ECD 521 INTERNSHIP IN GUIDANCE AND PERSONNEL SERVICES. Preqs.: Eighteen hrs. in dept. and CI. 3-6. F,S.** An internship of at least one-half semester. Intern will work with students, teachers, administrators, guidance staff, parents and resource personnel in the community. Supervision of intern by school counselor and university course instructor.

**ECD 522 INTERNSHIP IN COLLEGE STUDENT DEVELOPMENT. Preq.: ECD 641. 3-6. F,S.** A 600-hour internship to be completed in one or two consecutive semesters. Provides students with professional experience in a student affairs department with on-site supervision from a qualified professional. Expectations of intern include employment of broad repertoire of skills in the roles of counselor, student development educator and administrator. Weekly student meetings with faculty and on-site supervisors.

**ECD 523 INTERNSHIP IN AGENCY COUNSELING. Preqs.: 18 hrs. in dept. and CI. 3-6. F,S.** Provision of student opportunity for professional experience in an agency counseling setting, under the supervision of a professional counselor. Intern to employ broad repertoire of primary and secondary prevention approaches to individual and group techniques, workshop leadership skills, consultation techniques and advocacy methods.

**ECD 524 CAREER COUNSELING AND DEVELOPMENT. Preq.: Six hrs. of educ. or psy. 3(3-0) S,Sum.** Knowledge and skills needed to: (a) provide professional career counseling to individuals and (b) design, implement and evaluate career development programs for particular groups. Areas of study include: theories of career development and decision making; career guidance programs in educational, agency and industrial setting; career information sources and delivery systems; and assessment in career counseling.

**ECD 530 THEORIES AND TECHNIQUES OF COUNSELING. Preq.: Six hrs. of educ. or psy.; Coreq.: ECD 520 or equivalent. 3(3-0) F,S,Sum.** A combination of the study of theory and philosophy in counseling with techniques of counseling. Topics include behavioral approaches, psychoanalytic approaches, client-centered counseling, existential counseling and relationship models, and their relation to counseling. For each theory, the techniques related to the theoretical concepts and principles.

**ECD 533 GUIDANCE AND COUNSELING IN THE SECONDARY SCHOOLS. Preq.: Grad. standing. 4(3-1) F.** An examination of (1) theoretical framework for roles and functions of secondary school counselors, (2) primary and

secondary prevention strategies and (3) evaluation and administration procedures, to develop and implement model programs for secondary schools. A major focus on career and classroom developmental guidance as opposed to remediation and treatment.

**ECD 534 GUIDANCE AND COUNSELING IN ELEMENTARY AND MIDDLE SCHOOLS. Preq.: Grad. standing. 4(3-1) F.** An examination of (1) theoretical framework for roles and functions of elementary and middle school counselors, (2) primary and secondary prevention strategies and (3) evaluation and administration procedures to develop and implement model programs for elementary and middle schools. A major focus on classroom developmental guidance as opposed to remediation and treatment.

**ECD 535 STUDENT DEVELOPMENT IN HIGHER EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F.** Introduction to student development theory, research and practice as well as an overview of the profession. Emphasis on the three main professional roles of counselor, administrator and student development educator. Education about many different groups of college students and the provision of services by the various functions in student affairs.

**ECD 536 COMMUNITY SERVICE AGENCIES. Preq.: Six hrs. of ED, PSY or SOC or CI. 3(3-0). F.** An introduction to the issues, functions and scope of the work being done in various human service agency programs; an overview of helping approaches with selected client populations; related professional concerns examined.

**ECD 540 GENDER ISSUES IN COUNSELING. Preq.: Grad. standing or 6 hrs. of educ. or psy. 3(3-0) S.** Exploration of gender a primary identity and social construct. Emphasis on gender dynamics in counseling, client empowerment and preventive approaches.

**ECD 560 RESEARCH AND ASSESSMENT IN COUNSELING. Preq.: Grad. standing. 3(3-0) F,S.** Research and assessment issues in counseling. Emphasis on writing research proposals in counseling and critiquing articles in counseling research. Exploration of meaning and importance of assessment in counseling. Examination of research designs in counseling.

**ECD 590 SPECIAL PROBLEMS IN GUIDANCE. Preqs.: Six hrs. grad. work in dept. or equivalent and CI. Maximum 6 F,S.** For individual or group studies of one or more of the major problems in guidance and personnel work. Problems selected to meet the interests of individuals. The workshop procedure used whereby special projects, reports and research developed by individuals and by groups.

**ECD 599 Research Projects in Counselor Education. Preqs.: CI; ELP 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. The research chosen on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**ECD 621 INTERNSHIP IN COUNSELOR EDUCATION. Preqs.: Nine hrs. in grad. level courses and CI. 3-9 F,S,Sum.** Utilizing the participant-observer role, participation required in selected educational situations with emphasis upon development of observational skills, ability to record relevant observations by means of written journals, skills in analyzing experiences identifying critical incidents and projection of events and consequences. The student required to develop possible alternative courses of action in various situations, select one of the alternatives and evaluate the consequences of the course of action selected.

**ECD 625 CROSS CULTURAL COUNSELING. Preqs.: ECD 530; 9 sem. hrs. grad.-level educ. 3(3-0) S.** Theory and practice of counseling culturally different clients. Client populations include African-Americans, Asian-Americans, American Indians and Hispanics. Topics include cultural assumptions, cultural values, counselor credibility, prejudice and racism in the context of counseling.

**ECD 631 CAREER DEVELOPMENT THEORY AND RESEARCH. Preq.: ECD 524, ELP 532 and PSY 535. 3(3-0) F,S.** Analysis of theory and research in career development and work adjustment as a basis for intervention (career counseling, curricular, organizational) as research.

**ECD 636 OBSERVATION AND SUPERVISED FIELD WORK. Preq.: CI. Max. 3 F,S.** Opportunity for observation and practice of guidance and personnel services in schools, institutions of higher education, agencies, business and industry.

**ECD 637 SEMINAR IN COGNITIVE-DEVELOPMENTAL THEORY AND PRACTICE. Preqs.: Advanced grad. standing and CI. 3(3-0) F. Alt. yrs.** Analysis of major contemporary theories of cognitive development (Erikson, Kohlberg, Loevinger, Hunt, Perry) as a basis for deliberate counseling and curricular interventions.

**ECD 638 SEMINAR IN COGNITIVE-DEVELOPMENT RESEARCH. Preqs.: ECD 637; CI. 3(3-0) S. Alt. yrs.** A review of current systems of cognitive-developmental assessment; methods for measuring psychological growth included. Specific research design models reviewed as a basis for action-research.

**ECD 639 GROUP COUNSELING. Preqs.: ECD 530 and one of the following: ECD 520, 534, 535 or 536. 3(3-0) F,Sum.** Theory and practice of group counseling. Theoretical positions include client-centered, behavioral and rational-emotive. Aspects of group process include group leadership, group membership, establishing a group and maintaining a group.

**ECD 640 PREPRACTICUM IN COUNSELING. Preqs.: ECD 524, ECD 530, PSY 535; Coreq.: ECD 639. 3(2-3) F.** Preparation of students in usage of effective counseling skills in school, agency and student development settings. Counseling of a small number of clients in the counseling laboratory by trainees and participation in small group and individual supervision, in addition to class attendance.

**ECD 641 PRACTICUM IN COUNSELING. Preqs.: ECD 640 and CI. 5(2-10) S.** Student participation in individual and group counseling experiences under supervision in a school, college or agency setting.

**ECD 643 THE AMERICAN COLLEGE STUDENT. Preq.: ECD 535 or doctoral standing. 3(3-0) S. Alt. yrs.** An advanced-level course designed for investigation of the five main families of theories of college student development as presented by Chickering, Perry, R. Heath, Myers-Briggs, Holland and D. Heath. Assessment and research in student development considered, and students design and implement a developmental intervention based on Knefelkamp and Wells' Practice-to-Theory-to-Practice model.

**ECD 666 SUPERVISION OF COUNSELING. Preq.: CI. 3(1-8) F,S.** A supervised practicum for doctoral students in assisting with the supervision of first-year students in laboratory and practicum experiences in individual or group counseling.

**ECD 686 PROFESSIONAL ISSUES IN COUNSELING. Preq.: Doctoral standing. 1-3 F,S. Alt. yrs.** Consideration of contemporary issues, trends and recent research in the field of counseling.

**ECD 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of educ.; CI. Credits Arranged. F,S,Sum.** Individual research on a thesis or dissertation problem.

# Crop Science

**Degrees Conferred: Ph.D, M.S., Master of Agriculture**

**GRADUATE FACULTY**

*Professor* D. A. Knauft, ***Head of the Department***

*Associate Professor* R. C. Rufty, ***Interim Director of Graduate Programs***
Box 7620, (919) 515-3666

***Distinguished University Professor and William Neal Reynolds Professor:*** M. M. Goodman
***Philip Morris Professors:*** W. K. Collins, G. F. Peedin
***William Neal Reynolds Professor:*** E. A. Wernsman

***Professors:*** J. R. Anderson Jr., D. T. Bowman, B. E. Caldwell, H. D. Coble, F. T. Corbin, E. J. Dunphy, W. T. Fike Jr., J. T. Green Jr., R. E. Jarrett, W. M. Lewis, H. M. Linker, R. C. Long, J. P. Mueller, J. P. Murphy, R. P. Patterson, C. H. Peacock, H. T. Stalker Jr., G. A. Sullivan, J. B. Weber, W. W. Weeks, J. C. Wynne, A. C. York, C. T. Young;
***Professors (USDA):*** J. C. Burns, J. W. Burton, T. E. Carter Jr., S. C. Huber, J. E. Miller, D. E. Moreland, H. Seltmann, C. W. Stuber, R. F. Wilson;
***Adjunct Professor:*** D. T. Patterson;
***Professors Emeriti:*** C. T. Blake, C. A. Brim, D. S. Chamblee, J. F. Chaplin, W. A. Cope, D. A. Emery, D. U. Gerstel, W. B. Gilbert, W. C. Gregory, H. D. Gross, G. R. Gwynn, P. H. Harvey, G. L. Jones, J. A. Lee, R. P. Moore, L. L. Phillips, T. J. Sheets, D. L. Timothy, A. D. Worsham;
***Associate Professors:*** A. H. Bruneau, D. A. Danehower, K. L. Edmisten, J. M. Ferguson, T. G. Isleib, S.H. Kay, R. D. Keys, W. D. Smith, A. K. Weissinger, R. Wells, G. G. Wilkerson;
***Associate Professors (USDA):*** K. O. Burkey, E. L. Fiscus, D. S. Fisher, P. Kwanyuen, S. M. Reed, T. W. Rufty Jr., S. M. Schneider, V. A. Sisson;
***Adjunct Associate Professor:*** P. S. Zorner;
***Assistant Professors:*** R. E. Dewey, G. P. Fenner;
***Assistant Professors (USDA):*** M. G. Redinbaugh, P. H. Sisco Jr.;
***Visiting Assistant Professor:*** F. H. Yelverton

Areas of specialization include plant breeding, crop production and physiology, forage crops ecology, turfgrass science, weed control and plant chemistry.

Excellent facilities for graduate training are available. Many special facilities such as preparation rooms for plant and soil samples, cold storage facilities for plant material, greenhouse space, growth control chambers, computer local area network, and access to the plant environment laboratory (Phytotron) are provided if required.

Research farms located throughout North Carolina include a variety of soil and climatic conditions needed for experiments in plant breeding, crop management, forage ecology, turfgrass management and physiology, and weed control.

Strong supporting departments increase opportunities for broad and thorough training. Graduate students in crop science work cooperatively with or obtain instruction in the Departments of Biochemistry, Botany, Chemistry, Computer Science, Entomology, Horticultural Science, Genetics, Mathematics, Microbiology, Plant Pathology, Soil Science and Statistics.

### Admissions Requirements

To be admitted, a student should be a graduate of an accredited major in agronomy, biology, crop science, genetics, horticulture, plant science or related field of study. Graduates of other programs may be admitted but will be required to make up certain undergraduate deficiencies without graduate credit. Acceptance of applicants is competitive and limited by program space for new students. Exceptions to the 3.0 GPA may be made for students with special backgrounds, abilities or interests.

### Master's Degree Requirements

One hour of Crop Science Seminar (CS 690) and a minimum of 6 credit hours at the 600 level is required for M.S. candidates. A minimum of 4 hours of special problems (CS 591) is required for the M.Ag. degree. An exit seminar presentation to the department is required.

### Doctoral Degree Requirements

Course requirements for students are determined through the graduate advisory committee process. Core courses have been identified for students studying physiology, management, production, weed science and plant growth regulation. An exit seminar presentation to the department is required.

### Student Financial Support

Graduate assistantships and fellowships can be awarded to qualified applicants depending on funding availability and program space. Nonresident tuition may be waived for students granted assistantships.

### Other Relevant Information

A thesis (M.S. and Ph.D.) or special problems (M.Ag.) outline and graduate plan of work should be submitted to the Director of Graduate Programs by the end of the first regular (spring or fall) semester.

## SELECTED ADVANCED UNDERGRADUATE COURSES

CS 400 TURF CULTURAL SYSTEMS.
CS 411 ENVIRONMENTAL ASPECTS OF CROP PRODUCTION.
CS 413 PLANT BREEDING.
CS 414 WEED SCIENCE.
CS 415 AGRONOMIC PEST MANAGEMENT SYSTEM.
CS(SSC) 462 SOIL-CROP MANAGEMENT SYSTEMS.

CS(SSC) 490 SENIOR SEMINAR IN AGRONOMY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**CS 511 TOBACCO TECHNOLOGY. Preq.: BO 421 or equivalent. 3(3-0) S.** A study of special problems concerned with the tobacco crop. The latest research problems and findings dealing with this important cash crop.

**CS 513 PHYSIOLOGICAL ASPECTS OF CROP PRODUCTION. Preq.: BO 421. 3(3-0) S. Alt. yrs.** Emphasis upon pertinent physiological processes associated with crops and crop management such as plant growth, maturation, respiration and photoperiodism. Relationship of the environment to maximum crop yields.

**CS(HS) 515 WEED SCIENCE RESEARCH TECHNIQUES. Preq.: CS 414 or equivalent. 1(0-2) F.** Bioassay techniques for detection of herbicide residues in soils, chemical analytical (GLC, HPLC) techniques for identifying herbicide residues in soils and plants, procedures for studying adsorption and leaching in soils, procedures for measuring herbicide interference of photosynthesis and use of $^{14}C$-labeled herbicides for following uptake, transport and metabolism of herbicides in plants.

**CS(HS) 516 WEED BIOLOGY. Preq.: CS 414. 1(1-0) F.** Weed seed development and dispersal, seed domancy, oil seed bank, seedling development, growth analysis, reproduction, community structure, population dynamics, species interactions, environmental effects on interactions and influence of man. Taught first 5 weeks of semester. Drop date is last day of the 3rd week of the minicourse.

**CS(HS) 517 WEED MANAGEMENT SYSTEMS. Preq.: CS 414 or equivalent. 1(1-0) F.** Weed management systems including integration of cultural, biological, mechanical and chemical methods for vegetables, fruits, ornamentals, turf, small grains, corn, tobacco, cotton, peanuts, aquatic and non-cropland settings. Taught second 5 weeks of semester. Drop date is last day of the 3rd week of minicourse.

**CS(HS) 518 BIOLOGICAL CONTROL OF WEEDS. Preq.: CS 414 or equivalent. 1(1-0) F.** Concepts and methods in the use of biological agents for control of weeds. Primary emphasis on weed bio-control with insects and plant pathogens. Taught third 5 weeks of semester. Drop date is last day of the 3rd week of minicourse.

**CS(GN,HS) 541 PLANT BREEDING METHODS. Preqs.: GN 506, ST 511. 3(3-0) F.** Advanced study of methods of plant breeding as related to principles and concepts of inheritance.

**CS(GN) 574 ORIGIN AND EVOLUTION OF CULTIVATED PLANTS. Preqs.: GN 505 or GN (ZO) 540. 3(3-0) S. Alt. Yrs.** Review of progression to modern evolutionary thought; concepts of speciation and classification; origin of variation in plants; theories relating to origins of cultivation and spread of agriculture variation patterns and special attributes of cultigens; interactions of crops and environments; evolution under domestication; modern aspects of evolution as related to breeding.

**CS 591 SPECIAL PROBLEMS. Credits Arranged. F,S,Sum.** Special problems in various phases of crop science. Problems may be selected or will be assigned. Emphasis on review of recent and current research.

*FOR GRADUATES ONLY* (Students are expected to consult with instructor before registration.)

**CS(GN,HS) 615 QUANTITATIVE GENETICS IN PLANT BREEDING. Preqs.: CS(GN, HS) 541, ST 512, course in quantitative genetics recommended. 1(1-0) S. Alt. yrs.** Theory and principles of plant quantitative genetics. Experimental approaches of relationships between type and source of genetic variability, concepts of inbreeding, estimations of genetic variance and selection theory.

**CS(GN,HS) 616 BREEDING METHODS. Preqs.: CS (GN, HS) 541, ST 512. 2(2-0) S. Alt. yrs.** Theory and principles of plant breeding methodology including population improvement, selection procedures, genotypic evaluation, cultivar development and breeding strategies.

**CS(GN,HS) 617 NONCONVENTIONAL PLANT BREEDING. Preq.: CS(GN, HS) 541. 1(1-0) F. Alt. yrs.** Theory and principles of molecular and nonconventional plant breeding. Experimental approaches to induce genetic change, cytoplasmic recombination, haploid utilization and potentials of molecular techniques for solving breeding problems.

**CS(GN,HS,PP) 618 BREEDING FOR PEST RESISTANCE. Preqs.: CS(GN, HS) 541, PP 315, ST 512. 2(2-0) F. Alt. yrs.** Theory and principles of breeding for pest resistance. Experimental approaches for examining genetics of host-parasite interactions, expression and stability of pest resistance and breeding strategies for developing pest-resistant cultivars.

**CS(HS,SSC) 625 HERBICIDE CHEMISTRY. Preqs.: CH 107, CH 221. 1(3-0) S.** Chemical properties of herbicides including hydration and solvation, ionization, volatilization, lipophilicity, and reactivity and classification according to chemical description, mode of action or ionizability. Taught during first 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**CS(HS) 626 HERBICIDE BEHAVIOR IN PLANTS. Preqs.: BO 551 and BO 552 and CS(HS,SSC) 625. 1(3-0) S.** Chemical, physiological and biochemical actions of herbicides in plants including uptake, translocation, metabolism and mechanism of action. Taught second 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**CS(HS,SSC) 627 HERBICIDE BEHAVIOR IN SOIL AND WATER. Preqs.: CS(HS,SSC) 625, SSC 200. 2(6-0) S.** Absorption/desorption reactions, volatilization, movement and degradation of herbicides in soil, water and air. Taught during third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**CS 690 SEMINAR. 1(1-0) F,S.** A maximum of two credits allowed toward the master's degree; however, additional credits toward the doctorate allowed. Review and discussion of scientific articles, progress reports in research and special problems of interest to agronomists.

**CS 699 RESEARCH. Credits Arranged.** A maximum of six credits allowed toward the master's degree, but no restrictions toward the doctorate.

# Curriculum and Instruction

**Degrees Offered: Ed.D., M.S., M.Ed.**

GRADUATE FACULTY

*Professor* C. L. Crossland, ***Head of the Department***
*Professor* B. J. Fox, ***Director of Graduate Programs***
Box 7801, (919) 515-3221, fox@poe.coe.ncsu.edu

*Professors:* D. A. Cullinan, P. H. Martorella, B. M. Parramore, B. R. Poulton;
*Adjunct Professors:* D. D. Copeland, M. F. Durfee, R. A. Edelfelt;
*Associate Professors:* J. F. Arnold, C. W. Harper Jr., S. S. Osborne, C. A. Pope, R. J. Pritchard, E. J. Sabornie, H. A. Spires, L. Thies-Sprinthall, E. S. Vasu;
*Adjunct Associate Professor:* H. A. Fingeret;
*Assistant Professors:* P. L. Marshall;
*Clinical Assistant Professor:* A. J. Reiman;
*Adjunct Assistant Professor:* S. B. Buckner

**Admission Requirements**
A 500-800 word statement describing professional goals. Some areas of study require that applicants be qualified to hold a baccalaureate-level teaching certificate or have teaching experience.

**Master's Degree Requirements**
A minimum of 36 course credit hours, a written examination and a final oral examination are required. The Master of Science degree requires a thesis approved by the graduate committee.

**Doctoral Degree Requirements**
A minimum of 60 course credit hours which includes 15-18 hours of research and a curriculum specialty. Additionally, 12 hours of dissertation credit, a dissertation, preliminary written and oral examinations, and a final oral examination are required. Students must adhere to the Graduate School residency requirements.

**Student Financial Support**
No financial aid is available on a regular basis.

**Other Relevant Information**
The department offers master's degrees in curriculum and instruction with areas of concentration in elementary education, English education, reading, instructional technology-computers, social studies, and supervision. Master's degrees in special education are offered in the areas of behavior disorders, learning disabilities and mental retardation. A master's degree in middle grades education includes a dual concentration in language arts and social studies.

## *SELECTED ADVANCED UNDERGRADUATE COURSE*

**ECI 483 AN INTRODUCTION TO INSTRUCTIONAL MEDIA.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ECI 501 COMPUTER APPLICATIONS IN INSTRUCTION. Preq.: Six hrs. educ. or psy. or CI. 3(3-0) F,S.** Emphasis on the use and evaluation of existing educational software and research findings with respect to the uses of computers in instruction.

**ECI 502 THE SCHOOL CURRICULUM. Preq.: 12 sem. hrs. educ. or psy. or CI. 3(3-0) F,S.** The origin, development, and current status of the elementary and secondary school curriculum and an evaluation of the trends and issues likely to influence the curriculum in the future.

**ECI 504 SOCIAL STUDIES IN THE ELEMENTARY SCHOOL. Preq.: Six hrs. in ECI. 3(3-0) S.** Advanced professional training in the teaching of social studies for middle grades and elementary teachers, including in-depth introduction to research-based teaching strategies, instructional resources and literature of the field.

**ECI 506 EDUCATION OF EXCEPTIONAL CHILDREN. Preq.: 9 hrs. of educ. or psy. 3(3-0) F,S.** Introduction to the field of special education. Focus on the historical overview, definitions and terminology in the basic areas of exceptionality; etiological factors in exceptionality; developmental and learning characteristics of each area of exceptionality; and educational settings and strategies employed in special education. A review of current educational laws and policies affecting special education.

**ECI 507 FOUNDATIONS OF MIDDLE YEARS EDUCATION. Preq.: 6 hrs. of educ. or psy. 3(3-0) F,S.** Examination of five major aspects of middle years education: (a) the history and purposes of middle/junior high school, (b) pre- and early adolescent needs, interests and abilities, (c) curriculum design and content, (d) teaching methods and (e) school organization. Emphasis on both theoretical understandings and effective classroom strategies.

**ECI 508 EDUCATION OF SEVERELY HANDICAPPED. Preq.: ECI 531 or ECI 574 or CI. 3(3-0).** Study of severe and profound mental retardation and autism, including assessment procedures, educational and social/vocational programs, instructional strategies and evaluation. Examination of legal and ethical issues involved in working with the severely handicapped.

**ECI 509 METHODS AND MATERIALS–TEACHING RETARDED CHILDREN. Preqs.: ECI 506 and ECI 531 or CI. 3(3-0) S.** Methods and materials related to teaching mentally retarded school-age children. The learning and behavioral characteristics and educational programs for the mentally retarded in the areas of motor, communications, social, academic and vocational development.

**ECI 519 EARLY CHILDHOOD EDUCATION. Preq.: PSY 475 or PSY 576. 3(1-4) S.** Planning, selection and usage of human resources, activities, materials and facilities in the education of young children. Student observation, participation and evaluation of educational experiences for the developmental level of individual children for an optimum learning environment. A synthesis of the student's knowledge of human development, learning theory and research findings as related to classroom application.

**ECI 524 TEACHERS AND THE ELEMENTARY SCHOOL CURRICULUM. Preq.: Grad. standing. 3(3-0) F.** Exploration and analysis of issues surrounding the teacher's role in development, implementation and evaluation of elementary school curricula designed to meet schooling needs of diverse student populations.

**ECI 525 THEORY AND PRACTICE IN TEACHING DIVERSE POPULATIONS. Preq.: Grad. standing. 3(3-0) S.** Analysis of literature and research in relation to the impact of cultural factors on teaching and learning in contemporary

schools. Exploration of teaching techniques and curricular directions designed to improve school experiences for diverse populations in K-12 settings.

**ECI 531 MENTAL RETARDATION. Preq.: ECI 506 or CI. 3(3-0) F.** The definitions, classifications, diagnostic and treatment procedures for mental retardation from medical, sociological and educational points of view. Categories of retardation include mild, moderate, severe and profound.

**ECI 542 CONTEMPORARY APPROACHES IN THE TEACHING OF SOCIAL STUDIES. Preqs.: Advanced undergrad. or grad. standing. 3(3-0) S.** An analysis of the principles, strategies and application of new teaching approaches. Structured projects and practical experiences.

**ECI 544 THE TEACHING OF COMPOSITION. Preq.: 9 hrs. of educ., psy. and/or Eng.; to take this course in sum. as part of Capital Area Writing Project, student must apply and be selected. 3(3-0) S,Sum.** For classroom teachers. Practical field-tested ideas to help students improve as writers by focusing on composition as a process as well as a product. Activities for teaching prewriting, drafting, revising, proofreading, grammar and evaluating with suggestions for individual and group learning. Writing in the content areas and composition research/ theory.

**ECI 545 READING IN THE ELEMENTARY SCHOOL. Preqs.: Six hrs. educ. or psy. 3(3-0) F.** Theoretical foundations of reading instruction and current methods and materials for teaching reading, with an emphasis on planning and implementing reading programs for children in kindergarten through grade six.

**ECI 546 READING IN THE CONTENT AREAS. Preqs.: Six hrs. in educ. or psy. 3(3-0) S,Sum.** Methods in instruction for applying reading to content areas,

with emphasis on means of improving comprehension, vocabulary and learning strategies in subject matter classrooms.

**ECI 547 LANGUAGE ARTS IN THE ELEMENTARY SCHOOL. Preq.: Six hrs.in educ. 3(3-0) S. Alt. yrs.** Advanced professional training in the teaching of language arts for middle grades and elementary teachers, including an in-depth introduction to research-based teaching strategies, new instructional resources and the literature on the field.

**ECI 548 DEVELOPMENT OF MICROCOMPUTER SOFTWARE FOR INSTRUCTION. Preq.: Six hrs. educ. or psy. or CI. 3(3-1) F.** The instructional design principles underlying the development of microcomputer-based instructional software and accompanying materials and programming principles and their

implementation in courseware development. Additional topics include authoring languages, programming languages and graphics.

**ECI 551 PRINCIPLES AND PRACTICES OF SUPERVISION. Preqs.: 6 hrs. educ./psy. graduate study and CI. 3(3-0) S.** Designed to provide the educational leader with an understanding of the nature of instructional supervision, skills needed in supervising educational programs and an analysis of promising practices for improving programs. Opportunity for application of principles of supervision to one or more practical problems.

**ECI 556 LEARNING DISABILITIES. Preq.: ECI 506 or CI. 3(3-0) F.** The field of learning disabilities, including definitions, prevalence, etiology, characteristics and current educational trends for educating students with learning disabilities.

**ECI 557 METHODS AND MATERIALS IN LEARNING DISABILITIES. Preq.: ECI 556 or CI. 3(3-0) S.** The current methods and materials for the teaching students with learning disabilities in the elementary and/or secondary schools, including curriculum and instructional techniques. Focus on examination of commercial materials and the development of teacher-made materials for use with studnts with learning disabilities.

**ECI 558 RESOURCE TEACHING IN SPECIAL EDUCATION. Preq.: ECI 506 or CI. 3(3-0) S.** A study of resource teaching in the area of special education, with emphasis on resource teaching with students with special needs. Types of resource programs, establishment and maintainance of a program, selection of students, curriculum and materials.

**ECI 561 EDUCATIONAL DIAGNOSIS AND PRESCRIPTION FOR CHILDREN WITH EXCEPTIONALITIES. Preq.: ECI 506 or CI. 3(3-0) F.** The concept of educational diagnosis of students with exceptionalities, including an examination of educational diagnostic procedures in current use in special education. The development of informal diagnostic techniques and procedures for adapting curriculum and instruction for the learner with exceptionalities.

**ECI 562 COMMUNICATION DISORDERS IN THE CLASSROOM. Preq.: ECI 506 or CI. 3(3-0) Alt. yrs.** Occurrence of communication disorders in the school-age population, including types of disorders, prevalence, etiology, characteristics and corrective therapy. Focus on communication disorders among exceptional students and the classroom teacher's role in working with communication disorders.

**ECI 564 CLASSROOM MANAGEMENT IN SPECIAL EDUCATION. Preq.: ECI 506 or CI. 3(3-0) F.** The concepts and procedures involved in the design and implementation of techniques for managing students with disabilities in a classroom setting. Focus on methods for increasing and maintaining appropriate classroom behaviors in learners with disabilities.

**ECI 571 INTRODUCTION TO THE GIFTED INDIVIDUAL. Preq.: ECI 506 or CI. 3(3-0) Sum.** Theories and concepts of giftedness and procedures in identifying the gifted, with a consideration of factors influencing giftedness and ways it may be fostered.

**ECI 572 METHODS FOR TEACHING THE GIFTED. Preq.: ECI 571 or CI. 3(3-0) Sum.** Major approaches used in the education of the gifted, including an opportunity to develop a unit plan based upon one of these approaches.

**ECI 573 BEHAVIOR DISORDERS. Preq.: ECI 506 or CI. 3(3-0) F.** Definitions, etiology, characteristics, philosophies and approaches to educational programming for children and youth with behavior disorders, including the emotionally handicapped, autistic and socially maladjusted.

**ECI 574 METHODS AND MATERIALS: BEHAVIOR DISORDERS. Preq.: ECI 573 or CI. 3(3-0) S.** Curriculum materials, instructional strategies and behavior management techniques related to teaching children and youth with behavioral disorders including individualized instruction, group process, organization and evaluation of classroom programs, parent involvement, community resources and teachers' personal and professional growth and development.

**ECI 576 TEACHING/LEARNING APPROACHES FOR EMERGING ADOLESCENTS. Preqs.: ECI 507 or equivalent; grad standing and CI. 3(3-0) S.** Exploration of teaching/learning approaches appropriate to emerging adolescents. Learning styles; interdisciplinary inquiry; community-based curriculum; simulations and games; learning centers; mini-courses; design of physical space; all-school activities.

**ECI 583 DESIGN AND EVALUATION OF INSTRUCTIONAL MATERIALS. Preq.: Grad. standing. 3(3-0) S.** Emphasis upon the characteristics and selection of various media for instruction and their use in educational settings. Design and production of instructional materials. Analysis of the research in the field. Individualized projects and assignments. Application of grounded research and theory concerning learning to the design of instructional materials. Structured projects and practical experiences used to transfer design principles and evaluate instructional products.

**ECI 591 TEACHING LITERATURE FOR YOUNG ADULTS. Preq.: Sr. or grad. standing or PBS status. 3(3-0) S.** Designed to acquaint in-service and pre-service teachers with the breadth and diversity of contemporary literature for adolescents, with an emphasis on teaching young adult literature. Addresses the history and themes of young adult literature, readability of materials, reading preferences, literary merit, skills that can be taught through literature, censorship, motivating students to read and organizing literature units.

**ECI 598 SPECIAL PROBLEMS IN CURRICULUM AND INSTRUCTION. Preqs.: Six hrs. of educ. or psy. and CI. 1-6 F,S,Sum.** An in-depth study of topical problems in curriculum and instruction selected from the areas of current concern to practitioners in education.

**ECI 599 RESEARCH PROJECTS IN CURRICULUM AND INSTRUCTION. Preqs.: CI; ELP 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. The research chosen on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**ECI 602 CURRICULUM THEORY AND DEVELOPMENT. Preqs.: 9 sem. hrs. graduate PSY, ECI 502, ELP 514 or CI. 3(3-0) F.** Theory and research in the behavioral sciences and education designed to provide the theoretical background for the development of elementary and secondary curricula. Exploration of the knowledge base and skills for critical review of curricula and instructional materials and provison of an application opportunity.

**ECI 606 REMEDIATION OF READING DISABILITIES. Preq.: ECI 634 or CI. 3(3-0) S.** Advanced approaches to reading remediation including theory and research related to remedial instructional strategies, analyses of instructional designs and evaluations of the effectiveness of intervention programs.

**ECI 614 LITERACY INSTRUCTION FOR COLLEGE STUDENTS: RESEARCH, THEORY AND PRACTICE. Preq.: ECI 546. 3(3-0) F.** Examination of research, theory and classroom practices in relation to literacy instruction for academically at-risk students at the postsecondary level.

**ECI 620 INTERNSHIP IN CURRICULUM AND INSTRUCTION. Preq.: Grad. standing in Col. of Ed. and Psy. and CI. 1-6 F,S.** Supervised opportunities for advanced professional development in contexts concerned with curriculum development and/or educational supervision.

**ECI 621 INTERNSHIP IN READING EDUCATION. Preqs.: 9 hrs. in reading course work; grad. standing in Col. of Ed. and Psy. and CI. 1-6 F,S.** Supervised opportunities for advanced professional development in contexts concerned with literacy education.

**ECI 622 INTERNSHIP IN SPECIAL EDUCATION. Preq.: Grad. standing in Col. of Ed. and Psy. and CI. 1-6 F,S,Sum.** Supervised opportunities for advanced professional development in contexts concerned with special education.

**ECI 623 INTERNSHIP IN ELEMENTARY EDUCATION. Preq.: 3 hrs. grad.-level elementary education course work; grad. standing in Col. of Ed. and Psy. and CI. 1-6 S Alt. yrs.** Supervised opportunities for advanced professional development in contexts concerned with elementary grades education.

**ECI 624 INTERNSHIP IN MIDDLE GRADES EDUCATION. Preqs.: ECI 507, ECI 576; grad. standing in Col. of Ed. and Psy. or CI. 1-6 F,S,Sum.** Supervised opportunities for advanced professional development in contexts concerned with the education of young adolescents.

**ECI 625 INTERNSHIP IN INSTRUCTIONAL TECHNOLOGY - COMPUTERS. Preq.: Grad. standing in Col. of Ed. and Psy. and CI. 1-6 F. Alt. yrs.** Supervised opportunities for advanced professional development in contexts concerned with instructional technology.

**ECI 626 INTERNSHIP IN SOCIAL STUDIES. Preq.: 9 hrs. in C&I; grad. standing in Col. of Ed. and Psy. or CI. 1-6 Sum.** Supervised opportunities for advanced professional development in contexts concerned with social studies education.

**ECI 627 INTERNSHIP IN MENTORING. Preq.: ECI 641 and ECI 665; grad. standing in Col. of Ed. and Psy. or CI. 1-6 F,S.** Supervised opportunities teaching educational personnel in local school systems how to serve as mentors to their colleagues.

**ECI 634 DIAGNOSIS OF READING DISABILITIES. Preq.: ECI 545 or ECI 546, 3(3-0) F.** Formal and informal instruments for diagnosing reading disabilities including the completion of a diagnostic case study describing the reading performance of a disabled reader.

**ECI 640 PRACTICUM IN CURRICULUM AND INSTRUCTION. Preq.: Grad. standing in Col. of Ed. and Psy. or CI. 1-6 F,S.** Supervised practical experiences in schools and area agencies concerned with curriculum and instruction or educational supervision.

**ECI 641 DIAGNOSTIC-PRESCRIPTIVE PRACTICUM IN READING. Preqs.: ECI 545, ECI 546 and ECI 534; grad standing in Col. Ed. and Psy. and CI. 3(3-0) F,S.** Supervised teaching experience with students using diagnostic test date to prescribe remedial programs for reading-disabled individuals, implementing instructional prescriptions and evaluating the success of remedial plans.

**ECI 642 PRACTICUM IN SPECIAL EDUCATION. Preq.: Grad. standing in Col. of Ed. and Psy. or CI. 1-6 F,S,Sum.** Supervised practical experiences in schools and area agencies concerned with teaching children and adolescents with disabilities.

**ECI 643 PRACTICUM IN ELEMENTARY EDUCATION. Preq.: Grad. standing in Col. of Ed. and Psy. or CI. 1-6 F.** Supervised practical experiences in schools and area agencies concerned with education of elementary-age students.

**ECI 644 PRACTICUM IN MIDDLE GRADES EDUCATION. Preqs.: ECI 507, ECI 576; grad. standing in Col. of Ed. and Psy. or CI. 1-6 F,S,Sum.** Supervised practical experiences in schools and area agencies concerned with the education of middle school students in language arts and social studies.

**ECI 645 PRACTICUM IN INSTRUCTIONAL TECHNOLOGY - COMPUTERS. Preqs.: 12 hrs. in instructional technology; grad. standing in Col. of Ed. and Psy. or CI. 1-6 F. Alt. yrs.** Supervised practical experiences in schools and area agencies concerned with using instructional technology.

**ECI 646 PRACTICUM IN SOCIAL STUDIES. Preqs.: 9 hrs. in C&I; grad. standing in Col. of Ed. and Psy. or CI. 1-6 S. Alt. yrs.** Supervised practical experiences in schools and area agencies concerned with teaching of high school social studies.

**ECI 647 PRACTICUM IN MENTORING OF TEACHERS. Preqs.: ECI 665; grad. standing in Col. of Ed. and Psy. or CI. 1-6 F.** Supervised practical experiences in which participants become mentor to student teacher or teacher in school system.

**ECI 648 THEORY AND PROCESS IN READING AND LANGUAGE ARTS. Preqs.: ECI 545 and CI. 3(3-0) S.** Advanced study of theoretical models of reading, research issues in reading and in other language processes. In-depth theoretical models of reading. Critical examination and analysis of research investigating reading acquisition, mature reading behavior and related language processes.

**ECI 652 RESEARCH APPLICATIONS IN CURRICULUM AND INSTRUCTION. Preqs.: ST 507 or equivalent; doctoral students in C&I. 3(3-0)**

S. Focus on current issues and research methods used in the areas of curriculum development and supervision, instructional technology, English education, middle grades education, reading education, social studies education and special education.

**ECI 653 EFFECTIVE TEACHING. Preq.: Twelve hrs. educ. including student teaching. 3(3-0) F.** Analysis of the teaching-learning process; assumptions that underlie course approaches; identifying problems of importance; problem solution for effective learning; evaluation of teaching and learning; making specific plans for effective teaching.

**ECI 657 THEORY AND RESEARCH ON TEACHING AND LEARNING SOCIAL STUDIES. Preqs.: ECI 504 or ECI 542 or CI. 3(3-0) F. Alt. yrs.** A critical analysis of the literature relating to the teaching and learning of social studies and the drawing of implications for instructional practices.

**ECI 665 INSTRUCTIONAL SUPERVISION OF TEACHERS. Preq.: CI. 3(3-0) F,S.** Theory, research and practice of the professional role of a supervisor in the development of the effective and self-analytic teacher: pre-service (student teacher) and in-service (beginning and experienced teacher). For persons with at least two years of teaching experience in K-12 schools.

**ECI 687 SEMINAR IN CURRICULUM AND INSTRUCTION. Preq.: Doctoral standing. 1-3 S.** Consideration of contemporary issues, trends and recent research and development findings in curriculum and instruction.

**ECI 690 ADVANCED SEMINAR IN READING. Preq.: ECI 648. 3(3-0) S.** Critical analyses of research and methodology in reading comprehension processes and strategies for comprehension and retention of written discourse. Opportunity for design and conduct of a research project in reading or related area.

**ECI 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of ED; CI. Credits Arranged. F,S,Sum.** Individual research on thesis/dissertation problem.

# Ecology

**Degree Offered: M. S.**

**GRADUATE FACULTY**

*Professor* L. B. Crowder, *Director of Graduate Programs*
Box 7626, (919) 515-3804, larry_crowder@ncsu.edu

*Professors:* H. L. Allen Jr., R. C. Axtell, U. Blum, J. R. Bradley Jr., C. Brownie, A. W. Cooper, D. J. DeMaster, J. M. Dipaola, P.D. Doerr, E. C. Franklin, D. J. Frederick, F. L. Gould, L. F. Grand, F. P. Hain, D. Kamykowski, R. C. Kellison, G. G. Kennedy, R. A. Lancia, J. R. Meyer, J. M. Miller, R. L. Noble, C. H. Peacock, K. H. Pollock, V. K. Saxena, E. D. Seneca, R. E. Stinner, J. R. Walters, T. R. Wentworth, T. G. Wolcott, A. G. Wollum II;
*Professor (USDA):* J. C. Burns;
*Professors Emeriti:* D. A. Adams, C. B. Davey;
*Associate Professors:* J. E. Bailey, N. E. Blair, R. R. Braham, P. T. Bromley, S. W. Broome, J. M. Burkholder, S. Businger, S. P. Ellner, M. N. Feaver, J. F. Gilliam, J. D. Gregory, J. E. Mickle, S. C. Mozley, R. A. Powell, J. A. Rice, W. J. Showers, G. G. Wilkerson, B. E. Wilson;
*Associate Professors (USDA):* M. L. Carson, D. S. Fisher, S. R. Shafer;
*Associate Professor (USDI):* W. J. Fleming;
*Visiting Associate Professor:* D. L. Wolcott;
*Assistant Professor:* G. L. Brothers;
*Assistant Professors (USDI):* J. A. Collazo, J. E. Hightower;
*Adjunct Assistant Professor:* D. M. Checkley Jr.

Ecology is the science concerned with the interactions of organisms with each other and with their environment. It is an integrative science through which one gains an understanding of biological and physical interrelationships and predicts the consequences of altering one or several components of an ecosystem.

Students in a number of basic and applied curricula may elect to major in ecology at the master's level leading to an M.S. degree or minor in ecology at the master's and Ph.D. levels. The minor provides an opportunity for a coherent picture of the field of ecology but does not usurp the normal prerogatives of graduate advisory committees in structuring graduate programs.

The ecology minor is an interdepartmental program drawing faculty from the botany, crop science, entomology, forestry, marine, earth and atmospheric sciences, parks, recreation and tourism management, plant pathology, soil science, statistics and zoology departments. The program is administered by the Ecology Advisory Committee. Additional information about the program may be obtained by writing to one of the faculty members listed above or to Chair, Ecology Faculty, Box 7617, North Carolina State University, Raleigh, North Carolina 27695-7617.

The following courses are recognized as ecological and have been grouped into certain related areas. (For course descriptions, see respective program listings.)

**Population Ecology:** ZO 621 Fishery Science; ZO (FW) 553 Principles of Wildlife Science; ZO 691 Topics in Animal Behavior; ZO 517 Population Ecology; ST (ZO) 506 Sampling Animal Populations; ST (GN) 626 Statistical Concepts in Genetics; BO 561 Physiological Ecology;

BO (ZO) 660 Advanced Topics in Ecology I; CS 411 Environmental Aspects of Crop Protection; CS (HS) 516 Weed Biology; GN 509 Genetics II; Population Genetics; GN 510 Genetics II; Quantitative Genetics; GN (ZO) 540 Evolution; GN 555 Population Genetics; ENT 531 Insect Ecology; ENT 562 Insect Pest Management in Agricultural Crops; ENT (FOR) 565 Advanced Forest Entomology; ENT (ZO) 582 Medical and Veterinary Entomology.

**Community Ecology:** ZO(MEA) 624 Ecology of Fishes; ZO 618 Community Ecoldogy; BO 590 Topical Problems; BO 544 Plant Geography; BO 565 Plant Community Ecology; MEA(ZO) 534 Marine Benthic Ecology; SSC(MB) 532 Soil Microbiology; SSC 472 Forest Soils; FOR 583 Tropical Forestry; FOR 593 Colloquium on Tropical Forestry; FOR(SSC) 673 Forest Productivity; Edaphic Relationships; CS 415 Agronomics Pest Management Systems.

**Ecosystem Ecology:** MEA(ZO) 520 Principles of Biological Oceanography; MEA 622 Marine Plankton Ecology; MEA 555 Meteorology of the Biosphere; ZO(ENT) 509 Ecolog of Stream Invertebrates; ZO 519 Limnology; MDS(FOR) 584 The Practice of Environmental Impact Assessment; BO(ZO) 560 Principles of Ecology; BMA 567 Modeling of Biological Systems; BMA (MA, OR, ST) 610 Stochastic Modeling; MDS 495 Conservation of Biological Diversity.

**Requirements for a major in Ecology are:**
**(M.S.Degree):** Two credit hours in ECO 690, sixteen credit hours selected from the Classification of Ecology Courses Chart. At least one course from each of the three levels (population, community, ecosystem) and each of the four systems (marine/fresh water, terrestrial/zoological, terrestrial/botanical, agricultural/ forestry).

**Requirements for a minor in Ecology are:**
**(M.S. Degree):** Two credit hours in ECO 690, nine credit hours from the Classification of Ecology Courses Chart. No more than one course from the chart may be from any level or system. **(Ph.D. Degree):** Two credit hours in ECO 690, nine credit hours from the Classification of Ecoloy Courses Chart. No more than one course from the chart may be from any level or system. No courses from the chart which were used to meet major or minor requirements for the M.S. degree may be used to meet Ph.D. minor requirements.

**Other Relevant Information**
Students minoring in ecology, particularly at the Ph.D. level, are encouraged to take courses in mathematics and statistics, at least ST 511 and ST 512.

***FOR GRADUATES ONLY***

**ECO 690 ECOLOGY SEMINAR. 1(1-0) F.** Scientific articles, progress reports and special problems of interest to to ecologists reviewed and discussed. Minimum of one seminar presentation required for credit.

**ECO 693 SPECIAL PROBLEMS IN ECOLOGY. 1-6 F,S,Sum.** Investigation of special problems in ecology of particular interest to advanced students under the direction of a faculty member. Directed research in some specialized phase of ecology other than a thesis problem, but designed to provide experience in training and research.

# Economics

**Degrees Offered: Ph.D., M.S., M.A., Master of Economics**

## GRADUATE FACULTY

*Professor* J. A. Brandt, ***Head of the Department of Agricultural and Resource Economics***
*Professor* R. B. Palmquist, ***Head of the Department of Economics***
*Professor* R. M. Fearn, ***Director of Graduate Programs***
Box 8109, (919) 515-7156, fearn@econbus1.econ.ncsu.edu

*Distinguished University Professor:* V. K. Smith

*Professors:* S.G. Allen, G. A. Carlson, R. L. Clark, L. E. Danielson, J. E. Easley Jr., E. W. Erickson, E. A. Estes, D. Fisher, D. J. Flath, T. J. Grennes, A. R. Hall, D. M. Hoover, D. N. Hyman, L. A. Ihnen, T. Johnson, C. R. Knoeber, S. E. Margolis, C. L. Moore Sr., E. C. Pasour Jr., D. K. Pearce, R. A. Schrimper, J. J. Seater, C. B. Turner, M. L. Walden, R. C. Wells, M. K. Wohlgenant;
*Professors Emeriti:* R. C. Brooks, A. J. Coutu, R. D. Dahle, R. A. King, H. L. Liner, P. R. Johnson, T. E. Nichols Jr., B. M. Olsen, R. J. Peeler, C. R. Pugh, J. A. Seagraves, R. L. Simmons, J. G. Sutherland, W. D. Toussaint, J. C. Williamson Jr.;
*Associate Professors:* D. S. Ball, J. C. Beghin, G. A. Benson, P. L. Fackler, W. E. Foster, B. Goodwin, A. E. Headen Jr., J. S. Lapp, M. B. McElroy, C. M. Newmark, A. Padilla, C. D. Safley, W. N. Thurman, W. J. Wessels, K. D. Zering;
*Associate Professor Emeriti:* H. C. Gilliam Jr.;
*Assistant Professors:* A. B. Brown, L. A. Craig, A. W. Oltmans, M. A. Renkow, T. C. Tsoulouhas, T. Vukina

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* D. A. Dickey, J. D. Hess, D. M. Holthausen Jr.;
*Associate Professors:* J. C. Dutton Jr., E. A. McDermed

The economics graduate program is a joint program of the Department of Agricultural and Resource Economics and the Department of Economics. Emphasis is placed on economic theory and quantitative economic analysis and their application to economic problems. The major fields of specialization are: agricultural economics, environmental-resource economics, industrial organization, international economics, labor economics and macro-monetary economics.

### Admission Requirements

Minimum background for admission includes intermediate microeconomics and macroeconomics, at least one semester of calculus (two for Ph.D.) and undergraduate statistics. Some students are admitted conditional on their taking certain prerequisites. The submission of GRE scores is strongly recommended and is required for students applying for financial aid.

### Master's Degree Requirements

The Master of Science in agricultural economics and the Master of Arts in economics require core courses in microeconomics (ECG 501), macroeconomics (ECG 502), statistics (ST 514) and applied econometrics (ECG 561). The Master of Economics has the same core courses requirements but does not have a thesis requirement.

### Doctoral Degree Requirements

The Ph.D. program has no specific hour requirements but at least six semesters of work beyond the bachelor's degree are required. Students must pass written comprehensive examinations in microeconomics and macroeconomics. Course requirements include two semesters of econometrics and six field courses. An outside minor can substitute for two of the field courses.

### Student Financial Support

Research and teaching assistantships are available and are awarded on a competitive basis. Most of these assistantships go to Ph.D. students. Students applying for these assistantships are advised to apply by March 1 for fall admission.

### Other Relevant Information

Graduate students on financial support are provided office space or study carrels. Other students may be assigned study carrels if available. All students have access to the economics graduate student computer lab.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

EC(ARE) 401 ECONOMIC ANALYSIS FOR NONMAJORS.
EC 404 MONEY, FINANCIAL MARKETS AND THE ECONOMY.
EC 410 PUBLIC FINANCE.
EC 413 COMPETITION, MONOPOLY AND PUBLIC POLICY.

ARE 415 FARM APPRAISAL AND FINANCE.
ARE 430 AGRICULTURAL PRICE ANALYSIS.
EC 431 LABOR ECONOMICS.
EC 435 URBAN ECONOMICS.
EC(ARE) 436 ENVIRONMENTAL ECONOMICS.
EC 442 EVOLUTION OF ECONOMIC IDEAS.
EC 448 INTERNATIONAL ECONOMICS.
EC 451 INTRODUCTION TO ECONOMETRICS.
EC(HI) 470 THE JAPANESE ECONOMY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ECG 501 PRICE THEORY. Preqs.: MA 131 and EC(ARE) 301. 3(3-0) F,S, Sum.** An intensive analysis of the determination of prices and of market behavior, including demand, cost and production, pricing under competitive conditions and pricing under monopoly and other imperfectly competitive conditions.

**ECG 502 INCOME AND EMPLOYMENT THEORY. Preqs.: EC(ARE) 301, EC 302, BUS(ST) 350, MA 131. 3(3-0) F,S,Sum.** Determinants of national income, employment, wages, the interest rate and inflation. Emphasis on the real (as opposed to monetary) determinants of these variables and on the microfoundations of modern macroeconomics. Discussion of monetary and fiscal policy and stochastic elements in income determination.

**ECG(PRT) 503 ECONOMICS OF RECREATION. 3(3-0) F.** (See parks, recreation and tourism management.)

**ECG 504 MONETARY AND FINANCIAL MACROECONOMICS. Preq.: ECG 502. 3(3-0) S. Alt. yrs.** Financial and monetary determinants of national income and employment and levels of wages, the interest rate and inflation. Emphasis on the money supply and the banking system. Special topics include banking regulation, budgetary deficits and the dynamics of money stock determination.

**ECG 505 APPLIED MICROECONOMIC ANALYSIS. Preq.: EC 202 or 301. 3(3-0) F,S.** Applied course in microeconomics for management students. Behavior of producers and consumers in a market economy. Price and output determination in competitive and noncompetitive markets. Decision making under uncertainty and imperfect information.

**ECG 506 APPLIED MACROECONOMIC ANALYSIS. Preq.: ECG 505. 3(3-0) F,S,Sum.** Applied course in aggregate economics. Analysis of aggregate economic fluctuations and stabilization policy; inflation and disinflation; the Federal budget and the international balance of trade; and economic growth. Capital markets, monetary and fiscal policy, the banking system, foreign exchange markets and

their effects on business conditions. Development of a standard macroeconomic model in the context of specific applications.

**ECG 512 LAW AND ECONOMICS. Preq.: EC(ARE) 301 or EC(ARE) 401. 3(3-0) F. Alt. yrs.** An economic analysis of the sources and effects of law, including common law, statutory law and regulation. Topics include property rights and contracts, liability rules, crime and punishment, statutory enactment, bureaucratic behavior and institutional reform.

**ECG 515 ENVIRONMENTAL AND RESOURCE POLICY. Preq.: EC(ARE) 301 or 401. 3(3-0) F. Alt. yrs.** Application of price theory and benefit-cost analysis to public decisions related to resources and the environment. Emphasis on evaluation of water supply and recreation investments, water quality management alternatives, public-sector pricing, common property resources and optimum management of forest and energy resources.

**ECG 521 MARKETS AND TRADE. Preq.: EC(ARE) 301 or 401. 3(3-0) F.** Emphasis upon the space, form and time dimensions of market price and the location and produce combination decisions of firms. Consideration of the way in which non-price factors and public policy choices influence firm behavior and the efficiency of marketing systems. Emphasis upon application of these models to agricultural, industrial and public service questions, including the relationships between resource availability and the spatial arrangement of economic activity.

**ECG 523 PLANNING FARM AND AREA ADJUSTMENTS. Preqs.: EC(ARE) 301, ARE 303 or EC(ARE) 401. 3(2-2) S. Alt. yrs.** The application of economic principles to production problems on typical farms in the state; methods and techniques of economic analysis of the farm business; application of research findings to production decisions; development of area agricultural programs.

**ECG 533 ECONOMICS OF WORLD FOOD AND AGRICULTURAL POLICY. Preq.: EC(ARE) 301 or 401. 3(3-0) F.** Economic analysis of the causes and effects of agricultural policies commonly applied in developed, developing and planned economies. Emphasis on economic models of policy analysis. Examination of the impact of commodity, farm imput, international trade, consumer and general economic policies on agriculture and the whole economy. Effects of policy on income distribution and economic development.

**ECG 537 HEALTH ECONOMICS. Preq.: EC(ARE) 401 or ECG 501. 3(3-0) F.** Microeconomic analysis of public and private policy issues concerning health care financing and delivery in the United States including: choice under conditions of asymmetric information; health insurance; performance of physician, hospital, long-term care and pharmaceutical markets.

**ECG 540 ECONOMIC DEVELOPMENT. Preq.: EC(ARE) 301 or 401. 3(3-0) Alt. yrs.** An examination of the problems encountered in promoting regional and national economic development. Consideration given to the structural changes required for raising standards of living. Some basic principles of economics applied to suggest ways of achieving development goals. Topics include planning strategies, policies and external assistance.

**ECG 551 AGRICULTURAL PRODUCTION ECONOMICS. Preqs.: MA 131 and EC(ARE) 301 or 401. 3(3-0) S.** An economic analysis of agricultural production including: production functions, cost functions, programming and decision-making principles. Applications of these principles to farm and regional resources allocation, and to the distribution of income to and within agriculture.

**ECG(ST) 561 INTERMEDIATE ECONOMETRICS. Preqs.: ECG 501 and ST 514. 3(3-0) S.** The formalization of economic hypotheses into testable relationships and the application of appropriate statistical techniques emphasized. Major attention to procedures applicable for single equation stochastic models expressing microeconomic and macroeconomic relationships. Statistical considerations relevant in working with time series and cross sectional data in economic investigations covered. Survey of simultaneous equation models and the available estimation techniques.

**ECG 565 MATHEMATICAL METHODS FOR ECONOMICS. Preqs.: ECG 501, MA 231 or equivalent, introductory course in linear algebra. 3(3-0) S.** Linear algebra and matrices, optimization with equality and inequality constraints, comparative statistics, differential and difference equations, intertemporal optimization. Economic applications to utility and profit maximization, national income determination, economic growth, business cycles.

**ECG 570 ANALYSIS OF AMERICAN ECONOMIC HISTORY. Preq.: EC(HI) 371 or grad. standing or PBS status. 3(3-0) F. Alt. yrs.** Stress upon the application of economic analysis to the formulation and testing of hypotheses concerning economic growth and development in the historical context. Problems selected for analysis primarily from American economic history.

**ECG 590 SPECIAL ECONOMICS TOPICS. Preq.: CI. Maximum 6. F,S,Sum.** An examination of current problems on a lecture-discussion basis. Course content varies as changing conditions require new approaches to deal with emerging problems.

**ECG 598 TOPICAL PROBLEMS IN ECONOMICS. Preq.: CI. 1-6. F,S, Sum.** Investigation of topics of particular interest to advanced students under faculty direction on a tutorial basis. Credits and content vary with student needs.

*FOR GRADUATES ONLY*

**ECG 600 ADVANCED PRICE THEORY. Preqs.: ECG 501, MA 231. 3(3-0) F.** Theory of consumer behavior. Derivation of individual and market demand curves. Consumer surplus. Derivation of firm and market supply curves. Equilibrium and price determination in a market economy. Consideration of alternative market structures.

**ECG 601 PRICES, VALUE AND WELFARE. Preq.: ECG 600. 3(3-0) S.** Production and duality theory. The demand for and supply of factors of production. Theories of capital and interest. Welfare economics topics, including externalities, compensation, public goods and the social welfare function. General equilibrium.

**ECG 602 ADVANCED INCOME AND EMPLOYMENT THEORY. Preq.: ECG 502. 3(3-0) F.** An analysis of the forces determining the level of income and employment; a review of some of the theories of economic fluctuations; and a critical examination of a selected macroeconomic system.

**ECG 603 HISTORY OF ECONOMIC THOUGHT. Preqs.: ECG 501 and 502 or equivalent. 3(3-0) Sum. Alt. yrs.** A systematic analysis of the development and cumulation of economic thought, designed in part to provide a sharper focus and more adequate perspective for the understanding of contemporary economics.

**ECG 604 MONETARY ECONOMICS. Preq.: ECG 602. 3(3-0) S.** Consideration of the money market and portfolio management, the cost of capital, effects of monetary phenomena on investment and accumulation of wealth with emphasis throughout on problems arising from uncertainty; general equilibrium theory of money, interest, prices and output.

**ECG 606 INDUSTRIAL ORGANIZATION AND CONTROL. Preq.: ECG 501. 3(3-0) F.** Survey of microeconomic literature on industrial organization: the internal structure of the firm, number and sizes of firms in an industry, pricing and output behavior of firms. Public policy, including antitrust laws, patent and copyright laws, and government regulation of industry.

**ECG 607 TOPICS IN INDUSTRIAL ORGANIZATION. Preq.: ECG 501. 3(3-0) S.** Advanced study of selected topics such as oligopoly theory, empirical models of industry, principal-agent contracts, economic theories of firm organization, antitrust issues, economic theories of regulation and economics of property rights.

**ECG 610 THEORY OF PUBLIC FINANCE. Preq.: ECG 501. 3(3-0) F. Alt. yrs.** An application of microeconomic theory and welfare economics to the public

sector. Topics include externalities and public policy, the theory of public goods, collective choice, program budgeting and cost-benefit analysis, the theory of taxation and its application to tax policy, public debt and fiscal federalism.

**ECG 615 ENVIRONMENTAL AND RESOURCE ECONOMICS. Preq.: ECG 501. 3(3-0) F.** The theoretical tools and empirical techniques necessary for an understanding of resource and environmental economics, developed in both a static and dynamic framework. Discussions of the causes of environmental problems, possible policies and approaches to nonmarket valuation. Analysis of resource use over time using control theory for both renewable and exhaustible resources.

**ECG 616 TOPICS IN ENVIRONMENTAL AND RESOURCE ECONOMICS. Preq.: ECG 615. 3(3-0) S.** Advanced study of selected topics in environmental and resource economics. Topics vary with interests of instructor and students.

**ECG 630 LABOR ECONOMICS. Preqs.: ECG 501 and one of the following: ECG(ST) 561, ST 422, ST 512, ST 517. 3(3-0) F.** Application of microeconomic theory and econometric methods to labor market behavior in both static and dynamic contexts. Topics include labor demand analysis, labor force participation, hours of work, household production, human capital, distribution of earnings, information and search, and mobility.

**ECG 631 POLICY AND RESEARCH ISSUES IN LABOR ECONOMICS. Preqs.: ECG 501 and one of the following: ECG(ST) 561, ST 422, ST 512, ST 517. 3(3-0) S.** Survey of current literature on policy-related issues in labor economics, including trade union behavior, unemployment, macroeconomic aspects of labor market adjustment, discrimination, regulation of wages and benefits and public-sector labor markets. Examples from labor markets in the U. S. and developing countries. Recent research developments in labor economics, topics to vary according to the interests and needs of students.

**ECG 640 ADVANCED ECONOMIC DEVELOPMENT. Preqs.: ECG 501, 502, 540. 3(3-0) F. Alt. yrs.** An analysis of the factors determining the growth of poorer countries and regions of countries. Consideration of issues having arisen in current theoretical and empirical bases for policy decisions. The latter elements include the quantitative foundations for planned and programmed development. Evaluation of applications of alternative planning methods.

**ECG 641 AGRICULTURAL PRODUCTION AND SUPPLY. Preqs.: ECG 501 and ST 514. 3(3-0) F.** An advanced study in the logic of, and empirical inquiry into, producer behavior and choice among combinations of factors and kinds and qualities of output; aggregative consequences of individuals' and firms' decisions

in terms of product supply and factor demand; factor markets and income distribution; and general interdependency among economic variables.

**ECG 642 CONSUMPTION, DEMAND AND MARKET INTERDEPENDENCY. Preqs.: ECG 501 and ST 514. 3(3-0) S.** An analysis of the behavior of individual households and of consumers in the aggregate with respect to consumption of agricultural products; the impact of these decisions on demand for agricultural resources, the competition among agricultural regions and for markets; and the interdependence between agriculture and other sectors of the economy.

**ECG 648 THEORY OF INTERNATIONAL TRADE. Preqs.: ECG 501, 502. 3(3-0) F.** A consideration of the specialized body of economic theory dealing with the international movement of goods, services, capital and payments. Also, a theoretically oriented consideration of policy.

**ECG 649 MONETARY ASPECTS OF INTERNATIONAL TRADE. Preq.: ECG 502. 3(3-0) S.** The macroeconomic problems of an open economy including balance of payments adjustment mechanism, alternative exchange rate systems, external effects of monetary and fiscal policy, optimum currency areas and international monetary reform.

**ECG 650 ECONOMIC DECISION THEORY. Preq.: ECG 501. 3(3-0) S. Alt. yrs.** General theories of choice. Structure of decision problems, the role of information; formulation of objectives. Current research problems.

**ECG(ST) 651 ECONOMETRICS. Preqs.: ECG 600, ST 421, ST 422. 3(3-0) F.** The role and uses of statistical inference in economic research; the problem of spanning the gap from an economic model to its statistical counterpart; measurement problems and their solutions arising from the statistical model and the nature of the data; limitations and interpretation of results of economic measurement from statistical techniques.

**ECG(ST) 652 TOPICS IN ECONOMETRICS. Preq.: ECG(ST) 651. 3(3-0) S.** Survey of current literature on estimation and inference in simultaneous stochastic equations systems. Techniques for combining cross section and time series data including covariance, error correlated and error component models. Lag models and inference in dynamic systems. Production functions, productivity measurement and hypotheses about economic growth. Complete and incomplete prior information in regression analysis. Nonlinear estimation in economic models.

**ECG 682 ADVANCED MACROECONOMICS. Preq.: ECG 602. 3(3-0) F. Alt. yrs.** Advanced study of macroeconomics. Emphasis on business cycles and behavior of real variables. Topics include: real, incomplete information and disequilibrium

theories of the business cycle; rational expectations; contract theory and indexation; investment; and the effects of government expenditure, taxes and debt.

**ECG 684 MONETARY THEORY. Preqs.: ECG 600, 601, 602, 604. 3(3-0) S. Alt. yrs.** Advanced study of micro- and macroeconomic theories of the role of money in the economy. Primary emphasis on money demand and monetary growth models. Specific areas explored include: traditional and recent developments in both asset and transactions theory and rational expectations and optimal policy. Discussion of the empirical record included for most topics.

**ECG 699 RESEARCH IN ECONOMICS. Credits Arranged.** Individual research in economics under staff supervision and direction.

# Educational Administration and Supervision

For a listing of graduate faculty and program information, see educational leadership and program evaluation.

# Educational Leadership and Program Evaluation

**Degrees Offered: Ph.D., Ed.D., M.S., M.Ed.**
**Certification Programs: Principalship (CRP), Superintendency (CRS)**

## GRADUATE FACULTY

*Professor* B. MacPhail-Wilcox, ***Head of the Department***
***Assistant Professor*** P. F. Bitting, ***Director of Graduate Programs***
***Assistant Professor*** D. J. Eaker, ***Director of Graduate Programs***
Box 7801, (919) 515-3127, bitting@poe.coe.ncsu.edu

***Professors:*** B. G. Beezer, R. G. Taylor Jr.;
***Professor Emeritus:*** C. J. Dolce;
***Associate Professor:*** R. C. Serow;
***Assistant Professor:*** J. L. Keedy;
***Adjunct Assistant Professors:*** L. E. Crumpler, J. I. Dreyden, M. E. Ward

The graduate programs in educational administration and supervision and educational research and policy analysis have a multidisciplinary emphasis which includes courses in public administration, politics, psychology and sociology as well as in professional education. Programs are planned individually, based on an analysis of the student's career objectives, prior coursework and competencies obtained. In

addition to master's and doctoral degree programs, the department offers principal certification (CRP) and superintendent certification (CRS) programs.

### Admission Requirements

Scores from the Graduate Record Examination (GRE) or the Miller's Analogy Test (MAT) must be less than 5 years old. A GPA at or above 3.0 plus three strong letters of reference are needed. A career narrative statement which describes in detail the applicant's career objectives and specific objectives for enrolling in the graduate program is also required. In unusual circumstances, with unanimous faculty approval, a student may be recommended for conditional admission when one entry attribute is inconsistent with a strong positive predictor of success based on other entry attributes.

### Master's Degree Requirements (EAS)

The department offers an M.Ed. and M.S. degree in educational administration and supervision (EAS). A minimum of 30 to 39 course credits is required and must include at least 9 credits in a minor field.

### Ed.D. Degree Requirements (EAS)

A minimum of 51 graduate course credits beyond the master's degree is required for the Ed.D. in EAS. A field-based research study must be conducted and defended successfully as the culminating experience in the program. A year-long period of full-time resident study is required.

### Ph.D. Degree Requirements (ERP)

For students entering the Ph.D. program in educational research and policy analysis (ERP) with an M.S. degree, required prerequisites and thesis experience, the minimum program will range between 48 and 57 credit hours of work, excluding the dissertation preparation.

### Student Financial Support

The department offers a $10,000 Hodnett Doctoral Fellowship for one Ed.D. student on a regular basis. There are other fellowships and teaching assistantships available occasionally.

### Other Relevant Information

The Department of Educational Leadership and Program Evaluation offers degree and certification programs for those intending to pursue careers in elementary and secondary school administration.

**ELP 514 FORMATIVE IDEAS IN AMERICAN EDUCATION. Preq.: Six hrs. educ. or psy. CI. 3(3-0) F.** A consideration of the theory and practice of American education as an extension of the philosophical climate of opinion of different intellectual ages and how the present status of our educational system is grounded in the thought of the past.

**ELP 515 EDUCATION AND SOCIAL DIVERSITY. Preq.: Six hrs. educ., psy. and/or social science. 3(3-0) S.** An overview of the role of education within a culturally diverse society. Major attention to racial, ethnic, socioeconomic and regional subpopulations. The subcultural influences on public school performances, equality of educational opportunity, social stratification and mobility and the impact of schooling on intergroup relations.

**ELP 518 INTRODUCTION TO EDUCATION LAW. Preq.: Six hrs. grad. credit. 3(3-0) F.** Relationship of constitutional, statutory and case law to the elementary and secondary public school settings, particularly in the areas of students, teachers and liability. Particular emphasis placed on N. C. and federal law.

**ELP 532 INTRODUCTION TO EDUCATIONAL INQUIRY. Preq.: Grad. standing or PBS status. 3(3-0) F,S,Sum.** Basic concepts and methods of educational inquiry. Emphasis on the logic underlying various approaches to problem definition and solution and on the tools of the investigator, as well as on sources and interpretation of research information related to student's particular area of study.

**ELP 534 ETHICS AND EDUCATIONAL DECISION MAKING. Preqs.: Introduction to philosophy, ethics or CI; grad. standing. 3(3-0) S. Alt. yrs.** Application of moral theories and methods of moral reasoning to problems and issues involving educational policy and decision making. The character of morality; moral autonomy and leadership; intellectual freedom and the public interest; authority and education; punishment and due process; and leadership and rationality.

**ELP 535 DECISION RESEARCH IN EDUCATION. Preqs.: ELP 532; grad. standing or CI. 3(3-0) F.** Intuitive and graphic approaches to modeling for the purpose of supporting decisions in the public sector, especially in education. Decision making with determinant and probabilistic data. Optimization methods. Practical applications and solution to common problems. Frequent computer-based assignments.

**ELP 536 QUALITATIVE RESEARCH IN EDUCATION AND POLICY ANALYSIS. Preq.: ELP 532 or equivalent. 3(3-0) F.** Provision of public school personnel and educational policy analysts with research training and experience to

address educational research and policy problems using qualitative methods. Qualitative research design and strategies; data collection, management and analysis; interpretation and writing; qualitative evaluation and formation as applied particularly to educational research and policy analysis.

**ELP 541 PRACTICUM IN EDUCATION ADMINISTRATION. Preqs.: ELP 550 and CI. 1-6 F,S.** Supervised experience in an appropriate educational setting to enable the student to gain practice in applying concepts, principles and theories of education administration.

**ELP 550 PRINCIPLES OF EDUCATIONAL ADMINISTRATION. Preqs.: Grad. standing, CI. 3(3-0) F,S.** An introductory course in educational administration. Emphasis upon basic principles of administration, drawing upon administrative theory, business and public administration models as well as theoretical constructs from various disciplines.

**ELP 569 THE PRINCIPALSHIP. Preq.: ELP 550 or CI. 3(3-0) S.** A survey course covering the major responsibilities and tasks of a school principal, *e.g.*, curriculum and instructional leadership, teacher recruitment and selection, fiscal record keeping, pupil schedules, plant management. Combination of student findings from their readings with present practices to develop workable solutions to managerial and instructional problems.

**ELP 580 EVALUATION THEORY AND PRACTICE IN EDUCATION. Preq.: ELP 532 or equivalent. 3(3-0) F.** A review of educational program evaluation with emphasis on (1) theory and conceptual models of evaluation, (2) evaluation design, and (3) environmental practical factors influencing the design and implementation of evaluation studies.

**ELP 589 PERSONNEL APPRAISAL IN EDUCATION. Preqs.: ELP 532 or PSY 535. 3(3-0) S.** Examination of issues, models, theories and research pertaining to personnel appraisal in education.

**ELP 597 SPECIAL PROBLEMS IN EDUCATION. Preq.: Grad. standing or PBS status. 1-3 F,S,Sum.** Opportunity for graduate students in education to study problem areas in professional education under the direction of a member of the graduate faculty.

**ELP 599 RESEARCH PROJECTS IN EDUCATIONAL LEADERSHIP AND PROGRAM EVALUATION. Preqs.: CI; ELP 532 or equivalent. 1-3 F, S, Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. The research chosen on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**ELP 614 CONTEMPORARY EDUCATIONAL THOUGHT. Preqs.: Twelve hrs. educ.; CI. 3(3-0) F.** A reading and discussion of twentieth-century works in educational philosophy. Consideration of such movements as pragmatism, reconstruction, perennialism and existentialism.

**ELP 618 SCHOOL LAW FOR THE ADMINISTRATOR. Preq.: ELP 518 or equivalent. 3(3-0) S. Alt. yrs.** A comprehensive study of constitutional, statutory and case law as it relates to elementary and secondary school administration. Emphasis on legal issues associated with governance, finance, property, personnel and curricu-lum.

**ELP 620 CASES IN EDUCATIONAL ADMINISTRATION. Preq.: CI. 3(3-0) F.** Utilization of the case study and case simulation approach to the study of school administration. Development and application of administrative concepts to simulated situations and to actual case histories. View of the administrative process as a decision-making process. The student expected to make decisions after considering alternative courses of action and after projecting probable consequences.

**ELP 621 INTERNSHIP IN EDUCATIONAL LEADERSHIP AND PROGRAM EVALUATION. Preqs.: Nine hrs. in grad.-level courses and CI. 3-9 F, S.** Utilization of participant-observer role and required participation in selected educational situations with emphasis upon development of observational skills, ability to record relevant observations by means of written journals, skills in analyzing experiences identifying critical incidents and projection of events and consequences. Required development of possible alternative courses of action in various situations, selection of one of the alternatives and evaluation of the consequences of the selected course of action.

**ELP 632 APPLIED RESEARCH METHODS IN EDUCATION. Preqs.: ST 507 and ELP 532 or equivalent; Coreq.: ST 508 or CI. 3(1-4) S.** Through the use of simulated educational settings, consideration given to the development of research proposals or plans, selection and/or development of appropriate measurement instruments and the purposes and functions of various statistical designs and procedures. Preparation and analysis of simulated data using computer-based statistical packages, interpretation of the results and production of a research report.

**ELP 697 PROBLEMS OF RESEARCH DESIGN IN EDUCATION. Preqs.: ELP 632 and CI. 1-3 F,S.** Provision of an individualized but structured investigation of alternative problem definitions, research methodologies and statistical analyses for a problem of the student's choosing, usually associated with thesis or dissertation. In small groups or individually with the instructor, student considera-

tion of research design, measurements and statistical analysis necessary to conduct research.

**ELP 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of ELP; CI. Credits Arranged. F,S,Sum.** Individual research on a thesis or dissertation problem.

# Educational Research and Policy Analysis

For a listing of graduate faculty and program information, see educational leadership and program evaluation.

# Electrical and Computer Engineering

**Degrees Offered: Ph.D., M. S., Master of Electrical Engineering**

**GRADUATE FACULTY**

*Professor* R. K. Cavin III, *Head of the Department*
*Professor* W. E. Alexander, *Director of Graduate Programs*
Box 7911, (919) 515-5091, winser@eos.ncsu.edu

*Graduate Alumni Distinguished Professor:* J. B. O'Neal Jr.
*University Professor:* D. R. Rhodes

*Professors:* D. P. Agrawal, B. J. Baliga, S. M. Bedair, W. Chou, R. E. Funderlic, T. H. Glisson Jr., J. J. Grainger, J. R. Hauser, J. F. Kauffman, S. Khorram, R. M. Kolbas, M. A. Littlejohn, R. Luo, N. A. Masnari, N. F. Matthews, L. K. Monteith, H. T. Nagle Jr., A. A. Nilsson, C. M. Osburn, S. A. Rajala, A. Reisman, J. F. Schetzina, W. E. Snyder, H. J. Trussell, J. J. Wortman;
*Visiting Professors:* G. W. Rubloff, J. R. Suttle;
*Adjunct Professors:* F. Brglez, E. Christian, J. W. Gault, S. E. Kerns, J. W. Keyes Jr., M. A. Strocsio;
*Professors Emeriti:* W. J. Barclay, A. R. Eckels, A. J. Goetze, G. B. Hoadley;
*Associate Professors:* S. T. Alexander, E. F. Gehringer, R. S. Gyurcsik, A. W. Kelley, K. W. Kim, W. Liu, T. K. Miller III, M. C. Ozturk, D. S. Reeves, M. B. Steer, M. W. White;
*Visiting Associate Professor:* J. J. Brickley;
*Adjunct Associate Professors:* J. R. Burke, J. R. Jones, S. S. Lee, J. W. Mink;
*Associate Professors Emeriti:* N. R. Bell, G. F. Bland, E. G. Manning, W. C. Peterson;

*Assistant Professors:* M. Chow, A. Duel-Hallen, P. D. Franzon, C. S. Gloster Jr., P. K. McLarty, J. K. Townsend, I. Viniotis;
*Visiting Assistant Professors:* M. E. Baran, G. L. Bilbro, X. Xu;
*Adjunct Assistant Professors:* D. L. Dreifus, C. A. Hamilton, A. J. Rindos III, P. I. Santago, C. K. Williams;
*Lecturer:* J. C. Sutton III

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* H. G. Perros, W. E. Robbins, K. C. Tai;
*Associate Professors:* E. W. Davis Jr., M. F. M. Stallmann, M. A. V. Vouk

## INTERINSTITUTIONAL ADJUNCT GRADUATE FACULTY

S. Chen, K. Daneshvar, J. H. Kim, F. M. Tranjan

### Admissions Requirements

Admission to the M.S. program requires a B.S. in electrical engineering, computer engineering or computer science, an overall undergraduate GPA of at least 3.2, The minimum acceptable TOEFL score for admission to the M.S. program is 575. Admission is further limited by available room in the elected program of study and meeting the minimum above requirements alone does not guarantee admission.

Admission to the Ph.D. program requires a B.S. or M.S. in electrical engineering, computer engineering or computer science with an overall GPA of at least 3.5. (NOTE: Only exceptional students are admitted without first having an M.S. degree.) The minimum acceptable TOEFL score for admission to the Ph.D. program is 625. Admission is further limited by available room in the elected program of study, and meeting the minimum requirements as given above does not guarantee admission.

### Master's Degree Requirements

A thesis is optional. Students electing the Option B non-thesis option must meet core course requirements and have at least six credit hours of 600-level ECE courses.

### Doctoral Degree Requirements

Approximately 30 credit hours are required beyond the M.S. degree or 60 credit hours beyond the B.S. degree. A minimum of 21 of the 30 credit hours or a minimum of 45 of the 60 credit hours must be in scheduled courses. A minor is not required, but may be elected. Additional course restrictions apply if a minor is not elected.

The department wishes to evaluate a Ph.D. student's research potential as quickly as possible. Consequently, all Ph.D. students are required to pass a qualifying review before the end of their third semester of study. This review is based on the student's academic performance to-date, and the results of a project with one of their committee members. Results are presented to the committee in both written and oral form. Based on this review, the committee will decide if the student may continue in the Ph.D. program.

### Student Financial Support

The department offers financial support to qualified students in the form of teaching assistantships, research assistantships, fellowships and tuition remission.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

ECE 401 INTRODUCTION TO SIGNAL PROCESSING.
ECE 409 INTRODUCTION TO TELECOMMUNICATIONS ENGINEERING.
ECE 431 ELECTRONICS ENGINEERING.
ECE 432 COMMUNICATIONS ENGINEERING.
ECE 435 ELEMENTS OF CONTROL.
ECE 436 DIGITAL CONTROL SYSTEMS.
ECE 439 INTEGRATED CIRCUIT TECHNOLOGY AND FABRICATION.
ECE(CSC) 440 DIGITAL SYSTEMS INTERFACING.
ECE 441 INTRODUCTION TO SOLID-STATE DEVICES.
ECE 444 COMPUTER CONTROL OF ROBOTS.
ECE 446 VLSI SYSTEMS DESIGN.
ECE 448 MICROWAVE ANTENNAS, RADARS AND COMMUNICATION SYSTEMS.
ECE 451 POWER SYSTEM ANALYSIS.
ECE 452 POWER SYSTEMS PROTECTION.
ECE 454 ELECTRICAL MACHINERY.
ECE 455 COMPUTER CONTROL OF SCR MOTOR DRIVES.

ECE 457 SEMICONDUCTOR POWER CONVERSION.
ECE 492 SPECIAL TOPICS IN ELECTRICAL AND COMPUTER ENGINEERING.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ECE (CSC) 501 OPERATING SYSTEMS PRINCIPLES. 3(3-0) F.** (See computer science.)

**ECE 503 INSTRUMENTATION CIRCUITS. Preq.: ECE 431. 3(3-0) S.** Design principles of instrumentation circuits from a functional perspective. Detailed discussion of circuit techniques used in analog subsystems such as amplifiers, filters, mixers and power supplies. Broad coverage of circuit applications such as voiceband CODECs, FM receivers and automatic impedance analyzers.

**ECE(CSC) 505 DESIGN AND ANALYSIS OF ALGORITHMS. 3(3-0) F, S.** (See computer science.)

**ECE(CSC) 506 ARCHITECTURE OF PARALLEL COMPUTERS. 3(3-0) F,S.** (See computer science.)

**ECE(CSC) 510 SOFTWARE ENGINEERING. 3(3-0) F.** (See computer science.)

**ECE 511 ANALOG ELECTRONICS. Preqs.: ECE 431, grad. standing or B average in ECE and MA. 3(2-3) F.** Analog integrated circuits and analog integrated circuit design techniques. Review of basic device and technology issues Comprehensive coverage of MOS and Bipolar operational amplifiers. Brief coverage of analog-to-digital conversion techniques and switched-capacitor filters. Strong emphasis on the use of computer modeling and simulation as a design tool. Students required to complete an independent design project.

**ECE(CSC) 512 COMPILER CONSTRUCTION. 3(3-0) S.** (See computer science.)

**ECE 513 DIGITAL SIGNAL PROCESSING. Preqs.: ECE 401, B average in ECE and MA or CI. 3(3-0) F.** Digital processing of analog signals. Offline and real-time processing for parameter, waveshape and spectrum estimation. Digital filtering and applications in speech, sonar, radar, data processing and two-dimensional filtering and image processing.

**ECE 514 RANDOM PROCESSES. Preqs.: ECE 301, MA 314. 3(3-0) F.** Probabilistic descriptions of signals and noise, including joint, marginal and conditional densities, autocorrelation, cross-correlation and power spectral density. Linear and nonlinear transformations. Linear least-squares estima-tion. Signal detection.

**ECE 515 DIGITAL COMMUNICATIONS. Preq.: ECE 514. 3(3-0) F.** Theory and analysis of digital communications in the presence of noise and channel distortion. Information theory, modulation/demodulation, block and convolutional encoding/decoding, bit error rate analysis and detection theory. Modulation/ demodulation techniques include frequency shift keying, M-level phase shift keying and quadrature amplitude modulation.

**ECE 516 SYSTEM CONTROL ENGINEERING. Preq.: ECE 435 or ECE 301. 3(3-0) F.** Introduction to analysis and design of continuous and discrete-time dynamical control systems. Emphasis on linear, single-input, single-output systems using state variable and transfer function methods. Open and closed-loop representation; analog and digital simulation; time and frequency response; stability by Routh-Hurwitz, Nyquist and Liapunov methods; performance specifications; cascade

and state variable compensation. Assignments utilize computer-aided analysis and design programs.

**ECE(CSC) 518 COMPUTER GRAPHICS. 3(3-0).** (See computer science.)

**ECE(CSC) 520 FUNDAMENTALS OF LOGIC SYSTEMS. Preqs.: ECE 212 and ECE 342. 3(3-0) F,S.** Application of algebraic techniques to the design of sequential logic and fault diagnosis; introduction to the design of testable systems. Introduction to modern heuristic tools for combinational and sequential circuit design.

**ECE(CSC) 521 DIGITAL COMPUTER TECHNOLOGY AND DESIGN. Preq.: ECE 342. 3(3-0) F.** Design of computers through cost-performance analysis, reflecting how professional computer designers work today. Emphasis on making design decisions regarding the instruction set architecture, organization and implementation of a computer. Discussion of design choices, analysis techniques, detailed computer-based design techniques and implementation techniques. The relationships between architecture, organization and technology.

**ECE 525 OPTICAL SIGNAL PROCESSING. Preq.: ECE 301. 3(3-0) F.** Review of key principles from geometric optics; resolving power and the optical invariant and their relation to principles of communication theory; Fresnel and Fourier transformations and a study of direct and heterodyne detection, photodetectors, dynamic range, spatial filtering and carrier-frequency methods; applications such as spectrum analysis, pattern recognition and signal detection.

**ECE 530 PHYSICAL ELECTRONICS. Preqs.: ECE 303, B average in ECE and MA. 3(3-0) S.** Properties of charged particles under the influence of fields and in solid materials. Quantum mechanics, particle statistics, semi-conductor properties, fundamental particle transport properties, p-n junctions.

**ECE 531 PRINCIPLES OF TRANSISTOR DEVICES. Preq.: ECE 441. 3(3-0) S.** An analysis of the operating principles of transistor structures. Basic semiconductor physics reviewed and used to provide an explanation of transistor characteristics. Development and usage of device-equivalent circuits to interpret semiconductor-imposed limitations on device performance. Devices analyzed include MESFET'S, HEMT'S, Bipolar transistors, PBT'S, heterojunction BJT'S and SIT's.

**ECE 532 PRINCIPLES OF MICROWAVE CIRCUITS. Preq.: ECE 448. 3(3-0) F.** Principles required to understand the behavior of electronic circuits operating at microwave frequen cies. This course starts with a review of electromagnetic theory and establishes an understanding of the techniques required for

working with electronic circuits at microwave and millimeter-wave frequencies. Discussion of circuit components operating at these frequencies.

**ECE 533 DIGITAL ELECTRONICS. Preqs.: ECE 314. 3(3-0) S.** Digital integrated circuits and digital integrated circuit design techniques. Aims in digital circuit design; DC and transient analysis of CMOS, TTL, ECL, BiCMOS and GaAs digital circuits: optimizing for speed and power consumption; interconnect design and analysis; semiconductor memory circuits; packaging and timing considerations.

**ECE 537 CHARACTERIZATION OF HIGH-SPEED DEVICES. Preq.: ECE 448. 3(1-5) F.** A laboratory in principles of microwave characterization and operation of microwave test equipment such as spectrum analyzers, power meters, detectors and network analyzers. Performance of measurements of impedance noise figure, equivalent circuit parameters and frequency response on various circuit elements and devices.

**ECE 538 INTEGRATED CIRCUITS TECHNOLOGY AND FABRICATION. Preq.: ECE 441. 3(3-0) F.** Processes used in the fabrication of modern integrated circuits. Process steps for crystal growth, oxidation, diffusion, ion implantation, lithography, chemical vapor deposition, etching, metallization, layout and packaging. Process integration for MOS and biopolar processes. Characterization techniques, simulation, yield and reliability.

**ECE 539 INTEGRATED CIRCUITS TECHNOLOGY AND FABRICATION LABORATORY. Preq.: ECE 538. 3(1-4) S.** Integrated circuit laboratory companion to ECE 538. Fabrication and testing of integrated circuit devices. Effects of process variations on measurable parameters. Hands-on experience in the semiconductor laboratory.

**ECE 540 ELECTROMAGNETIC FIELDS. Preq.: ECE 448. 3(3-0) S.** Maxwell's Equations, constitutive relations and boundary conditions. Reflection and refraction of plane waves; power and energy relations in isotropic media. Potential functions, Green's functions and their applications to radiation and scattering. Antenna fundamentals: linear antennas, uniform linear arrays and aperture antennas. Introduction to special relativity, uniform linear arrays and aperture antennas.

**ECE(CSC) 542 DATABASE MANAGEMENT. 3(3-0) F.** (See computer science.)

**ECE 544 DESIGN OF ELECTRONIC PACKAGING AND INTERCONNECTS. Preq.: ECE 314. 3(3-0) S.** Electrical design and optimization of interconnects and packaging. Topics: single chip, PCB and multichip module packaging technologies; design for delay and noise control (signal integrity); backplane design;

EMI and EMC control; CAD/CAE tools; measurement issues; thermal design; packaging technology selection/system-optimization.

**ECE 546 VLSI SYSTEMS DESIGN. Preq.: ECE 342. 3(3-0) F.** Digital systems design in CMOS VLSI technology: CMOS devise physics, fabrication, primitive components, design and layout methodology, integrated system architectures, timing, testing future trends of VLSI technology.

**ECE 547 VLSI ARCHITECTURE. Preqs.: ECE 401, ECE 446. 3(3-0) F.** Study of algorithms and special purpose architectures for applications requiring high performance systems such as digital signal and image processing. Topics include computer arithmetic, systolic arrays, DSP chips, wavefront processors and VLSI system design.

**ECE 550 POWER SYSTEM OPERATION AND CONTROL. Preqs.: ECE 305 or ECE 331, B average in ECE and MA. 3(3-0) F.** Fundamental concepts of economic operation and control of power systems. Real and reactive power balance. System components, character istics and operation. Steady state and dynamic analysis of interconnected systems. Tieline power and load-frequency control with integrated economic dispatch.

**ECE(PY) 552 INTRODUCTION TO THE STRUCTURE OF SOLIDS. 3(3-0) S.** (See physics.)

**ECE 557 PRINCIPLES OF MOS TRANSISTORS. Preq.: ECE 341 or 441 or equivalent. 3(3-0) F. Alt. yrs.** MOS capacitor and transistor regions of operation. Depletion and enhancement mode MOSFETs. MOSFET scaling, short and narrow channel effects. MOSFETs with ion-implanted channels. High field effects in MOSFETs with emphasis on recent advances in design of hit carrier suppressed structures. Small and large signal MOSFET models. State of the art in MOS process integration.

**ECE 558 DIGITAL IMAGE PROCESSING. Preqs.: ECE 401, ST 371, high-level programming capability. 3(3-0) Every yr.** Introduction to the basic techniques of image processing. Topics include image formation and perception, digitization, Fourier transform domain processing, restoration and tomographic reconstruction.

**ECE 559 PATTERN RECOGNITION. Preqs.: ECE(CSE) 514, ST 371, B average in ECE and MA. 3(3-0) S.** A study of image pattern recognition techniques and computer-based methods for scene analysis, including discriminate functions, fixture extraction, classification strategies, clustering and discriminant analysis. Coverage of applications and current research results.

**ECE(CSC,IE,OR) 562 COMPUTER SIMULATION TECHNIQUES. 3(3-0) F.** (See computer science.)

**ECE 570 TELECOMMUNICATIONS SYSTEMS ENGINEERING. Preqs.: ECE 409 and ECE 432; ST 361 or ST 422. 3(3-0) S.** Systems aspects of telecommunications system design and analysis. Interrelationships of component sub-systems affecting the behavior of the whole system. Statistical definitions of system requirements and system performance. Economics of telecommunications systems and the regulated environment. Case studies.

**ECE(CSC) 571 COMPUTER NETWORKS. Preqs.: CSC 312 or ECE 318. 3(3-0) S.** Detailed description and related performance issues of OSI layers two and three for wide area networks, well-known standards for metropolitan area networks such as FDII and DQDB, and basic random access mechanisms for local area networks.

**ECE(CSC) 572 INTRODUCTION TO COMPUTER COMMUNICATIONS. Preq.: CSC 312 or ECE 318; Coreq.: B average in technical subjects. 3(3-0) F.** Computer communications including local area networks (LANs), metropolitan area networks (MANs), wide area networks (WANs), standard organizations, open system architecture (OSI), IBM's system network architecture (SNA), network performance and topological optimization.

**ECE(CSC) 573 INTRODUCTION TO COMPUTER PERFORMANCE MODELLING. 3(3-0) F.** (See computer science.)

**ECE(CSC) 574 REAL TIME COMPUTER SYSTEMS. 3(3-0) Alt. S.** (See computer science.)

**ECE(CSC,IE) 575 VOICE INPUT/OUTPUT COMMUNICATION SYSTEMS. 3(3-0) F.** (See computer engineering.)

**ECE 578 OPTICAL FIBER COMMUNICATIONS. Preq.: ECE 432 or equivalent. 3(3-0) S.** Components, subsystems and system design techniques used in optical fiber communications systems. Up-to-date information pertaining to components and design techniques. Analysis and design of subsystem and system levels. Topics include: historical aspects, optical fiber technology, cabling, optical sources and detectors, transmitter and receiver techniques.

**ECE 591, 592 SPECIAL TOPICS IN ELECTRICAL ENGINEERING. Preq.: B average in technical subjects. 3(3-0) F,S.** A two-semester sequence to develop new courses and to allow qualified students to explore areas of special interest.

**ECE 593 INDIVIDUAL TOPICS IN ELECTRICAL ENGINEERING. Preq.: B average in technical subjects. 1-3 F,S.** Provision of an opportunity for individual students to explore topics of special interest under the direction of a member of the faculty.

*FOR GRADUATES ONLY*

**ECE 601 ANALOG VLSI. Preq.: ECE 511. 3(3-0) S.** Advanced topics in very large-scale analog circuits (VLSI). In-depth coverage of analog-to-digital and digital-to-analog conversion, and switched-capacitor and other monolithic filtering techniques. Special circuits for telecommunications and biomedical applications.

**ECE 603 COMPUTER-AIDED CIRCUIT ANALYSIS. Preq.: ECE 511. 3(3-0) F.** Steady state and transient analysis of circuits with emphasis on circuit theory and computer methods. Consideration of many analysis techniques, including linear nodal, signal flow graph, state equation, time-domain and functional simulation and analysis of sampled data systems. Sensitivity and tolerance analysis, macromodeling of large circuits and nonlinear circuit theory.

**ECE 604 LOGIC DESIGN FOR TESTABILITY. Preq.: ECE 520. 3(3-0) S.** Design for testability and testing methods. Fault modeling, fault simulation, test generation, built-in self test, scan methods and automatic test equipment.

**ECE(CSC) 606 CONCURRENT SOFTWARE SYSTEMS. 3(3-0) S.** (See computer science.)

**ECE 613 ADVANCED FEEDBACK CONTROL. Preq.: ECE 516. 3(3-0) S.** Advanced topics in dynamical systems and multivariable control. Current research and recent developments in the field.

**ECE 619 MICROWAVE CIRCUITS DESIGN. Preq.: ECE 532. 3(3-0) S. Alt. yrs.** Development and examination of techniques for the design of microwave and millimeterwave components and systems. Radar and radiometer systems introduced and discussed. Investigation of system-imposed constraints upon component performance. Specific topics include mixer, oscillator and amplifier performance and design. Usage of modern computer-aided design techniques.

**ECE 622 ELECTRONIC PROPERTIES OF SOLID-STATE MATERIALS. Preq.: ECE 530. 3(3-0) S.** Review of energy bands in semiconductors. Detailed treatment of thermal and electrical transport phenomena, equilibrium and non-equilibrium semiconductor statistics. Also optical properties and hot electron effects in solid-state materials.

**ECE 623 OPTICAL PROPERTIES OF SEMICONDUCTORS. Preq.: ECE 530. 3(3-0) F. Alt. yrs.** Materials and device-related properties of compound optical semiconductors studied. Included topics: optical constants, absorption and emission processes in semiconductors, photodetectors, LED's semiconductor lasers.

**ECE 624 ELECTRONIC PROPERTIES OF SOLID-STATE DEVICES. Preq.: ECE 530. 3(3-0) S.** Basic physical phenomena responsible for the operation of solid-state devices. Examination and utilization of semiconductor equations examined and utilized to explain basic principles of operation. Examination of rectifying and ohmic contacts. Various state-of-the-art devices studied in detail.

**ECE 625 ADVANCED SOLID-STATE DEVICE THEORY. Preq.: ECE 624. 3(3-0) F.** Latest developments in solid-state devices. Topics selected from subjects of current interest and state-of-the-art results. Emphasis on the basic fundamental physical principles of operation as opposed to circuit applications.

**ECE(PY) 627 SEMICONDUCTOR THIN FILMS TECHNOLOGY. Preq.: ECE 530. 3(3-0) S. Alt. yrs.** Techniques and processes encountered in the growth and characterization of epitaxial semiconductor films. Examples of growth techniques: solution growth, chemical vapor deposition, molecular beam epitaxy and sputtering. Film characterization includes electrical characterization using Hall techniques, optical characterization using x-ray and electron microscopy techniques, surface and thin film analysis such as auger and secondary ion mass-spectrometer.

**ECE 628 PREPARATION OF ELECTRONIC MATERIALS. Preq.: ECE 530. 3(3-0) S. Alt. yrs.** Principles governing the preparation of the electronic materials from the solid, liquid and gaseous states. Emphasis on the experimental methods and on factors which affect the electronic behavior of materials, such as non-stoichiometry, charged and uncharged defects.

**ECE 629 GROWTH OF THIN FILMS FROM THE VAPOR PHASE. Preq.: ECE 530. 3(3-0) S. Alt. yrs.** Practical and basic aspects of single and polycrystal growth using chemical vapor transport processes. Emphasis on materials of interest in microelectronics and on experimental methods used to implement chemical vapor processes and to understand chemical vapor processes.

**ECE 632 POWER SYSTEM STABILITY AND CONTROL. Preqs.: ECE 451, ECE 516. 3(3-0) S.** Modeling of synchronous machines and their control systems. Coupled electric circuit approach, Park's transformations, additional rotor windings. Rudiments of dynamic and transient stability. Excitation systems, governor-control systems, power-system stabilizers. State space formulations for computer-based dynamic studies.

**ECE 633 COMPUTER ANALYSIS OF LARGE-SCALE POWER SYSTEMS. Preq.: ECE 550. 3(3-0) F.** Computer-based matrix methods of analysis of large networks. Problem statements, algorithmic formulations and solution techniques emphasizing efficient use of the computer for short-circuit calculations, computations of power flows under normal and emergency conditions and stability studies. Linear programming and optimization methods in power system planning.

**ECE(CSC) 640 PARALLEL PROCESSING. Preq.: CSC 506. 3(3-0) S.** Pipeline and vector computers, SIMD computers and performance enhancement, multiprocessing control and algorithms, example multiprocessors, data flow computer, VLSI-based architecture, recent research papers in parallel processing area.

**ECE 641 SEQUENTIAL MACHINES. Preq.: ECE(CSE) 520. 3(3-0) F.** Advanced topics in sequential machine theory and languages, Turing machines, decision problems.

**ECE 642 ARTIFICIAL NEURAL NETWORKS. Preq.: ECE 401 and ECE (CSE) 520. 3(3-0) S.** Artificial neural networks in pattern recognition, artificial intelligence, adaptive signal processing, self-organization and goal-directed behavior.

**ECE 643 ADVANCED COMPUTER ARCHITECTURE. Preq.: ECE 640. 3(3-0) F.** Multiprocessor interconnection and performance evaluation, multicomputer interconnections and associated problems, other architectural considerations, VLSI and computer architecture, application-directed architecture and case studies.

**ECE 644 FAULT TOLERANT COMPUTING. Preq.: ECE 520. 3(3-0) F.** Methods for designing highly reliable computer systems. Design project. Latest fault tolerance methods proposed in literature.

**ECE 646 HIGH PERFORMANCE VLSI DESIGN. Preq.: ECE 546. 3(3-0) S.** Design methods and principles for high-speed digital systems. ASIC design using advanced CAD tools for logic synthesis, layout generation and testability. Packaging issues and choices. Design and analysis of high-speed interconnect. Timing analysis and optimization. Advanced technologies and design methods.

**ECE 647 MULTIDIMENSIONAL DIGITAL SIGNAL PROCESSING. Preq.: ECE 513. 3(3-0) F.** Multidimensional signal processing techniques and algorithms. Multidimensional transforms, multidimensional digital filters, computational structures for implementation of multidimensional systems and multidimensional filter design.

**ECE 650 DESIGN AUTOMATION FOR VLSI. Preq.: ECE 505. 3(3-0) S.** VLSI CAD (computer-aids-to-design) tools research: physical design automation--layout, module generator, silicon compiler; logical design automation--CAD language, synthesis; simulation--circuit level, switch level, logic level, functional level; optimization techniques: graph theory, simulated annealing.

**ECE 651 DETECTION AND ESTIMATION THEORY. Preq.: ECE 514, ECE 401. 3(3-0) S.** Methods of detection and estimation theory as applied to communications, speech and image processing. Statistical description of signals and representation in time, spatial and frequency domains; Baysian methods, including Wiener, Kalman and MAP filters; performance measures; applications to both continuous and discrete systems.

**ECE 652 ADVANCED DIGITAL COMMUNICATIONS SYSTEMS. Preq.: ECE 515. 3(3-0) F. Alt. yrs.** Advanced concepts for modern digital communications systems. Signal acquisition and tracking. Channel characteristics and modeling. Adaptive processing for echo cancellation and channel equalization. Emphasis on computer simulation of systems using computer-aided-design environments.

**ECE 658 DIGITAL IMAGE PROCESSING. Preqs.: ECE 513, ECE 514. 3(3-0) F.** Advanced techniques of image processing. Image formation and perception, digitalization, Fourier transform domain processing, restoration and tomographic reconstruction.

**ECE 659 COMPUTER VISION. Preqs.: MA 501 and MA 502. 3(3-0) F.** Analysis of images by computers. Specific attention is given to analysis of the geometric features of objects in images, such as region size, connectedness and topology. Topics covered include: segmentation, template matching, motion analysis, boundary detection, region growing, shape representation, 3-D object recognition including graph matching.

**ECE(CSC) 671 ADVANCED COMPUTER PERFORMANCE MODELLING. 3(3-0) S.** (See computer science.)

**ECE(CSC,IE) 675 ADVANCES IN VOICE INPUT/OUTPUT COMMUNICATION SYSTEMS. 3(2-3) S.** (See industrial engineering.)

**ECE(CSC) 676 PERFORMANCE EVALUATION OF COMPUTER NETWORKS. Preq.: ECE(CSC) 571. 3(3-0) S.** Performance modelling of random access networks. Synthesis and analysis of local area networks, metropolitan area networks and packet radio networks. Routing and flow control in computer networks.

**ECE(CSC) 677 TELECOMMUNICATIONS NETWORK DESIGN. Preq.: ECE(CSC) 572. 3(3-0) S.** Analytic modelling and topological design of telecommunications networks, including centralized polling networks, packet switched networks, T1 networks, concentrator location problems, routing strategies, teletraffic engineering and network reliability.

**ECE 691, 692 SPECIAL STUDIES IN ELECTRICAL ENGINEERING. 3(3-0) F,S.** Opportunity for small groups of advanced graduate students to study topics in their special fields of interest under direction of members of the graduate faculty.

**ECE 693 INDIVIDUAL STUDIES IN ELECTRICAL ENGINEERING. 1-3 F, S.** Advanced topics of special interest to individual students under the direction of faculty members.

**ECE 699 ELECTRICAL ENGINEERING RESEARCH. Preqs.: Grad. standing in ECE, consent of advisor. Credits arranged.**

# Electrical Engineering

For a listing of graduate faculty and program information, see electrical and computer engineering.

# Elementary Education

For a listing of graduate faculty and program information, see curriculum and instruction.

# Engineering

The College of Engineering offers a program leading to the Master of Engineering. This is primarily an off-campus program. This Option B program has no residency, final oral examination or thesis requirements. Requirements also include two core courses and a minimum of three courses in a specific concentration. A student may receive up to 6 credit hours from project work approved by the advisor and directed by a member of the Graduate Faculty.

# English

**Degrees Offered: M.A. in English, M.S. in Technical Communication**

## GRADUATE FACULTY

*Associate Professor* C. A. Prioli, ***Interim Head of the Department***
*Professor* H. C. West, ***Director of Graduate Programs***
Box 8105, (919) 515-4107, west@social.chass.ncsu.edu
*Professor* C. R. Miller, ***Coordinator, M. S. in Technical Communication***

***William C. Friday Distinguished Professor:*** W. A. Wolfram

***Professors:*** B. J. Baines, G. W. Barrax, J. W. Clark Jr., J. D. Durant, J. A. Gomez, J. M. Grimwood, A. H. Harrison, M. T. Hester, L. T. Holley, L. H. MacKethan, W. E. Meyers, C. R. Miller, M. S. Reynolds, L. S. Rudner, L. Smith, J. J. Smoot, A. F. Stein, W. B. Toole III, J. N. Wall Jr., R. V. Young Jr.;
***Professors Emeriti:*** P. E. Blank Jr., L. S. Champion, M. Halperen, H. G. Kincheloe, A. S. Knowles, B. G. Koonce Jr., F. H. Moore, M. C. Williams, P. J. Williams;
***Associate Professors:*** L. J. Betts Jr., M. P. Carter, D. H. Covington, B. A. Fennell, J. Ferster, C. Gross, J. J. Kessel, M. F. King, D. L. Laryea, C. Nwankwo, A. M. Penrose, J. O. Pettis, D. B. Wyrick;
***Associate Professors Emeriti:***E. D. Clark Sr., E. P. Dandridge Jr., H. A. Hargrave, C. E. Moore, N. G. Smith;
***Assistant Professors:*** E. Y. Amiran, C. E. Chaski, A. Davis-Gardner, G. L. Hammill, D. J. Herman, S. B. Katz, R. C. Kochersberger Jr., R. C. Lane, B. S. Mehlenbacher, J. D. Morillo, J. E. Morrison, M. E. N. Orr, S. M. Setzer, L. R. Severin, J. J. Small, J. F. Thompson, J. M. Unsworth

## ENGLISH

The Master of Arts program offers course work in English and American literature, rhetoric and composition, linguistics and creative writing. It can serve either as a complete course of study or as the first year of study toward a doctoral degree at another institution.

### Admission Requirements

Applicants should submit GRE scores (General Aptitute Test) and a writing sample. Undergraduate preparation should include 24 semester hours in English, with 12 of these hours in upper-division literature courses.

### Requirements for M.A. in English

All students take a distribution of four courses, one each in English literature before 1660, English literature after 1660, American literature and a fourth category including composition theory, rhetoric, linguistics and literary theory. In addition, all students must take an introduction to research and bibliography, pass a language requirement, write a thesis and pass an oral exam on the thesis research.

Beyond these basic requirements, the program permits several emphases. Students interested primarily in the study of literature take additional courses in literature for a total of eight courses. Students interested in creative writing may substitute three workshops in creative writing for two literature courses and present a creative work or series of short works as their thesis. Students interested in the study and teaching of writing may take the composition concentration, which requires specific courses in composition, rhetoric and linguistics; the thesis is on a topic in one of these areas. Students interested in language structure and variation may take the linguistics concentration, which requires four courses in language study and five courses in literature. The thesis may be pure linguistics or its application in rhetoric, composition or literature.

### Student Financial Support

Teaching assistantships are available for promising students. These students take a course in teaching Freshman English (ENG 504) in the fall semester and, under the supervision of experienced teachers, devote half time in subsequent semesters to teaching freshman composition. ENG 504 gives graduate credit but does not count toward fulfillment of degree requirements.

### Other Relevant Information

The department offers two options for students who hold "A" certification from the N. C. Department of Public Instruction. The M.A. with Graduate ("G") Certification requires 30 semester hours of graduate credit in English, as outlined above, and 9 semester hours of graduate credit in Education. The M.A. with Sixth-Year Certification requires 60 semester hours of graduate study beyond the bachelor's degree, with course work in English, education and electives. Students and faculty in the Department of English are eligible for fellowships to participate in programs sponsored by the Folger Institute of Renaissance and Eighteenth-Century Studies, which is located in Washington, DC, at the Folger Shakespeare Library.

## TECHNICAL COMMUNICATION

The Master of Science in technical communication is designed to prepare professional communicators for advanced positions in industry and research organizations; with appropriate electives, students can prepare for careers in software documentation, environmental communication, industrial training in writing and editing, publications management and related areas.

**Admission Requirements**
Applicants should submit a resume and a writing sample. Prerequisites for the program are basic editing, technical writing and computer literacy (ENG 214, ENG 331, and CSC 200).

**Requirements for M.S. in Technical Communication**
The program requires 33 semester hours: four courses in English (in the fields of writing, rhetoric and linguistics), one in communication, one in visual media, one in technical methods and three electives selected to complement the student's professional goals. Students must also satisfy a requirement for one semester of professional work experience.

**Student Financial Support**
Teaching assistantships are available for promising students. These students take a course in teaching technical communication (ENG 603) in the fall semester and, under the supervision of experienced teachers, devote half time in subsequent semesters to teaching technical communication. ENG 603 gives graduate credit but does not count toward fulfillment of degree requirements.

***FOR GRADUATES AND ADVANCED UNDERGRADUATES***

*NOTE: The prerequisite for all 500-level English courses is upper division or graduate standing.*

**ENG 504 PROBLEMS IN COLLEGE COMPOSITION. Preq.: Grad. standing. 3(3-0) F.** Preparation for the profession of teaching composition and literature; emphases include assignment and course design, grading strategies and discussion management, as well as theories of rhetorical analysis, pedagogy and consideration of the institutional nature of English studies. Required of all teaching assistants in M.A. program.

**ENG 515 AMERICAN COLONIAL LITERATURE. 3(3-0) Alt. yrs.** Survey of American literature and thought from the beginning to the adoption of the constitution. Representative works such as travel and exploration reports, Indian captivity narratives, diaries, journals, auto biographies, sermons and poetry.

**ENG 521 ADVANCED TECHNICAL WRITING AND EDITING. Preqs.: ENG 214 and 321. 3(2-1) F,S.** Advanced study of specialized documents, technical editing and publications management for students planning careers in writing and editing. Course covers software documentation, manuals, indexing, style manuals, document design, legibility, readability testing, computerized production, on-screen documentation, desk-top publishing and publications management issues such as staffing, scheduling, cost-reduction, ethics and subcontracting.

**ENG 524 INTRODUCTION TO LINGUISTICS. Preq.: Grad. standing or 12 hrs. in ENG. 3(3-0) F.** Introduction to theoretical linguistics, especially for students in language, writing and literature curricula. Phonology, syntax, semantics, history of linguistics; relation of lingu istics to philosophy, sociology and psychology; application of theory to analysis of texts.

**ENG 525 VARIETY IN LANGUAGE. Preq.: Grad. standing or 12 hrs. in ENG. 3(3-0) S.** Language variation description, theory, method and application; focus on regional, social, ethnic and gender varieties; sociolinguistic analysis, basic discourse analysis.

**ENG 561 MILTON. 3(3-0) S.** An intensive reading of Milton with attention to background materials in the history and culture of seventeenth-century England.

**ENG 575 SOUTHERN WRITERS. 3(3-0) S.** An introduction to the literary culture of "the South," tracing the roots of the twentieth-century "Southern Renaissance" in such ante-bellum genres as plantation fiction, Southwestern humor, fugitive-slave narration and pastoral elegy. Examination of the persistence of "Southern" writing within the increasingly standardized culture of the United States.

**ENG 578 ENGLISH DRAMA TO 1642. Preqs.: ENG 261 and upper division or grad. standing. 3(3-0) F. Alt. yrs.** Elizabethan and Jacobean drama from 1580 to 1642, excluding Shakespeare. Coverage of such writers as Marlowe, Jonson, Webster, Beaumont and Fletcher, Heywood, Tourneur and Ford.

**ENG 579 RESTORATION AND 18TH-CENTURY DRAMA. 3(3-0) S. Alt. yrs.** Representative British plays of the period 1660-1780 studied in cultural, social and ethical contexts. Usually includes works by Etherege, Wycherley, Behn, Dryden, Otway, Vanburgh, Farquhar, Congreve, Lillo, Gay, Goldsmith and Sheridan.

**ENG 588 FICTION WRITING WORKSHOP. Preq.: ENG 488 or ENG 489 and CI. 3(3-0) F.** Advanced work in techniques of writing fiction for students with substantial experience in writing. Workshop sessions with students commenting on each other's work.

**ENG 589 POETRY WRITING WORKSHOP. Preq.: ENG 488 or ENG 489 and CI. 3(3-0) S.** Advanced work in techniques of writing poetry for students with substantial experience in writing. Workshop sessions with students commenting on each other's work.

**ENG 603 TEACHING METHODS FOR PROFESSIONAL WRITING. Preq.: Appointment as teaching assistant in Technical Communication or CI; Coreq.: ENG 604. 3(3-0) F.** Study and practice in techniques and approaches for teaching undergraduate technical writing courses; study of the uses and functions of writing in business, industry and research; practice in this kind of writing.

**ENG 604 WRITING: THEORY AND RESEARCH. 3(3-0) F,S.** Contemporary theory about the writing process, text structures and the functions of discourse. Attention to the assumptions and results of different research methods; cognitive, ethnographic and discourse analysis. Theories and research results relevant to audience, invention, coherence, revision, literacy, relations between oral and written discourse, content (including but not emphasizing the classroom context).

**ENG 605 EMPIRICAL RESEARCH IN COMPOSITION. Preq.: ENG 604. 3(3-0) S.** Reading and evaluation of empirical research in written composition; guided practice in qualitative and quanititative methods. Basic principles of research; problem definition, research design and statistical analysis, description and assessment of written products and processes.

**ENG 609 OLD ENGLISH LITERATURE. 3(3-0) S. Alt. yrs.** Study of Old English language with selections from important poems including *Beowulf*. Examination of the poetry in the light of various modern critical approaches.

**ENG 610 MIDDLE ENGLISH LITERATURE. 3(3-0) S. Alt. yrs.** A study of major works of medieval English literature (exclusive of Chaucer's *Canterbury Tales*) in historical context, as reflections of and influences on social and cultural change. Includes works such as *Sir Gawain and the Green Knight, Pearl*, Langland's *Piers Plowman* and Malory's *Morte d'Arthur*.

**ENG 620 16TH-CENTURY NON-DRAMATIC ENGLISH LITERATURE. 3(3-0) F.** Prose and poetry of the English Renaissance, excluding drama. Special attention to major authors, including Spenser and Sidney, and to intellectual, cultural and literary backgrounds and developments. Introduction to pertinent methods and issues of scholarly inquiry and critical interpretation.

**ENG 621 RHETORIC OF SCIENCE AND TECHNOLOGY. 3(3-0) S.** Study of the relationships among rhetoric, scientific knowledge and technological development and of changes in how these relationships have been understood historically. Practice in critical analysis of scientific and technical discourse. Consideration of scientific and technical language and of public controversy concerning science and technology.

**ENG(COM) 622 THE RHETORIC OF WRITTEN DISCOURSE. 3(3-0) S.** Contemporary rhetorical theory and its development from classical rhetoric; emphasis on the differences between oral and written communication and the relevance of traditional theory to the purposes and con straints of writing. Special attention to current issues: the revival of invention, argumentation and truth, contributions of research in composition.

**ENG(COM) 623 RHETORICAL CRITICISM: THEORY AND PRACTICE. Preq.: COM 321 or 411 or ENG 621 or 622. 3(3-0) F.** Development, achievements, limitation of major critical methods in the 20th century, including neo-Aristotelian, generic, metaphoric, dramatistic, feminist, social-movement, fantasy-theme and postmodern approaches. Criticism of political discourse, institutional discourse, discourses of law, medicine, religion, education, science, the media. Relations between rhetorical and literary criticism and other forms of cultural analysis.

**ENG 624 MODERN ENGLISH USAGE. Preq.: ENG 524. 3(3-0) F. Alt. yrs.** Analysis of what "usage" means, a look at the shaping of attitudes about English in the twentieth century and the service of language during that period to form social groups. Attention to the transmission of these attitudes and to the role of the schools in that transmission.

**ENG 625 LANGUAGE VARIATION RESEARCH SEMINAR. Preq.: ENG 525. 3(3-0) S.** Field-initiated research. Group and individual research topics focused on current sociolinguistic issues related to language variation and changes. Ethnographic and quantitative methods of analysis.

**ENG 626 HISTORY OF THE ENGLISH LANGUAGE. 3(3-0) F. Alt. yrs.** A survey of the growth and development of the language from its Indo-European beginnings to the present.

**ENG 627 LINGUISTICS AND LITERACY. Preq.: One course in linguistics or reading. 3(3-0) S.** Focus on the two-way relationship between linguistic theory and literacy. Metalinguistic awareness and the acquisition of literacy, orthography and phonology, oral vs. written language, oral vs. literate cultures, and metalinguistic assumptions in linguistic theory.

**ENG 630 17TH-CENTURY ENGLISH LITERATURE. 3(3-0) S.** A close examination of the literature of England from 1600 to 1660 with emphasis on major literary figures and movements, the development of important literary forms and genres and the relationship between the literary texts of this period and their philosophical, political and theological contexts. Some bibliographical and textural assignments.

Content and focus varies according to instructor's emphasis, but writers covered usually include Donne, Herbert, Crashaw, Marvell and Browne.

**ENG 640 HISTORY OF LITERARY CRITICISM. 3(3-0) F.** Survey of the history of literary criticism from Antiquity to the early Modern period. Introduction to major theoretical definitions of literature and modes of practical criticism. Close study of Aristotle's *Poetics*, Sidney's *Apology for Poetry*, Pope's *Essay on Criticism*, Coleridge's *Biographia Literaria*, Eliot's essays and other landmark works in the development of literary criticism.

**ENG 641 CONTEMPORARY LITERARY THEORY. 3(3-0) S.** Survey of major developments in twentieth-century literary theory. Introduction to central concepts, issues and theorists in contemporary literary criticism. Examination of range of modern critical practices. Study of relations between literary theory and such adjacent disciplines as linguistics, anthropology, social theory, psychology and philosophy.

**ENG 648 AFRICAN-AMERICAN LITERATURE. 3(3-0) F.** Advanced study of critical theories of African-American literature, the contexts of cultural criticism and twentieth-century novels of African-American writers within these frames.

**ENG 649 MODERN AFRICAN LITERATURE. 3(3-0) S. Alt. yrs.** A study of the works of the most important writers shaping modern African literature in English (and English translation). Selections from East, West, North and South Africa, spanning colonial through post-colonial Africa--from the literature of protest and culture conflict to that of disillusionment, re-appraisal and feminism.

**ENG 650 ENGLISH ROMANTIC PERIOD. 3(3-0) F.** A detailed study of the six major romantic poets--Blake, Wordsworth, Coleridge, Byron, Shelley, and Keats; some attention as well to the political, social and literary background and to a few minor writers and critics.

**ENG 651 CHAUCER. Preqs.: ENG 451 or equivalent. 3(3-0) F.** An intensive study of the works of Chaucer in the light of medieval literary traditions, medieval history and a variety of medieval and modern critical approaches.

**ENG 655 AMERICAN ROMANTIC PERIOD. 3(3-0) F.** Study of the literary culture of the United States from the 1820s through the 1860s, setting works of transcendentalists and other romantic writers within sociohistorical contexts. Consideration of writing by women, slave narratives and popular fiction as well as such major figures as Emerson, Hawthorne, Thoreau and Melville.

**ENG 658 STUDIES IN SHAKESPEARE. Preqs.: ENG 486 or ENG 487 or equivalent. 3(3-0) F,S.** An intensive study of a particular phase of the Shakespeare canon. Emphasis normally on one dramatic genre (tragedy, comedy, history), but occasionally the focus may be more limited. Students may register for credit for a maximum of six hours.

**ENG 660 VICTORIAN POETRY AND CRITICAL PROSE. 3(3-0) S.** Studies in the literature of Victorian England: 1837-1901; the major poets and essayists, movements and questions in their historical contexts, religious, political and aesthetic.

**ENG 662 18TH-CENTURY ENGLISH LITERATURE. 3(3-0) F.** British writers of the period 1600-1790 studied in historical and cultural contexts. Usually includes works by Dryden, Swift, Pope, Defoe, Mandeville, Boswell and Johnson, but addition of other significant writers possible.

**ENG 663 18TH-CENTURY ENGLISH NOVEL. 3(3-0) S. Alt. yrs.** Selected British novels of the Restoration and eighteenth century from a variety of contemporary critical perspectives. Such writers as Fielding, Richardson, Sterne, Burney, Smollett and Austen.

**ENG 664 VICTORIAN NOVEL. 3(3-0) F. Alt. yrs.** Study of selected British novels published between 1837 and 1901 in the contexts of the development of the genre, the historical period and current literary theory. Such writers as Dickens, Thackeray, Bronte, Trollope, Eliot, Meredith and Hardy.

**ENG 665 AMERICAN REALISM AND NATURALISM. 3(3-0) S.** Study of the literary culture of the United States from the 1860s to the early 1900s with emphasis on fiction by such realists and naturalists as Twain, Howells, Chesnutt, James, Crane, Wharton, Dreiser and Norris. Inclusion of prose of writers such as Adams and DuBois possible.

**ENG 670 20TH-CENTURY BRITISH PROSE. 3(3-0) F. Alt. yrs.** An examination of British fiction of this century and relationship of significant intellectual, historical and political issues. Inclusion of such writers as Joyce, Conrad, Woolf, Lawrence, Beckett and Murdoch possible but also post-colonial novelists as well.

**ENG 671 20TH-CENTURY BRITISH POETRY. 3(3-0) S. Alt. yrs.** The development of English poetry from its late Victorian phase through Modernism to the present post-war scene. Inclusion of such writers as Hardy, Yeats, Eliot, Smith, Auden, Larkin, Heaney, Wolcott and Hill possible.

**ENG 672 MODERN BRITISH DRAMA. 3(3-0) F. Alt. yrs.** Survey of modern British drama from its beginnings at the turn of the century to the present.

**ENG 673 MODERN AMERICAN DRAMA. 3(3-0) F. Alt. yrs.** A survey of modern American drama centering on major figures.

**ENG 675 20TH-CENTURY AMERICAN PROSE. 3(3-0) F. Alt. yrs.** An examination of representative American writers of the novel and short fiction.

**ENG 676 20TH-CENTURY AMERICAN POETRY. 3(3-0) S. Alt. yrs.** The development of modern American poetry from the rebellion against the romantic and genteel verse of the 1890's; special attention to Robinson, Frost, Pound, Williams, Stevens and Ransom.

**ENG 678 LITERARY POSTMODERNISM. 3(3-0) S. Alt. yrs.** Post-1945 literary theory in relationship with representative avant-garde writers. Theoretical and argumentative essays in such areas as chaos theory, deconstruction, feminism and the limits of fiction. Fiction readings by Calvino, Pynchon, Barthelme, Cortazar and others.

**ENG 682 STUDIES IN LITERATURE. 3(3-0) F,S.** Variation in content. Selected problems and issues in literature.

**ENG 683 STUDIES IN COMPOSITION AND RHETORIC. 3(3-0) F,S.** Variation in content. Selected problems and issues in composition and rhetoric.

**ENG 684 STUDIES IN LINGUISTICS. 3(3-0) F,S.** Variation in content. Selected problems and issues in linguistics.

**ENG 685 STUDIES IN FILM. 3(3-0) F,S.** Variation in content. Selected problems and issues in film.

**ENG 686 STUDIES IN THEORY. 3(3-0) F,S.** Variation in content. Selected problems and issues in theory.

**ENG 688 STUDIES IN CREATIVE WRITING. Preq.: ENG 588 or 589. 3(3-0) S.** Techniques special to a particular kind of writing within the traditional genres of prose, poetry or drama, such as "Speculative Fiction" or "The Long Poem or Poetic Sequence." Various subjects.

**ENG 690 DIRECTED READINGS. 1-6 F,S,Sum.** Intensive study of a specific topic from the various specializations of the English faculty. Negotiation between

the student and the director for variable credit and approved by the Director of Graduate Studies.

**ENG 698 BIBLIOGRAPHY AND METHODOLOGY. 1-3.** Intensive study of the bibliography and methodology of literary research. Required of all graduate students in English.

**ENG 699 THESIS RESEARCH. Preq.: Consent of graduate adviser. Credits Arranged. F,S.** Independent investigation of a problem in literature, literary theory, linguistics, composition, rhetoric, creative writing or technical communication directed by a graduate faculty member and leading to the writing of a master's thesis.

# English Education

For a listing of graduate faculty and program information, see curriculum and instruction.

# Entomology

**Degrees Offered: Ph.D., M.S., Master of Agriculture**

**GRADUATE FACULTY**

*Professor* J. D. Harper, ***Head of the Department***
*Professor* W. M. Brooks, ***Director of Graduate Programs***
Box 7613, (919) 515-3771

***Blanton J. Whitmire Professor:*** C. Schal
***Philip Morris Professor:*** J. W. Van Duyn
***William Neal Reynolds Professors:*** F. L. Gould, G. G. Kennedy

***Professors:*** J. T. Ambrose, C. S. Apperson, J. J. Arends, R. C. Axtell, J. S. Bacheler, J. R. Baker, J. R. Bradley Jr., R. L. Brandenburg, L. L. Deitz, F. P. Hain, R. J. Kuhr, J. R. Meyer, B. M. Parker, K. A. Sorensen, P. S. Southern, R. E. Stinner, C. G. Wright;
***Visiting Professor:*** F. L. Hastings;
***Adjunct Professors:*** C. Y. Kawanishi, P. M. Marsh;
***Professors Emeriti:*** W. V. Campbell, M. H. Farrier,K. L. Knight, W. J. Mistric Jr., H. B. Moore Jr., H. H. Neunzig, R. L. Rabb, R. L. Robertson, T. J. Sheets;
***Associate Professors:*** R. M. Roe, J. F. Walgenbach;
***Associate Professor (USDA):*** D. M. Jackson;

*Associate Professor Emeriti:* R. C. Hillmann;
*Assistant Professor:* M. E. Barbercheck;
*Assistant Professor (USDA):* D. W. Keever;
*Adjunct Assistant Professors:* R. C. McDonald, C. A. Nalepa

## ASSOCIATED FACULTY OF THE PROGRAM

*Professors:* W. C. Dauterman, H. M. Linker

Course offerings or research facilities are available in the following areas: agricultural entomology, apiculture, behavior, ecology, forest entomology, host-plant resistance, invertebrate pathology, medical and veterinary entomology, pest management, physiology, population dynamics, soil entomology, urban entomology, systems analysis and systematics.

### Admission Requirements

A minimum score of 1000 (verbal plus quantitative) is necessary for admission to the M.A. or M.S. program while a score of 1100 is required for the Ph.D. program. Students are expected to have a background in biology in addition to appropriate courses in chemistry, biochemistry, mathematics, and physics. A "B" average (3.0 GPA) is required in biology courses and an overall 3.0 GPA during the last 2 years of the undergraduate program.

### Student Financial Support

Graduate assistantships and other forms of aid are available to students as described in the Fellowships and Graduate Assistantships section of the *Graduate Catalog*.

### Other Relevant Information

Admission is permitted only after acceptable applicants have secured an advisor and appropriate financial support. All students are expected to begin their research as soon as possible upon arrival in the department.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**ENT 402 FOREST ENTOMOLOGY.**
**ENT(ZO) 425 GENERAL ENTOMOLOGY.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ENT 502 INSECT SYSTEMATICS. Preq.: ENT 425 or equivalent. 4(2-4) F.**
Survey of the diversity of insect biology and structure with emphasis upon the identification of adults; includes speciation, evolutionary relationships, approaches to classification, nomenclature, zoogeography and techniques of collection.

**ENT 503 INSECT MORPHOLOGY AND PHYSIOLOGY. Preqs.: CH 221, 223 and ENT 425 or equivalent. 4(3-3) S.** The morphology, histology and function of the organ systems of insects. Basic physiological principles discussed in the context of insect growth and development. Laboratory to give students practical experience with modern physiological techniques.

**ENT(ZO) 509 ECOLOGY OF STREAM INVERTEBRATES. 4(2-6) S. Alt. yrs.** (See zoology.)

**ENT 520 INSECT PATHOLOGY. Preqs.: ENT 425 and MB 401 or equivalent. 3(2-3) S. Alt. yrs.** A treatment of the noninfectious and infectious diseases of insects, the etiological agents and infectious processes involved, immunological responses and applications.

**ENT 531 INSECT ECOLOGY. Preqs.: ENT 425 and BO (ZO) 560 or equivalent. 3(2-2) F. Alt. yrs.** The interrelationships among insects and components of their effective environments which result in dynamic spatial and temporal patterns of particular species. Also, the diverse roles of insects in the structure and function of communities and ecosystems.

**ENT 541 IMMATURE INSECTS. Preq.: ENT 502 or equivalent. 3(1-4) F. Alt. yrs.** Biology and taxonomy of immature insects with emphasis on identification of the larval stage of endopterygote orders. A collection of immatures and associated reared adults required.

**ENT 550 FUNDAMENTALS OF INSECT CONTROL. Preq.: ENT 312 or 301. 3(2-2) F.** The principles underlying modern methods for protecting food, clothing, shelter and health from insect attack.

**ENT 562 INSECT PEST MANAGEMENT IN AGRICULTURAL CROPS. Preq.: ENT 425 or CI. 3(3-0) S. Alt. yrs.** Critical review of the biology and ecology of representative beneficial and injurious insects and arachnids of agricultural crops and the advantages and limitations of advanced concepts of their management in se-lected agroecosystems.

**ENT(FOR) 565 ADVANCED FOREST ENTOMOLOGY. Preq.: ENT 402 or ENT 502 or CI. 3(2-2) S. Alt. yrs.** Coverage of the important insect pests of forest and shade trees including regeneration pests, defoliating insects, inner-bark borers, wood borers, sucking insects, and bud, twig and root feeding insects. Detailed examination of concepts in forest pest management and population dynamics.

**ENT(ZO) 582 MEDICAL AND VETERINARY ENTOMOLOGY. Preqs.: ENT 425 and ZO 315 or equivalent. 3(2-3) S. Alt. yrs.** The morphology, taxonomy,

biology and control of the arthropod parasites and disease vectors of man and animals. The ecology and behavior of vectors in relation to disease transmission and control.

**ENT 590 SPECIAL PROBLEMS. Preq.: CI. Credits Arranged. F, S.** Original research on special problems in entomology not related to a thesis problem. Provides experience and training in research.

**ENT 591 SPECIAL TOPICS IN ENTOMOLOGY. Preq.: Grad. standing. 1-3 F,S.** A variable credit lecture and laboratory series offering topics such as advanced beekeeping, morphology, physiology, systematics, behavior, biological control, nursery and ornamental pests, host plant resistance, information retrieval, biological monitoring and sampling, population modelling, extension entomology, computer methods and urban, forest and stored product pests.

**ENT 592 AGRICULTURAL ENTOMOLOGY PRACTICUM. Preq.: Economic entomology (ENT 562 recommended). 3(0-9) Sum. Alt. yrs.** Practical experience in research, extension and commercial aspects of insect pest management on a broad range of agricultural crops under actual field conditions. Class meets 9 hours each Friday for 10 weeks from early June to mid-August. Students should register for second summer session.

*FOR GRADUATES ONLY*

**ENT 622 INSECT TOXICOLOGY. Preqs.: ENT 550, BCH 551 or equivalent. 3(2-3) S. Alt. yrs.** The relation of chemical structure to insect toxicity, the mode of action of toxicants used to kill insects, the metabolism of insecticides in plant and animal systems, the selectivity within the cholinesterase inhibitors and other selective mechanisms and the analysis of insecticide residues.

**ENT 690 SEMINAR. Preq.: Grad. standing in ENT or closely allied fields. 1(1-0) F,S.** Discussion of entomological topics selected and assigned by seminar chair.

**ENT 699 RESEARCH. Credits Arranged. F, S.** Original research in connection with thesis problem in entomology.

# Fiber and Polymer Science

**Degree Offered: Ph.D.**

## GRADUATE FACULTY

*Charles A. Cannon Professor* S. P. Hersh, ***Program Director***
Box 8301, (919) 515-3057, sol_hersh@ncsu.edu

***Professors:*** R. L. Barker, S. K. Batra, K. R. Beck, D. R. Buchanan, C. L. Bumgardner, J. A. Cuculo, A. H. El-Shiekh, H. S. Freeman, R. E. Fornes, P. L. Grady, B. S. Gupta, H. B. Hopfenberg, L. A. Jones, T. J. Little, C. D. Livengood, R. McGregor, G. N. Mock, M. H. M. Mohamed, H. G. Olf, C. B. Smith, M. W. Suh, M. H. Theil, C. Tomasino, P. A. Tucker Jr., S. C. Winchester, C. F. Zorowski;
***Professors Emeriti:*** J. F. Bogdan, D. M. Cates, D. W. Chaney, R. D. Gilbert, D. S. Hamby, P. R. Lord, H. A. Rutherford, V. T. Stannett, W. C. Stuckey Jr., W. K. Walsh, W. M. Whaley, R. W. Work;
***Associate Professors:*** C. M. Balik, P. Banks-Lee, T. G. Clapp, T. F. Gilmore, H. Hamouda, S. M. Hudson, W. Oxenham, C. M. Pastore, S. T. Purrington, J. W. Rucker, A. E. Tonelli;
***Associate Professors Emeriti:*** T. H. Guion, T. G. Rochow;
***Assistant Professors:*** T. K. Ghosh, H. H. A. Hergeth, W. J. Jasper, J. P. Rust, A. M. Seyam;
***Adjunct Assistant Professors:*** A. C. Bullerwell

Fiber and polymer science is a multidisciplinary program bringing together the disciplines of mathematics, chemistry and physics and the application of engineering principles for the development of independent scholars versed in all aspects of fiber materials science. Thus, fiber and polymer science is concerned with the formation of and the mechanical, physical and chemical properties of polymeric materials, fibers produced from them, fiber assemblies in one-, two- and three-dimensional forms, and fiber reinforced composites, as well as the utilization thereof.

### Admission Requirements

Students majoring in the physical sciences, engineering, mathematics, textiles and having a master's degree will normally qualify for admission. For exceptionally qualified students, the master's degree requirement may be waived, and the student can be admitted directly into the Ph.D. program.

### Doctoral Degree Requirements

There are no fixed credit-hour requirements for the Doctor of Philosophy degree. Students are admitted to candidacy for the Ph.D. degree after passing a series of

written cumulative examinations, completing a scholarly critique of existing knowledge in the field of specialization, and orally defending a research proposal. A written examination in a minor field may be accepted in place of the scholarly critique. They must also have passed an English technical writing course during their college career.

**Student Financial Support**
Financial aid in the form of assistantships and fellowships is normally available for all full-time students.

**Other Relevant Information**
In 1991, the College of Textiles moved to its new 298,000 square foot complex, now valued at over $50 million, which houses exceptional teaching, research, computer, and library facilities. With a graduate faculty of 45 and over $7,000,000 spent on research in 1993, opportunities abound ranging from preserving the local environment (research sponsored by EPA) to exploring outer space (Mars Mission Research Center sponsored by NASA).

*COURSE OFFERINGS* (See departmental listing for descriptions. Extensive use may be made of graduate course offerings in other colleges on campus when developing the minor field.)

## *GENERAL COURSES*

T 402 INTRODUCTION TO THE THEORY AND PRACTICE OF FIBER FORMATION.
TC(CH) 461 INTRODUCTION TO FIBER-FORMING POLYMERS.
TC 504 FIBER FORMATION–THEORY AND PRACTICE.
TC(CH,MAT) 562 PHYSICAL CHEMISTRY OF HIGH POLYMERS–BULK PROPERTIES.
TES 500 FIBER AND POLYMER MICROSCOPY.
TES 505 TEXTILE INSTRUMENTATION AND CONTROL SYSTEMS.
TES 561 MECHANICAL AND RHEOLOGICAL PROPERTIES OF FIBROUS MATERIAL.
TES(MAT) 563 CHARACTERIZATION OF STRUCTURE OF FIBER FORMING POLYMERS.
TC 591 SPECIAL TOPICS IN TEXTILE SCIENCE.
TES(TC) 691 SPECIAL TOPICS IN FIBER SCIENCE.

## *COURSES IN AREAS OF SPECIALIZATION*

*Polymer Chemistry and Synthesis*
TC 520 CHEMISTRY OF DYES AND COLOR.
TC 521 DYE SYNTHESIS LABORATORY.
TC 525 DYEING CELLULOSE.
TC 530 THE CHEMISTRY OF TEXTILE AUXILIARIES.
TC 561 ORGANIC CHEMISTRY OF HIGH POLYMERS.
TC(CHE) 671 SPECIAL TOPICS IN POLYMER SCIENCE.

*Polymer Physics and Physical Chemistry*
TES 500 FIBER AND POLYMER MICROSCOPY.
TC 504 FIBER FORMATION--THEORY AND PRACTICE.
TC 505 THEORY OF DYEING.
TC(CH,MAT) 562 PHYSICAL CHEMISTRY OF HIGH POLYMERS--BULK PROPERTIES.
TC(CH,MAT) 662 PHYSICAL CHEMISTRY OF HIGH POLYMERS--SOLUTION PROPERTIES.
TC(CHE) 569 POLYMERS, SURFACTANTS AND COLLOIDAL MATERIALS.
TC(CHE) 570 RADIATION CHEMISTRY AND TECHNOLOGY OF POLYMERIC SYSTEMS.
TC(CHE) 669 DIFFUSION IN POLYMERS.
TES 562 PHYSICAL PROPERTIES OF FIBER FORMING POLYMERS, FIBERS AND FIBROUS STRUCTURES.
TES(TC) 691 SPECIAL TOPICS IN FIBER SCIENCE.

*Mechanics of Textile Materials and Processes*
TAM 610 YARN PRODUCTION PROPERTIES.
TES(TAM) 520 YARN PROCESSING DYNAMICS.
TES 549 WARP KNIT ENGINEERING AND STRUCTURAL DESIGN.
TES(TAM) 555 PRODUCTION MECHANICS AND PROPERTIES OF WOVEN FABRICS.
TES 565 TEXTILE COMPOSITES.
TES(TAM) 640 PHYSICAL AND MECHANICAL PROPERTIES OF KNITTED FABRICS.
TES(TAM) 651, 652 FABRIC DEVELOPMENT AND CONSTRUCTION.
TES(TAM) 663 MECHANICS OF TWISTED STRUCTURES.
TES(TAM) 664 MECHANICS OF FABRIC STRUCTURES.

# Food Science

**Degrees Offered: Ph.D., M.S.**

## GRADUATE FACULTY

*William Neal Reynolds Professor* K. R. Swartzel, *Interim Head of the Department*
*Associate Professor* D. K. Larick, *Director of Graduate Programs*
Box 7624, (919) 515-2971

*Graduate Alumni Distinguished Professor and William Neal Reynolds Professor:*
T. R. Klaenhammer
*William Neal Reynolds Professor:* H. E. Swaisgood;

*Professors:* R. E. Carawan, D. E. Carroll Jr., G. L. Catignani, E. A. Foegeding, P. M. Foegeding, D. D. Hamann, A. P. Hansen, H. M. Hassan, H. R. Horton, F. T. Jones, C. J. Lackey, T. C. Lanier, J. L. Oblinger, D. H. Pilkington, S. J. Schwartz, B. W. Sheldon, L. G. Turner, D. R. Ward, C. T. Young;
*Professors (USDA):* H. P. Fleming, R. F. McFeeters, H. E. Pattee, T. H. Sanders, W. M. Walter Jr.;
*Adjunct Professor:* J. P. Adams;

*Professors Emeriti:* L. W. Aurand, H. R. Ball Jr., T. A. Bell, T. N. Blumer, E. S. Cofer, H. B. Craig, M. E. Gregory, M. W. Hoover, H. N. Jacobson, I. D. Jones, V. A. Jones, W. M. Roberts, M. L. Speck, F. R. Tarver Jr., F. B. Thomas, F. G. Warren;
*Associate Professors:* J. C. Allen, L. C. Boyd, J. E. Rushing;
*Assistant Professor:* P. A. Curtis

The department's professional activities include teaching, research, and extension functions. The program provides an educational, research, and informational center in food science for North Carolina and the nation. The department also houses two research centers, the Southeastern Dairy Foods Research Center and the Center for Aseptic Processing and Packaging Studies. Course offerings and research facilities are available in the following areas: chemistry-biochemistry, engineering, microbiology, nutrition and processing technology.

### Admissions Requirements

To be admitted, a student should be a graduate of an accredited program in food science or the equivalent. Graduates of other majors can be admitted but will be required to make up certain undergraduate deficiencies without graduate credit. The best qualified applicants will be accepted up to the number of spaces that are available or new students.

### Master's Degree Requirements

A master's program must include courses from at least 2 of the following categories: chemistry-biochemistry, engineering, microbiology, nutrition and processing technology. No fewer than 6 credits must be at the 600 level. A minor is required. Credits for the minor are variable depending upon the requirements of the minor department or program.

### Doctoral Degree Requirements

A doctoral program must include courses from at least 3 of the categories listed above (or equivalent courses at another university). Courses must be selected from groups embracing one principal subject of concentration, the major, and from a cognate field, the minor. Total credits and credits for the minor are not specified and will vary depending on the needs of the student. All doctoral students are required to pass a departmental administered written preliminary exam, designed to evaluate a Ph.D. student's general knowledge and comprehension of food science.

### Student Financial Support

Graduate assistantships and other forms of student aid available to students in this program are described elsewhere in the Graduate Catalog.

**Other Relevant Information**
Students are encouraged to make personal contact with individual faculty whose research program is of interest to them. The department provides a *Graduate Studies in Food Science* brochure describing each faculty member's program for this purpose.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

FS(NTR) 400 PRINCIPLES OF HUMAN NUTRITION.
FS 402 FOOD CHEMISTRY.
FS 403 FOOD ANALYSIS.
FS(MB) 405 FOOD MICROBIOLOGY.
FS 416 QUALITY CONTROL OF FOOD PRODUCTS.
FS 421 FOOD PRESERVATION.
FS 425 PROCESSING DAIRY PRODUCTS.
FS(HS) 462 POSTHARVEST PHYSIOLOGY.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**FS 504 FOOD PROTEINS AND ENZYMES. Preq.: FS 402 or BCH 451. 3(2-3) F. Alt. yrs.** An advanced course in food chemistry with emphasis on proteins and enzymes of particular importance to foods. Protein interactions and their effect on the physical-chemical characteristics of a product. Particular emphasis on the preparation and kinetic properties of immobilized enzymes and their use as biochemical reactors in processing operations or as specific electrodes for analytical purposes.

**FS 507 FOOD TOXICOLOGY. Preq.: BCH 451. 2(2-0) F. Alt. yrs.** Basic principles of toxicology with primary emphasis on food components. Overview of allergenic and toxic constituents of plant, animal and fungal origin. Safety of food additives, environmental contaminants, pesticides and antibiotic residues. Food safety assessment including discussion of procedures, laws and regulations.

**FS 509 FOOD LIPIDS. Preq.: FS 402. 1(1-0) S. Alt. yrs.** Chemical, physical and functional properties of lipids in foods. Chemistry and technology of fats and oils, including nutritional and safety considerations. Changes during processing and storage.

**FS(MB) 525 FERMENTATION MICROBIOLOGY. Preqs.: BCH 451, MB 401; Coreq.: GN 411. 3(3-0) S. Alt. yrs.** Fermentation bioprocessing and the characteristics, function and ecology of responsible microorganisms. Fermentative activities, growth responses and culture interactions related to the metabolism, physiology and genetics of the lactic acid bacteria and selected yeasts and molds.

Current developments in starter culture technology and genetics; application to food and industrial fermentations.

**FS(NTR) 530 HUMAN NUTRITION. Preqs.: FS 400 or NTR 415 or 419; BCH 451. 3(3-0) S. Alt. yrs.** Biochemical and physiological bases of nutrition. Human nutrient requirements, assessment of nutritional status, clinical and subclinical disorders resulting from nutrient deficiencies or inadequacies.

**FS 551 FOOD INGREDIENT TECHNOLOGY IN PRODUCT DEVELOPMENT. Preqs.: FS 402, FS 405, FS 421. 4(3-3) S.** Chemistry and functional properties of the major food ingredient materials. Legal and regulatory restrictions, as well as consumer biases, which exist with respect to selection of ingredients, package materials, processes and labeling statements. Skills and techniques needed for efficiently and successfully conducting food product development projects in a competitive corporate setting.

**FS 552 PRINCIPLES OF SENSORY EVALUATION. Preq.: FS 402. 3(2-3) S. Alt. yrs.** Theory, principles and methods for measuring sensory properties of foods using sensory evaluation, Institute of Food Technologist guidelines, headspace analysis by gas chromatography and descriptive analysis.

**FS 580 FOOD KINETICS. Preqs.: FS 212, FS 402, FS 405, MA 212 or CI. 3(3-0) S. Alt. yrs.** Basic and applied kinetic principles, development and use of kinetic data of food components, food processing system design, system modeling, system evaluation and storage stability considerations.

**FS(BAE) 585 FOOD RHEOLOGY. Preqs.: FS 331 or MAE 314. 3(2-3) F.** Principles and methods for measuring rheological properties. Theories of elastic, viscous, viscoelastic and viscoplastic behavior and relationships to food texture and commodity damage during harvest, handling and processing. Influence of time, composition and processing.

**FS 591 SPECIAL PROBLEMS IN FOOD SCIENCE. Preq.: Grad. or sr. standing. Max. 6. F,S,Sum.** Analysis of scientific, engineering and economic problems of current interest in foods. The problems designed to provide training and experience in research.

*FOR GRADUATES ONLY*

**FS 605 PHYSICAL AND CHEMICAL PROPERTIES OF MUSCLE FOODS. Preq.: BCH 453/553. 3(3-0) S. Alt. yrs.** Current knowledge and analysis of the literature in muscle biology and muscle foods. Major topics: 1) muscle composition, structure and contraction, 2) structural/functional relationships in muscle

proteins, 3) biological control of myofibrillar protein isoforms and 4) conversion of muscle to meat products.

**FS(NTR) 606 VITAMIN METABOLISM. Preqs.: ANS(NTR,PO) 415 and BCH 554. 2(2-0) F. Even yrs.** Structures, chemical and physical properties, functions, deficiency symptoms, distribution, absorption, transport, metabolism, storage, excretion and toxicity of the vitamins in humans and domestic animals. Nutritional significance of the essential fatty acids and the metabolism of prostaglandins, prostacyclins and leucotrienes.

**FS 680 SEMINAR IN FOOD SCIENCE. 1(1-0) F,S.** Preparation and presentation of scientific papers, progress reports and research and special topics of interest in foods.

**FS 691 SPECIAL RESEARCH PROBLEMS IN FOOD SCIENCE. Credits Arranged. F,S,Sum.** Directed research in a specialized phase of food science designed to provide experience in research methodology and philosophy.

**FS 699 RESEARCH IN FOOD SCIENCE. Credits Arranged. F, S, Sum.** Original research preparatory to the thesis for the Master of Science or the dissertation for the Doctor of Philosophy degree.

# Forestry

**Degrees Offered: Ph.D., M.S., Master of Forestry, Master of Wildlife Biology, Master of Natural Resources Administration**

**GRADUATE FACULTY**

*Professor* A. W. Cooper, *Head of the Department*
*Professor* D. L. Holley Jr., *Director of Graduate Programs*
Box 8002, (919) 515-2892, holley@cfr.cfr.ncsu.edu

*Distinguished University Professor:* E. B. Cowling

*Professors:* H. L. Allen Jr., P. T. Bromley, R. I. Bruck, H. A. Devine, P. D. Doerr, E. C. Franklin, D. J. Frederick, L. F. Grand, F. P. Hain, A. E. Hassan, L. E. Hinesley, J. B. Jett Jr., R. C. Kellison, S. Khorram, J. G. Laarman, R. A. Lancia, R. Lea, R. L. Noble, R. R. Sederoff, J. D. Wellman, E. A. Wheeler, A. G. Wollum, II;
*Professors (USDA):* F. E. Bridgwater Jr., F. W. Cubbage, D. E. Moreland, G. Namkoong;
*Adjunct Professors:* G. L. Debarr, G. F. Dutrow, P. Farnum, J. D. Hair, J. R.

Jorgensen, S. Linder, R. W. Stonecypher;
*Professors Emeriti:* D. A. Adams, C. B. Davey, J. W. Duffield, E. L. Ellwood, W.L. Hafley, W. T. Huxster Jr., J. O. Lammi, W. D. Miller, L. A. Nelson, T. O. Perry, R. J. Preston, P. A. Sanchez, B. J. Zobel;
*Associate Professors:* R. C. Abt, H. V. Amerson, R. R. Braham, J. D. Gregory, E. J. Jones, S. E. McKeand, R. A. Powell, J. P. Roise, A. M. Stomp, R. J. Weir, B. E. Wilson;
*Research Associate Professor:* W. S. Dvorak;
*Associate Professors (USDA):* M. A. Buford, P. M. Dougherty;
*Associate Professor (USDI):* W. J. Fleming;
*Adjunct Associate Professors:* D. L. Bramlett, R. G. Campbell, J. E. de Steiguer, C. C. Lambeth, D. L. Loftis, J. N. Woodman;
*Assistant Professors:* G. B. Blank, B. Goldfarb, L. T. Henry, W. D. Smith;
*Research Assistant Professors:* B. Liu, D. M. O'Malley, R. W. Whetten;
*Assistant Professor (USDI):* J. A. Collazo;
*Visiting Assistant Professors:* S. C. McKelvey, T. H. Shear
*Adjunct Assistant Professors:* M. C. Conner, L. J. Frampton Jr., T. P. Holmes, W. E. Ladrach, R. B. McCullough, R. C. Purnell, K. R. Roeder, M. M. Schoeneberger, D. N. Wear

The department offers training in all of the major sub-disciplines of forest-related science and management. Considerable flexibility is allowed in developing graduate programs tailored to the student's objectives.

### Admission Requirements

The GPA on previous work must exceed 3.0 and GRE scores on verbal and quantitative combined must exceed 1000. At the department's discretion, an applicant may be considered for provisional admission. At least one faculty member in an applicant's area of interest must be willing to serve as major professor.

### Master's Degree Requirements

Course work requirements range from 30 to 36 credits depending on the specific master's option. Students without an appropriate background will require additional preparatory work.

### Doctoral Degree Requirements

Students must complete a Master's degree before entering the Ph.D. program. However, students doing outstanding work at the master's level may request to have their degree objective changed to Ph.D. after one year in a master's program. In addition to the dissertation, programs typically require 30 credits beyond the master's degree.

**Student Financial Support**
Merit-based research assistantships are available every year in most fields of specialization. Stipend levels allow students to graduate without incurring significant debt. Those who begin without an assistantship are considered for funding as projects become available.

**Other Relevant Information**
Every graduate student must meet the following three requirements: (1) register for a 1-credit research methodology course, FOR 689, in the first semester, (2) meet a one-time teaching requirement by assisting a faculty member teach an undergraduate forestry course and (3) begin the final oral exam with a seminar to the Department based on work accomplished during the graduate program.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

FOR 401 FOREST HYDROLOGY AND WATERSHED MANAGEMENT.
FOR(FW) 404 FOREST WILDLIFE MANAGEMENT.
FOR 405 FOREST MANAGEMENT.
FOR 406 FOREST INVENTORY, ANALYSIS AND PLANNING.
FOR 411 FOREST TREE IMPROVEMENT.
FOR 412 FOREST TYPES OF THE SOUTHEAST.
FOR 422 FOREST BUSINESS: CONSULTING AND PROCUREMENT.
FOR(WPS) 423 FOREST MACHINERY AND SYSTEMS.
FOR(WPS) 434 MANAGEMENT DECISION MAKING IN FORESTRY AND WOOD PRODUCTS.
FOR 472 RENEWABLE RESOURCE POLICY AND MANAGEMENT.
FOR 491 SENIOR PROBLEMS IN FORESTRY AND RELATED NATURAL RESOURCES.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**FOR 510 QUANTITATIVE FOREST GENETICS METHODS. Preqs.: GN 506, ST 512. 3(3-0) F. Alt. yrs.** Fundamental principles and procedures for partitioning experimental variance, estimating parameters of interest from different mating schemes and experimental designs and their uses in making tree breeding decisions.

**FOR 511 TREE IMPROVEMENT RESEARCH TECHNIQUES. Preq.: FOR 411 or GN 411. 3(1-4) S. Alt. yrs.** Research methods involved in forest tree breeding and genetics programs. Emphasis on laboratory, greenhouse and field research techniques. Stress also on summary and presentation of research results.

**FOR 512 FOREST ECONOMICS. Preq.: Basic course in economics. 3(3-0) S. Alt. yrs.** Economics applied to problems in forest management, including timber demand and supply models, optimal rotation length, benefit-cost analysis of forestry

projects, impacts of forest taxation and consideration of non-market forest goods and services.

**FOR 534 ADVANCED FOREST MANAGEMENT PLANNING. Preq.: FOR 405 or FOR 434 or OR 501; Coreq.: FOR 572A. 3(3-0) S. Alt. yrs.** History, principles, structures and use of modern forest management planning and decision-making techniques. Emphasis on optimization procedures and public forest management.

**FOR 540 ADVANCED DENDROLOGY. Preq.: BO 403 or FOR 212. 3(2-3) S. Alt. yrs.** Identification and life histories of native and naturalized woody plants. Use of taxonomic manuals and literature. Identification of problematic groups. Concentration on North America, with discussion of other continents. Overnight field trips to natural forest communities.

**FOR 553 ENVIRONMENTAL REMOTE SENSING. Preq.: FOR 353. 3(2-3) F. Alt. yrs.** Principles and applications of remote sensing technology to earth resources and environmental studies. Electromagnetic energy, data acquisition platforms, sensors and scanners, processing of digital remotely sensed data, error analysis and accuracy assessments, and integration of remotely sensed data with other data types used in natural resource management.

**FOR(ENT) 565 ADVANCED FOREST ENTOMOLOGY. 3(2-2) S.** (See entomology.)

**FOR 572A,B FOREST MANAGEMENT POLICIES ON THE PUBLIC LANDS. 2(2-0) S. Alt. yrs.** History, development and current status of policies relating to forest management on the public lands. FOR 572A deals with history and policies through passage of the National Forest Management Act. FOR 572B deals with current issues. Students may enroll in either FOR 572A or FOR 572A and FOR 572B but not FOR 572B alone.

**FOR 574 TOPICS IN FOREST MODELING. Preqs.: MA 121, ST 311. 3(2-2) F. Alt. yrs.** The development and use of quantitative models in forestry. Mathematical modeling and parameter estimation, tree growth and stand development, wildlife habitat and population dynamics, modeling amenity outputs. Emphasis on underlying biological and mensurational assumptions and their impact on applicability and analysis.

**FOR(SSC) 577 CONSERVATION AND SUSTAINABLE DEVELOPMENT I: CONCEPTS AND METHODS. Preq.: CI. 3(3-0) F.** Agronomic, ecological and economic concepts of sustainability, with emphasis on application in developing countries; forest, soil and wildlife resources; models in conservation biology; his-

torical, cultural and sociological perspectives; policy analysis. Offered as part of the program of the Center for World Environment and Sustainable Development.

**FOR(SSC) 578 CONSERVATION AND SUSTAINABLE DEVELOPMENT II: INTEGRATED PROBLEM SOLVING. Preq.: FOR(SSC) 577. 3(3-0) S.** Approaches to reconciling conservation and development with emphasis on developing countries. Case studies; project formulation, implementation and evaluation; institutional policy formation; conflict resolution. Offered as part of the program of the Center for World Environment and Sustainable Development.

**FOR(SSC) 581 AGROFORESTRY. Preq.: CI. 3(3-0) S.** Global agroforestry systems across diverse agroecological zones and under an array of socioeconomic conditions. Methods for selecting sustainable forestry, agricultural and silvipastoral crops that draw upon production agriculture and forestry, community and ecosystem ecology, sociology, and economics. Extension of research results to the rural poor in developing countries.

**FOR 582 SILVICULTURE AND MANAGEMENT OF FOREST PLANTATIONS IN THE TROPICS. Preq.: Grad. standing or CI. 3(3-0) S.** Establishment and management of forest tree plantations in the tropics and subtropics. Genetic adaptability of trees used as exotics, establishment and management of tree improvement programs, tree harvesting, wood manufacturing, gene conservation and maintaining site productivity.

**FOR 583 TROPICAL FORESTRY. Preq.: Sr. standing. 3(3-0) F. Alt. yrs.** Principles of tropical ecology, dendrology and agroforestry. Establishment and management of tropical plantations and natural stands. Operation and management of tropical nurseries. Economics of the international forest products trade. Governmental regulations, policies and permit procedures.

**FOR 584 THE PRACTICE OF ENVIRONMENTAL IMPACT ASSESSMENT. 4(2-4) F.** Impact assessment principles, practices and their evolution. Lectures and field practicums concerning problems addressed by environmental assessment practitioners. Practical implications of current regulatory requirements, especially concerning endangered species and wetlands, as they affect environmental practitioners' performance. Required reports combine varied technical tasks and documentation for regulatory process review.

**FOR(FW) 585 ADVANCED WILDLIFE HABITAT MANAGEMENT. Preqs.: ZO(FW) 553 and ZO(FW) 554. 3(2-3) S. Alt. yrs.** Discussion and evaluation about assessing and modeling habitat capability for wildlife species. Student development of models of habitat requirements for wildlife species and integration of the models into wildlife management plans. Laboratory exercises include manipulation

of habitat management computer packages and development of a wildlife management plan.

**FOR 592 SPECIAL TOPICS IN FORESTRY. Credits Arranged. F,S,Sum.** Individual students or groups of students, under the direction of a faculty member, may explore topics of special interest not covered by existing courses. Format may consist of readings and independent study, problems or research not related to thesis. Also used to develop and test new 500-level courses.

**FOR(FW) 594 SEMINAR IN WILDLIFE MANAGEMENT. 1(1-0) S. Alt. yrs.** Current topics and issues in wildlife biology and management. Students select and research topics, give seminars and lead group discussions.

*FOR GRADUATES ONLY*

**FOR 601 ADVANCED HYDROLOGY. Preqs.: FOR 401, ST 512. 3(3-0) S. Alt. yrs.** The physical concepts of water movement through the hydrologic cycle and interactions with ecosystem components. Mathematical approaches to characterizing and quantifying hydrologic processes derived and applied to problem solutions. Discussion and utilization of experimental design and statistics needed for collecting and analyzing hydrologic data. Development and use of simulation models.

**FOR(GN) 611 FOREST GENETICS. Preq.: GN 411 or CI. 3(3-0) S.** Application of genetic principles to silviculture, management and wood utilization. Emphasis on variation in wild populations, the bases for selection of desirable qualities and fundamentals of controlled breeding.

**FOR(GN) 612 ADVANCED TOPICS IN QUANTITATIVE GENETICS. Preqs.: GN(FOR) 611, GN(ST) 626 or GN(ANS) 603 or CI. 3(3-0) F. Alt. yrs.** Advanced topics in statistics and population genetics pertinent to current research problems in genetics with special applications to forestry. Basic statistical and genetic theory reviewed as bases for intensive study of selection theory and experimental and mating design evaluation. Study of the genetics of natural populations for evolutionary interest as well as for their implications to breeding theory.

**FOR 613 ADVANCED TOPICS IN SILVICULTURE. Preq.: FOR 304. 3(3-0) F.** Critical examination of selected silvicultural topics, with special emphasis on concepts and phenomena distinguishing forests from other biotic communities and silviculture from other fields of applied biology. Emphasis on intensive silviculture in the United States and selected international locations. A written research proposal a course requirement.

**FOR 672 CURRENT ISSUES IN NATURAL RESOURCE POLICY. 2(2-0) S. Alt. yrs.** Discussion of the current and historical dimensions of major natural resource policy issues, including water and air pollution control, land use planning, public works development projects, wilderness, hazardous waste disposal and land preservation.

**FOR 673 ECOPHYSIOLOGY OF FOREST PRODUCTION. Preq.: BO(ZO) 560. 3(3-0) F.** An advanced ecophysiological consideration of forest stand productivity and how it is influenced by resource availability, genetics and their interactions. This knowledge used as a foundation to discuss the influence of natural stresses, silvicultural treatments and other anthropogenic disturbances on forest productivity.

**FOR 689 SEMINAR IN FOREST RESEARCH. 1(1-0) F.** Philosophy and objectives of scientific research and the steps in the research process. Basic and applied research, inductive and deductive reasoning and the need for hypothesis development and testing as a basis for scientific research. Special emphasis on the preparation of study plans, graduate theses, published articles and technical presentations.

**FOR 691 GRADUATE SEMINAR. 1(1-0) F,S,Sum.** Weekly seminar in which students registered for the course present the results of research and special projects. Invitation to all graduate students and faculty in the department to attend and join the discussion.

**FOR 692 ADVANCED TOPICS IN FORESTRY. Credits Arranged. F, S, Sum.** Individual students or groups cf students, under the direction of a faculty member, may explore topics of special interest not covered by existing courses. Format may consist of readings and independent study, problems or research not related to dissertation. Also used to develop and test new 600-level courses.

**FOR 699 RESEARCH IN FORESTRY. Credits Arranged. F, S, Sum.** Individual research, under faculty supervision, that will furnish material for a thesis or dissertation.

# Genetics

**Degrees Offered: Ph.D., M.S.**

**GRADUATE FACULTY**

*Associate Professor* S. E. Curtis, ***Head of the Department***
Box 7614, (919) 515-2291,securtis@ncsu.edu

*Distinguished University Professor and William Neal Reynolds Professor:* C. S. Levings III
*Distinguished University Professor:* J. G. Scandalios
*William Neal Reynolds Professor:* W. R. Atchley

*Professors:* W. E. Kloos, T. F. Mackay, D. F. Matzinger, W. H. McKenzie, R. H. Moll, H. E. Schaffer, S. L. Spiker;
*Professor (USDA):* C. W. Stuber;
*Adjunct Professor:* M.-D. Chilton;
*Professors Emeriti:* C. H. Bostian, W. D. Hanson, T. J. Mann, L. E. Mettler, A. C. Triantaphyllou;
*Associate Professors:* M. T. Andrews, M. A. Conkling, T. H. Emigh;
*Assistant Professor:* J. W. Mahaffey

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* E. J. Eisen, M. M. Goodman, B. T. McDaniel, R. M. Petters, J. O. Rawlings, O. W. Robison, R. R. Sederoff, W. F. Thompson, B. S. Weir, E. A. Wernsman;
*Associate Professors:* R. S. Boston, C. H. Opperman, K. G. Tatchell;
*Assistant Professor:* L. K. Hanley-Bowdoin

The department provides a well-balanced program of graduate course work and research training. The faculty conducts research in genetics of animals, plants, and bacteria. The student has a choice of research projects in the broad areas of molecular, biochemical, developmental, quantitative and population genetics.

### Admission Requirements

Applicants may come from a number of undergraduate programs that include biological, agricultural, physical and mathematical science training. All applications are screened by a departmental committee and the best qualified applicants will be accepted up to the number of spaces that are available for new students.

### Master's Degree Requirements

A 6-hour sequence of 6 minicourses is required of all majors and minors. A minimum of 2 additional graduate genetics courses are required.

### Doctoral Degree Requirements

A 6-hour sequence of 6 minicourses is required of all majors and minors. A minimum of 4 additional graduate genetics courses are required. A minor may be interdisciplinary or in a specific department.

**Student Financial Support**
Graduate assistantships and fellowships are available to the students from a number of sources. Information will be provided at the time of application.

**Other Relevant Information**
New students will rotate through 3 laboratories during their first semester. At the end of the semester, they will choose a laboratory for their research activities consistent with their interests and available research projects. Provisions are available for a co-major and cooperative research in more than one laboratory.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

GN 411 THE PRINCIPLES OF GENETICS.
GN 412 ELEMENTARY GENETICS LABORATORY.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**GN 501 GENETICS I: MOLECULAR GENETICS. Preq.: GN 411. 1(1-0) F.** Principles presented as a series of five-week minicourses: GN 501, molecular genetics; GN 502, biochemical genetics; GN 503, developmental genetics. Majors and minors must enroll for the entire course. Others may enroll for specific minicourses and attend the first lecture of semester for schedule. Taught first 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN 502 GENETICS I: BIOCHEMICAL GENETICS. Preq.: GN 411. 1(1-0) F.** Principles presented as a series of five-week minicourses: GN 501, molecular genetics; GN 502, biochemical genetics; GN 503; developmental genetics. Majors and minors must enroll for the entire course. Others may enroll for specific minicourses and attend the first lecture of semester for schedule. Taught second 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN 503 GENETICS I: DEVELOPMENTAL GENETICS. Preq.: GN 411. 1(1-0) F.** Principles presented as a series of five-week minicourses: GN 501, molecular genetics; GN 502, biochemical genetics; GN 503, developmental genetics. Majors and minors must enroll for the entire course. Others may enroll for specific minicourses and attend the first lecture of semester for schedule. Taught third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN 504 HUMAN GENETICS. Preq.: GN 301 or 411 or equivalent. 3(3-0) F.** The basic principles needed for an understanding of the genetics of humans. Current knowledge and important areas of research in human genetics.

**GN(ANS) 508 GENETICS OF ANIMAL IMPROVEMENT. 3(3-0) S.** (See animal science.)

**GN 509 GENETICS II: POPULATION GENETICS. Preq.: GN 411; Coreq.: ST 511. 1(1-0) S.** Principles presented as a series of five-week minicourses: GN 509, population genetics; GN 510, quantitative genetics; GN 511, cytogenetics. Majors and minors must enroll for the entire series. Others may enroll for specific minicourses and attend the first lecture of the semester for schedule. Taught first 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN 510 GENETICS II: QUANTITATIVE GENETICS. Preq.: GN 411; Coreq.: ST 511. 1(1-0) S.** Principles presented as a series of five-week minicourses: GN 509, population genetics; GN 510, quantitative genetics; GN 511, cytogenetics. Majors and minors must enroll for the entire series. Others may enroll for specific minicourses and attend the first lecture of the semester for schedule. Taught second 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN 511 GENETICS II: CYTOGENETICS. Preq.: GN 411; Coreq.: ST 511. 1(1-0) S.** Principles presented as a series of five-week minicourses: GN 509, population genetics; GN 510, quantitative genetics; GN 511, cytogenetics. Majors and minors must enroll for the entire series. Others may enroll for specific minicourses and attend the first lecture of the semester for schedule. Taught third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**GN(PO) 520 POULTRY BREEDING. 3(2-2) S.** (See poultry science.)

**GN(ZO) 540 EVOLUTION. Preqs.: GN 509, GN 510. 3(3-0) S.** The genetic basis of evolution. Topics include molecular evolution, molecular population genetics, evolutionary genetics of quantitative characters and the genetics of speciation. Critical reading of original research publications and student seminars.

**GN(CS,HS) 541 PLANT BREEDING METHODS. 3(3-0) F.** (See crop science.)

**GN(CS) 545 ORIGIN AND EVOLUTION OF CULTIVATED PLANTS. 3(3-0) S. Alt. yrs.** (See crop science.)

**GN(BO,CS,HS) 547 CELL AND TISSUE TECHNIQUES IN PLANT BREEDING. 3(1-4) F. Alt. yrs.** (See crop science.)

**GN 555 POPULATION GENETICS. Preqs.: GN 509, MA 102. 3(3-0) S. Alt. yrs.** Theoretical population genetics and its relationship to natural and experimental populations. Topics include: single locus and multilocus systems, history of a gene

in a population, diffusion approximations, suitability of models to natural and experimental populations.

**GN(MB) 558 PROKARYOTIC MOLECULAR GENETICS. 3(3-0) S.** (See microbiology.)

**GN 560 MOLECULAR GENETICS. Preqs.: GN 411; BCH 451. 3(3-0) F.** A discussion of the structure and function of the genetic material at a molecular level. Consideratoin of both prokaryotic and eukaryotic systems. The aim to describe genetics in terms of chemical principles.

**GN(ST) 565 GENETIC DATA ANALYSIS. 3(3-0) S. Alt. yrs.** (See statistics.)

*FOR GRADUATES ONLY*

**GN(ANS) 603 QUANTITATIVE GENETICS AND BREEDING. 3(3-0) F.** (See animal science.)

**GN(FOR) 611 FOREST GENETICS. 3(3-0) S.** (See forestry.)

**GN(FOR) 612 ADVANCED TOPICS IN QUANTITATIVE GENETICS. 3(3-0) F. Alt. yrs.** (See forestry.)

**GN(CS,HS) 615 QUANTITATIVE GENETICS IN PLANT BREEDING. 1(1-0) S. Alt. yrs.** (See crop science.)

**GN(CS,HS) 616 BREEDING METHODS. 2(2-0) S. Alt. yrs.** (See crop science.)

**GN(CS,HS) 617 NONCONVENTIONAL PLANT BREEDING. 1(1-0) F. Alt. yrs.** (See crop science.)

**GN(CS,HS,PP) 618 BREEDING FOR PEST RESISTANCE. 2(2-0) F. Alt. yrs.** (See crop science.)

**GN(ST) 626 STATISTICAL CONCEPTS IN GENETICS. 3(3-0) S. Alt. yrs.** (See statistics.)

**GN(BO,MB,PP) 627 FUNGAL GENETICS AND PHYSIOLOGY. 3(2-3).** (See plant pathology.)

**GN 641 COLLOQUIUM IN GENETICS. Preq.: CI. 2(2-0) F,S.** Informal group discussion of prepared topics assigned by the instructor.

**GN 650 DEVELOPMENTAL GENETICS. Preq.: GN 501, 502 and 503. 3(3-0) S. Alt. yrs.** The action and regulation of genes and gene-products in development and differentiation. Examples from microorganisms, plants and animals. Emphasis on molecular and biochemical aspects of mechanisms controlling gene expression in eukaryotic cell differentiation.

**GN(BCH) 658 NUCLEIC ACIDS: STRUCTURE AND FUNCTION. 3(3-0) F. Alt. yrs.** (See biochemistry.)

**GN(MB) 660 EXPERIMENTAL MICROBIAL GENETICS. 4(2-6) S.** (See microbiology.)

**GN(BCH) 661 ADVANCED MOLECULAR BIOLOGY OF THE CELL. 3(3-0) S. Alt. yrs.** (See biochemistry.)

**GN 691 SEMINAR. 1(1-0) F,S.**

**GN 695 SPECIAL PROBLEMS IN GENETICS. Preqs.: Advanced grad. standing, CI. 1-3 F,S.** Special topics designed for additional experience and research training.

**GN 699 RESEARCH. Preq.: Permission of adviser. Credits Arranged.** Original research related to the student's thesis problem. A maximum of six credits for the master's degree; by arrangement for the doctorate.

# Graphic Design

**Degree Offered: Master of Graphic Design**

**GRADUATE FACULTY**

*Professor* M. Davis, *Head of the Department and Director of Graduate Programs* Box 7701, (919) 515-2202

*Professor:* A. S. Lowery;
*Associate Professor:* M. Scotford;
*Assistant Professors:* K. L. Bailey, A. K. Blauvelt, J. Spadaro, S. Townsend

Recognizing that graphic design is both a social activity and a form of cultural production, faculty and students in the Department of Graphic Design define the study of the discipline as necessarily contextual; graduate research examines the creation, reproduction, distribution, and reception of design from a multi-disciplinary perspective. The Master of Graphic Design Program also emphasizes

the importance of understanding design as the creation of cognitive and cultural artifacts; study focuses on the construction of messages, the reproduction of such artifacts, the systems for their distribution, and their reception within various cultures of society.

Graduate students in graphic design learn through their own search for problems within critical content frameworks presented by the faculty. The program places primary importance on the ability of students to be critical agents; to seek problems and to pose questions. Faculty evaluate graduate students on their capacity to define individual investigations and to support their decision-making with an independent program of reading and research; on their ability to critically evaluate and articulate discoveries; and on their skills in synthesizing ideas through the creation of design artifacts.

The Master of Graphic Design Program provides focused study and research in the discipline that reflects concern for how designers will shape and respond to the changing technological and social communications environments of the future. The Program has the broad objective to educate socially responsible, intellectually curious, historically aware, and technologically adept communication design professionals.

In the Track III Program, students whose undergraduate preparation is in fields other than graphic design examine relationships between their previous study and graphic design. While acquiring design skills and knowledge in graphic design, they apply concepts and methods from their previous study to design research and innovation.

**Admissions Requirements**
Students must make application to the Department of Graphic Design by January 15. In addition to Graduate School requirements, the department requires department personal data forms and a slide portfolio of design and two-dimensional visual work.

**Master's Degree Requirements**
Studio credits presented for transfer must be accompanied by a portfolio of work from the courses under consideration.

**Student Financial Support**
The department has limited provisions for tuition remission and assistantships. Assistantships are awarded on the basis of student and departmental needs. Assistantship applications are available from the Department of Graphic Design and should be submitted with the application for admission (for incoming students) or by the advertised deadline (for continuing students).

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**GD 517 ADVANCED TYPOGRAPHIC SYSTEMS. Preqs.: GD 217 and GD 317. 3(2-2).** Systematic approaches to structuring typographic form according to information hierarchies, user needs and visual expression. Application to the organization of tables, charts, books, magazines, corporate identities and signage.

**GD 518 ADVANCED TYPOGRAPHIC EXPRESSION. Preqs.: GD 217 and GD 317 or equivalent. 3(2-2).** Experimentation in typography for the purpose of subjective expression. Analysis of historical precedent, contemporary usage and the semiotics of shaped writing provide a basis for the advanced student to study and use typography as image, metaphor and symbol.

**GD 570 THEORY IN PRACTICE: GRAPHIC DESIGN SINCE 1945. Preq.: GD 242. 3(3-0) S.** Influence of critical theory on the creation, production and interpretation of graphic design since mid-century. Lectures, readings and discussions of contemporary issues in graphic design with focus on their social and cultural contexts.

**GD 580 SPECIAL TOPICS IN GRAPHIC DESIGN HISTORY. Preq.: GD 242. 3(3-0) S. Alt. yrs.** Topics of current interest in interpretation, criticism, methodology and research, relating to graphic design history. Further specialized study in the history of printing, typography, communication, image-making and information systems. Investigation of how we study artifacts, production and producers.

**GD 591 SPECIAL PROJECT IN GRAPHIC DESIGN. Preq.: Grad. standing. 1-3 F,S.** Seminar on subjects of current interest in graphic design, presented by persons not part of the regular faculty.

**GD 592 SPECIAL TOPICS IN GRAPHIC DESIGN. Preq.: Grad. standing. 2-3 F,S.** Topics of current interest to the program/option offered by faculty in the School. Subjects offered under this number normally used to test and develop new courses.

**GD 595 INDEPENDENT STUDY IN GRAPHIC DESIGN. 1-3 F,S.Sum.** Special problems in various aspects of graphic design developed under the direction of a faculty member on a tutorial basis.

*FOR GRADUATES ONLY*

**GD 600 ADVANCED GRAPHIC DESIGN (SERIES). Preq.: Portfolio review. 6(0-12) F,S.** Advanced studies in graphic design. Special emphasis given to problem

identification, problem formulation and application of advanced design methods. All problems of an individual nature leading to a synthesis of previous design experiences.

**GD 681 FINAL PROJECT RESEARCH. Preq.: Bachelor's degree or equivalent. 3(3-0).** A seminar designed to assist students in preparing the foundation for the final project to be conducted in the design studio.

**GD 688 FINAL PROJECT STUDIO IN GRAPHIC DESIGN. Preq.: GD 681. 6(0-12) F,S.** Final project for graduate students supervised by members of their graduate advisory committees.

**GD 691 SPECIAL TOPICS IN GRAPHIC DESIGN. Preq.: Permission of grad. advisor. 1-6 F,S.** An investigation of special topics in graphic design of a particular interest to advanced students under the direction of the chair of the graduate committee on a tutorial basis; credit and content vary with each student.

# Health Occupations Teacher Education

For a listing of graduate faculty and program information, see occupational education.

# Higher Education Administration

For a listing of graduate faculty and program information, see adult and community college education.

# History

**Degree Offered: M.A.**

**GRADUATE FACULTY**

*Professor* W. C. Harris, *Head of the Department*
*Professor* A. J. De Grand, *Director of Graduate Programs*
Box 8108, (919) 515-2483, degrand@social.chass.ncsu.edu
*Graduate Alumni Distinguished Professor* J. D. Smith, *Coordinator, Public History Program*

*Professors:* J. R. Banker, B. F. Beers, C. H. Carlton, M. S. Downs, J. P. Hobbs, A. J. LaVopa, L. O. McMurry, J. K. Ocko, S. T. Parker, J. M. Riddle, R. H. Sack, R. W. Slatta, K. S. Vincent;

*Adjunct Professor:* R. L. Greaves;
*Professors Emeriti:* M. L. Brown Jr., R. W. Greenlaw, D. E. King, M. E. Wheeler, B. W. Wishy;
*Associate Professors:* D. P. Gilmartin, W. A. Jackson III, W. C. Kimler, K. P. Luria, J. A. Mulholland, R. B. Mullin, G. W. O'Brien, S. L. Spencer, G. D. Surh, K. P. Vickery;
*Adjunct Associate Professor:* D. Olson;
*Associate Professor Emeritus:* R. N. Elliott;
*Assistant Professors:* J. E. Crisp, S. Middleton, P. Tyler, D. A. Zonderman;
*Adjunct Assistant Professors:* V. Berger, J. W. Caddell, J. C. Cashion, F. D. Gatton, W. S. Price Jr., H. K. Steen

## ASSOCIATE MEMBER OF THE PROGRAM

*Visiting Assistant Professor:* J. C. Bonham

### Admission Requirements

In the required career goals statement, the major country, topic and historical period of interest should be included. Students admitted provisionally must complete at least 9 hours of graduate courses making grades of A or B to be considered for full graduate standing.

### Master's Degree Requirements

#### Master of Arts Degree in History

Each student's program is tailored to enhance his or her career objectives. Social studies teachers, for example, are awarded a G certificate on completion of the M.A. in history with a minor in education.

#### Master of Arts Degree in Public History

This non-thesis program requires thirty-six hours of course work. Half the hours fall in historical studies, the rest in applied history classes, including innovative courses in iconographic materials and archival conservation, documentary editing, and historic preservation. Students may select a practicum that places them under the direct supervision of the State Archivist of North Carolina. Students may select another practicum in their own special area of interest--including historic site administration, museology, historic preservation, or historical publications.

### Student Financial Support

Graduate assistantships and fellowships are available to students in both programs and are awarded by open competition.

**Other Relevant Information**
Application deadlines are the second Monday of April for fall admission and the second Monday of October for spring admission. Students are normally admitted for the fall semester.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

*NOTE: Prerequisite: (500 level) Six hours of advanced history or equivalent.*

**HI 500 CIVILIZATIONS OF THE ANCIENT NEAR EAST. Credit for both HI 400 and HI 500 is not allowed. 3(3-0).** The civilizations of Mesopotamia and Egypt from earliest times to the fall of Babylon in 539 B.C.

**HI 504 ROME TO 337 A.D. Credit for both HI 404 and HI 504 is not allowed. 3(3-0).** The development of ancient Rome from its origins in Italy, through its rise as an Empire embracing the entire Mediterranean World and Western Europe, to Constantine, Christianity and the foundation of Constaninople. Critical examination of the political achieve ment of a people who rose from an obscure Italian city to a world empire, with emphasis on the analysis of primary courses.

**HI 505 HISTORY AND ARCHAEOLOGY OF THE ROMAN EMPIRE. Credit for both HI 405 and HI 505 is not allowed. 3(3-0).** Analysis of Rome's unparalleled rule over the entire Mediterranean World in the first four centuries A. D. through use of literary and archaeological sources. Special emphasis on imperial army and frontier security.

**HI 506 FROM ROMAN EMPIRE TO MIDDLE AGES. Credit for both HI 406 and HI 506 is not allowed. 3(3-0).** Late Antiquity and the early Middle Ages. The transition from classical civilization to the basis of modern civilizations: the Fall of Rome, the Germanic kingdoms, Byzantium, the establishment of Christianity, the birth and growth of Islam.

**HI 507 ISLAMIC HISTORY TO 1798. Credit for both HI(REL) 407 and HI 507 is not allowed. 3(3-0).** The history of the Islamic Near East to 1798. Topics include the East Mediterranean before Islam, Muhammad and the development of Islam, sources of Muslim civilization; Islamic law, science, philosophy, art and architecture; Islam in Spain, India, Asia and Africa, the Crusades, the Ottomans; Islam and Europe.

**HI 509 THE HIGH MIDDLE AGES. Credit for both HI 409 and HI 509 is not allowed. 3(3-0).** Medieval culture 936-1250: revival of the Roman Empire, monastic and papal reform, rise of universities, evolution of representative bodies,

the Gothic style, troubadour and goliardic poetry, scholasticism and revival of Roman law.

**HI 510 ITALIAN RENAISSANCE. Credit for both HI 410 and HI 510 is not allowed. 3(3-0).** Examination of Renaissance humanism, an educational ideal and an awareness of humans as the sole creator in the world historical world, in its relationship to the Italian republics and princedoms of the 14th through 16th century.

**HI 511 THE PROTESTANT AND CATHOLIC REFORMATION OF THE 16TH CENTURY. Credit for both HI 411 and HI 511 is not allowed. 3(3-0).** The conditions and criticisms which led to reform and the nature of the institutional, theological and social changes effected by the various churches and sects. Special attention to Luther and Calvin.

**HI 514 FRANCE IN THE OLD REGIME. Credit for both HI 414 and HI 514 is not allowed. 3(3-0).** France from the sixteenth century to the Revolution, development of renaissance and absolutist state, social and economic change, religious reform and Enlightenment, origins and beginnings of the Revolution.

**HI 515 REVOLUTIONARY EUROPE. Credit for both HI 415 and HI 515 is not allowed. 3(3-0).** A broadly based analysis of France's first revolutionary era. The Enlightenment and its impact, the causes and character of the Revolution in France and the impact of these events in France and Europe.

**HI 517 EUROPE IN CRISIS: 1890-1917. Credit for both HI 417 and HI 517 is not allowed. 3(3-0).** Survey of the social, economic, political, ideological changes in Europe on eve of World War I; prewar origins of fascism and communism; political polarization during World War I to the outbreak of the Bolshevik Revolution.

**HI 518 FASCISM-REVOLUTION-REACTION: EUROPE 1919-1939. Credit for both HI 418 and HI 518 is not allowed. 3(3-0).** Rise and defeat of revolutionary movements in Central Europe and Italy (1919-1939); emergence and development of communism, fascism and nazism; crisis of the European socialist movement during the 1930s; and Spanish Civil War.

**HI 519 MODERN EUROPEAN IMPERIALISM. Credit for both HI 419 and HI 519 is not allowed. 3(3-0).** Historical background of European Colonialism. Its influence on modern independence movements and major power foreign policy. Third World concept in international relations.

**HI 520 EUROPEAN DIPLOMATIC HISTORY. Credit for both HI 420 and HI 520 is not allowed. 3(3-0).** Survey of major issues and events in European international relations; Congress of Vienna, 1815, to defeat of Axis powers and origins of Cold War in 1945.

**HI 521 EUROPEAN INTELLECTUAL HISTORY: THE EIGHTEENTH CENTURY. Credit for both HI 421 and HI 521 is not allowed. 3(3-0).** Historical examination of some of the major figures of the European Enlightenment, beginning with Locke and ending with Kant.

**HI 522 EUROPEAN INTELLECTUAL HISTORY: THE 19TH CENTURY. Credit for both HI 422 and HI 522 is not allowed. 3(3-0).** Historical examination of some of the major figures of European thought during the 19th century, beginning with the enthusiasm of the period of the French Revolution and ending with the disillusionment of the fin de siecle.

**HI 525 TUDOR AND STUART ENGLAND. Credit for both HI 425 and HI 525 is not allowed. 3(3-0).** British history from the Reformation to the Civil War. Primary emphasis on certain key developments in social, political and economic life, such as the development of a new concept of kingship, the growing independence of Parliament, the search for religious uniformity and the changing status of the aristocracy and gentry.

**HI 529 20TH CENTURY BRITAIN. Credit for both HI 429 and HI 529 is not allowed. 3(3-0).** British political, social and economic history since 1914, with reference to the effects of two world wars, growth of the Welfare State, Britian's decline in power and its search for a new role in the world.

**HI 530 MODERN FRANCE. Credit for both HI 430 and HI 530 is not allowed. 3(3-0).** French history from the downfall of Napoleon I to the present, with a short introductory survey of the Old Regime and the French Revolution. Cultural, social and economic developments and political trends.

**HI 531 GERMANY: LUTHER TO BISMARCK 1500-1871. Credit for both HI 431 and HI 531 is not allowed. 3(3-0).** Germany from the Reformation through national unification. Emphasis on impact of socio-economic changes on politics and culture.

**HI 532 HISTORY OF GERMANY SINCE 1871. Credit for both HI 432 and HI 532 is not allowed. 3(3-0).** Germany from the Reformation through national unification. Emphasis on impact of socio-economic changes on politics and culture.

**HI 538 THE RUSSIAN EMPIRE TO 1917. Credit for both HI 438 and HI 538 is not allowed. 3(3-0).** History of the Russian Empire to the Revolution of 1917. Topics: Kiev Rus and the Mongol conquest; serfdom, territorial expansion and cultural insularity of the Great Russian state in Moscow; Westerization, reform and great power status in 18th and 19th centuries; peoples of the multi-national empire; culture, educated society and revolutionary opposition; industrialization, rapid urbanization, war and revolution.

**HI 539 HISTORY OF THE SOVIET UNION AND AFTER. Credit for both HI 439 and HI 539 is not allowed. 3(3-0).** History of the Soviet state and society from the 1917 Revolution, including the post-Soviet situation. Political disarray and resistance to the Bolshevik regime, 1917-21; industrialization, urbanization and application of coercive techniques of rule; popular reconcilication with Party state and great power status during World War II and after; fate of non-Russian nationalities; de-Stalinization, stagnation and the failed attempt at Party renewal after 1985.

**HI 543 U.S. CONSTITUTIONAL HISTORY. Credit for both HI 443 and HI 543 is not allowed. 3(3-0).** The origins and growth of the U.S. Constitution from its English common law heritage to the Modern era. Federalism and judicial interpretation; economic, social and political movements; expansion of constitutional authority in the 20th century.

**HI 546 CIVIL WAR AND RECONSTRUCTION. Credit for both HI 446 and HI 546 is not allowed. 3(3-0).** Examination of the sectional polarization of the 1850s, the impact of the war on both northern and southern societies and trauma of reconstructing the Union.

**HI 548 AMERICAN WOMEN IN THE TWENTIETH CENTURY. Credit for both HI 448 and 548 is not allowed. 3(3-0).** Women's historical experience in America, 1890-1990. Changes in women's work, education, legal and political status, and sex roles; age, class, race, sexual preference and region as significant variables in women's experience.

**HI 552 RECENT AMERICA. Credit for both HI 452 and HI 552 is not allowed. 3(3-0).** Examination of contemporary opinions and "historial" interpretations of major problems in American life since 1939 including World War II, its social and economic consequences; Korea and the Cold War; big business and labor; civil rights and feminist movements; countercultures, Vietnam and Watergate.

**HI 553 U. S.-LATIN AMERICAN RELATIONS SINCE 1823. Credit for both HI 453 and HI 553 is not allowed. 3(3-0).** Analysis of periods, issues and events in U.S.-Latin American relations since 1823, Monroe Doctrine, Manifest Destiny, Mexican and Spanish-American Wars, Dollar Diplomacy, Good Neighbor Policy,

anti-Communist crusade since 1945, Alliance for Progress, U. S. responses to revolution. Historical perspective on contemporary inter-American problems--drugs, environment, debt crisis, human rights abuses.

**HI 554 HISTORY OF U. S. FOREIGN RELATIONS, 1900-PRESENT. Credit for both HI 454 and HI 554 is not allowed. 3(3-0).** American diplomatic history since 1900; the expansion of American economic and cultural relations; the evolution of the American foreign policy bureaucracy; and the historical forces and personalities that shaped American relations with other nations.

**HI 555 HISTORY OF THE CIVIL RIGHTS MOVEMENT. Credit for both HI 455 and HI 555 is not allowed. 3(3-0).** The "black revolution;" stages and leaders of the movement; successes and failures in fight for desegregation, the vote and economic opportunity; impact of Civil Rights movement on the United States.

**HI 556 AMERICAN HERITAGE. Credit for both HI 456 and HI 556 is not allowed. 3(3-0).** Development of American ideals since colonial times studied through the words of famous Americans and in the context of events like the American Revolution and the Great Depression. Stress on the conflicts, during important crises, between freedom and order, liberty and equality, free enterprise and social justice, religious truth and workaday morality, the nation and the world.

**HI 557 TWENTIETH-CENTURY U. S. INTELLECTUAL HISTORY. Credit for both HI 457 and HI 557 is not allowed. 3(3-0).** American intellectuals and their views on 20th-century topics such as politics, culture, race and gender in historical context.

**HI 558 MODERN AMERICAN HISTORICAL BIOGRAPHY. Credit for both HI 458 and HI 558 is not allowed. 3(3-0).** American history in the 20th century through the medium of historical biography.

**HI 561 CIVILIZATION OF THE OLD SOUTH. Credit for both HI 461 and HI 561 is not allowed. 3(3-0).** The distinctive features of the Old South as part of the regional development of the United States. Colonial factors in the making of the South, development of the plantation system and slavery, Southern social order, intellectual and cultural life, economic development and rise of Southern nationalism.

**HI 562 SOCIAL HISTORY OF THE NEW SOUTH. Credit for both HI 462 and HI 562 is not allowed. 3(3-0).** Analysis of southern society from the Civil War through the present, with an emphasis on social history methods, approaches and sources.

**HI 569 LATIN AMERICAN REVOLUTIONS IN THE TWENTIETH CENTURY. Credit for both HI 469 and HI 569 is not allowed. 3(3-0).** Comparative analysis of causes, participants, process and outcome of revolutions in Mexico, Bolivia, Cuba and Central America.

**HI 571 REVOLUTIONARY CHINA. Credit for both HI 471 and HI 571 is not allowed. 3(3-0).** China 1900 to present. Examination of political, cultural and socio-economics revolutionary phases of China's 20th-century transformation from traditional empire to communism. Particular attention to post-1949 problems of nation building.

**HI 576 LEADERSHIP IN MODERN AFRICA. Credit for both HI 476 and HI 576 is not allowed. 3(3-0).** The conditions under which 20th century African leaders have obtained and exercised power. Case studies of prominent leaders, both radicals, reactionaries, democrats and tyrants, such as Nkrumah, Kenyatta, Nyerere, Amin, Cabral, Vorster and Senghor.

**HI 580 SCIENTIFIC REVOLUTION: 1300-1700. Credit for both HI 480 and HI 580 is not allowed. 3(3-0).** Factors behind dramatic scientific changes of the seventeenth century. Role of mathematics and experiment. Interaction of the new science with trends in philosophy, religion, alchemy, magic, medicine and with institutional educational, political, economic and technological factors.

**HI 581 HISTORY OF LIFE SCIENCES. Credit for both HI 481 and HI 581 is not allowed. 3(3-0).** The major ideas, methods, institutions and individuals that have contributed to the biological sciences from the Renaissance to modern times. The connections between the life sciences and other aspects of culture, including the physical sciences, religious belief, medical practice and agriculture.

**HI 582 DARWINISM IN SCIENCE AND SOCIETY. Credit for both HI 482 and HI 582 is not allowed. 3(3-0).** Darwinism and its reception by the scientific community and the general public. Social impact of theories of evolution as expected in social Darwinism, eugenics, sociobiology and the relationship of science to ethics and religion.

**HI 585 INTRODUCTION TO PUBLIC HISTORY. Preqs.: Grad. standing; 6 hours of history or equivalent. Credit for both HI 485 and HI 585 is not allowed. 3(3-0).** An introduction to applications of history to public life and to the conservation and presentation of historical materials, with particular attention to conservation problems generated by modern technology. Topics include archives, records management, historical editing, museology, historic preservation, historic sites and computer applications.

**HI 586 HISTORY AND PRINCIPLES OF THE ADMINISTRATION OF ARCHIVES AND MANUSCRIPTS. 3(3-0).** Nature, importance and use of original manuscript resources; history and evolution of written records and the institutions administering them; the principles and practices of archival administration.

**HI 587 APPLICATION OF PRINCIPLES OF ADMINISTRATION OF ARCHIVES AND MANUSCRIPTS. Preqs.: Six hours of advanced history and HI 586. 3(3-0).** Training in the application of the principles and practices of archival management as developed in HI 586.

**HI 588 RECORDS MANAGEMENT. Preqs.: HI 585 and HI 586. 3(3-0).** Introduction to the theory and practice of records management; acquisition, appraisal, preservation, dissemination and disposal of records; centralized records management in institutions.

**HI 589 AUTOMATION AND PUBLIC HISTORY. Preqs.: HI 585 and HI 586. 3(3-0).** Computer uses in public history, Library of Congress and other electronic protocols. Creation, accession and networking of records systems.

*FOR GRADUATES ONLY*

*NOTE: Prerequisite: (600 level) Six hours of advanced history or equivalent.*

**HI 601 HISTORIOGRAPHY AND HISTORICAL METHOD. 3(3-0).** A study of the major steps in the development of historical investigation; analysis of elements of historical research; discussion of methodology and archival materials used by the contemporary scholarly historian.

**HI 602 HISTORICAL WRITING. 3(3-0).** Critical studies in the methods and practice of contemporary historical writing.

**HI 684 INTRODUCTION TO MUSEOLOGY. 3(3-0).** Organization and operation of museums as historical agencies. Role of museums in historical research and education.

**HI 685 INDEPENDENT STUDY. 1-6.** Individualized study conducted under supervision of graduate faculty. Course of study, assigned readings, course projects or papers, and methods of evaluating work to be detailed in writing and approved by department head.

**HI 688 CONSERVATION OF ARCHIVAL AND LIBRARY MATERIALS. Preq.: HI 585, 586, 587 or CI. 3(2-2).** Introduction to archival materials. Examination of and practice in the storage and care of paper and books, prints, engrav-

ings and maps. Films, transparencies, negatives, magnetic tapes and phonorecords. Emphasis on preventive conservation.

**HI 689 DOCUMENTARY EDITING. Preq.: HI 485/585. 3(3-0).** An introduction to the field of documentary editing and historical publication. Development of historical editing and the rules of literal, expanded and modern editorial method. Special documentary/papers projects.

**HI 691 PRACTICUM IN PUBLIC HISTORY. Preq.: HI 585, 601, 602 and CI. 1-6.** Supervised internship experience in archival management and/or applied history.

**HI 699 RESEARCH IN HISTORY. Credits Arranged. 1-6.** Individual research under graduate thesis supervisor.

# Horticultural Science

**Degrees Offered: Ph.D., M.S., Master of Agriculture**

**GRADUATE FACULTY**

*Professor* T.J. Monaco, ***Head of the Department***
*Professor* E. Young, ***Director of Graduate Programs***
Box 7609, (919) 515-5366, eric_young@ncsu.edu

*Professors:* J. R. Ballington Jr., T. E. Bilderback, F. A. Blazich, W. W. Collins, A. A. De Hertogh, P. R. Fantz, R. G. Gardner, L. E. Hinesley, W. E. Hooker, R. A. Larson, C. M. Mainland, P. V. Nelson, K. B. Perry, D. M. Pharr, E. B. Poling, M. A. Powell Jr., J. C. Raulston, D. C. Sanders, W. A. Skroch, C. R. Unrath, T. C. Wehner, D. J. Werner, L. G. Wilson;
*Adjunct Professor:* D. T. Patterson;
*Professors Emeriti:* W. E. Ballinger, F. D. Cochran, R. J. Downs, F. L. Haynes Jr., W. R. Henderson, J. M. Jenkins, T. R. Konsler, J. W. Love, C. H. Miller, D. T. Pope;
*Associate Professors:* D. A. Bailey, S. M. Blankenship, W. C. Fonteno, D. W. Monks, M. M. Peet, S. L. Warren;
*Adjunct Associate Professors:* D. R. Carlson, P. S. Zorner;
*Associate Professors Emeriti:* T. F. Cannon, D. C. Zeiger;
*Assistant Professors:* J. M. Davis, M. L. Parker, T. G. Ranney, J. R. Schultheis;
*Lecturer:* M. E. Traer

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* D. E. Carroll Jr., R. H. Moll

Course offerings or research facilities are available in the following areas: plant physiology, breeding and genetics, herbicide physiology, nutrition, propagation, tissue culture, biotechnology, growth regulators, postharvest physiology, control of environment, agricultural meteorology, Christmas tree research, landscape horticulture and biochemistry of varietal differences.

### Admission Requirements

At the discretion of a graduate program, a student may be admitted provisionally for graduate study in a program without the GRE scores. To be admitted, a student should have completed course work in physics, mathematics, chemistry, soils, plant pathology, genetics, entomology and several courses in horticulture. An applicant deficient in course work may be admitted on a provisional basis until the deficiency is made up.

### Master's Degree Requirements

For the Master of Science degree, the program must include 4 credit hours of the horticultural science core courses, seminar preparation, and presentation of one seminar, and teaching and outreach experiences.

### Doctoral Degree Requirements

The program must include three credit hours of the horticultural science core courses, seminar preparation, presentation of two seminars, and teaching and outreach experiences. The preliminary comprehensive examination consists of written and oral examinations. The Ph.D. requires research and a thesis which is defended orally during the final examination.

### Student Financial Support

The department has a number of graduate teaching and research assistantships available for promising students; these include Agricultural Foundation and Experiment Station assistantships. Recipients may enroll for up to 9 credit hours per semester. Those interested should apply at least 9 months prior to their anticipated enrollment date.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

**HS 400 RESIDENTIAL LANDSCAPING.**
**HS 411 NURSERY MANAGEMENT.**
**HS 416 PRINCIPLES OF ORNAMENTAL PLANTING DESIGN.**
**HS 421 TREE FRUIT PRODUCTION.**
**HS 422 SMALL FRUIT PRODUCTION.**

HS 431 VEGETABLE PRODUCTION.
HS 440 GREENHOUSE MANAGEMENT.
HS 441 FLORICULTURE I.
HS 442 FLORICULTURE II.
HS(FS) 462 POSTHARVEST PHYSIOLOGY.
HS 471 TREE AND GROUNDS MAINTENANCE.
HS 490 HORTICULTURAL SCIENCE SEMINAR.
HS 495 SPECIAL TOPICS IN HORTICULTURAL SCIENCE.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**HS(CS) 515 WEED SCIENCE RESEARCH TECHNIQUES. 1(0-2) F.** (See crop science.)

**HS(CS) 516 WEED BIOLOGY. 1(1-0) F.** (See crop science.)

**HS(CS) 517 WEED MANAGEMENT SYSTEMS. 1(1-0) F.** (See crop science.)

**HS(CS) 518 BIOLOGICAL CONTROL OF WEEDS. 1(1-0) F.** (See crop science.)

**HS 531 PHYSIOLOGY OF LANDSCAPE PLANTS. Preq.: BO 421 or CI. 3(2-3) S.** Designed to cover relationships of plants to landscape environments. Study of plant function, basic climatology and plant physiological principles involved in the selection, utilization and maintenance of physical landscape environments in exterior and interior ornamental landscape plantings.

**HS 532 VEGETABLE CROP PHYSIOLOGY. Preqs.: BO 421, HS 431, SSC 341. 2(2-0) F. Alt. yrs.** Physiological aspects of field and greenhouse vegetable production: germination, photoperiod, nutrition, growth regulations, fruit quality, physiological disorders, source-sink interactions, environmental physiology and physiological aspects of plant protection. Emphasis on current areas of research and the physiological implications of new production techniques.

**HS 534 VEGETABLE CROPS PRACTICUM. Preq.: HS 431. 3(1-6) S. Alt. yrs.** Field techniques for research on vegetable production problems. Eleven all-day field trips (two overnight) required during the period May-August.

**HS(CS,GN) 541 PLANT BREEDING METHODS. 3(3-0) F.** (See crop science.)

**HS(BO,CS,GN) 547 CELL AND TISSUE TECHNIQUES IN PLANT BREEDING. 3(1-4) F. Alt. yrs.** (See crop science.)

**HS 595 SPECIAL TOPICS IN HORTICULTURAL SCIENCE. Preq.: CI. 1-6 F,S,Sum.** Investigation of special theoretical problems at the 500 level in horticultural science not related to a thesis problem; new 500-level courses during the developmental phase.

**HS 599 RESEARCH PRINCIPLES. Preq.: CI. Credits Arranged, Maximum 6.** Investigation of a problem in horticulture under the direction of the instructor. The students obtain practice in experimental techniques and procedures, critical review of literature and scientific writing. The problem may last one or two semesters. Credits determined by the nature of the problem, not to exceed a total of three hours for any one problem. A written report and final oral exam required for completion of course.

*FOR GRADUATES ONLY*

**HS 601 CARBOHYDRATE METABOLISM AND TRANSPORT. Preq.: BO 421. 1(1-0) S.** Historical and current research related to the regulation of aspects of carbohydrate metabolism important to plant growth, yield and quality. Taught first five weeks of semester. Drop date is last day of 3rd week of the minicourse.

**HS 602 ENVIRONMENTAL STRESS PHYSIOLOGY. Preq.: BO 421. 1(1-0) F.** Nature of environmental stresses which plants encounter such as chilling, freeze, heat, drought, excess water, and physiology of plant responses and resistance mechanisms. Taught second 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**HS 603 BREEDING ASEXUALLY PROPAGATED CROPS. Preq.: CS 413. 1(1-0) F.** Principles and problems associated with breeding clonally propagated crops and the techniques used in overcoming these problems. Taught third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**HS 604 PLANT NOMENCLATURE. Preq.: BO 421. 1(1-0) S.** A practical foundation in plant nomenclature and nomenclatural references. Emphasis on the evolution of the international rules for naming plant taxa and their application to both wild and cultivated plants. Nomenclatural applications used in patents, cultivar releases and journal articles. Taught mid-semester. Drop date is last day of 3rd week of the minicourse.

**HS 605 PHYSIOLOGY OF FLOWERING. Preq.: BO 421. 1(1-0) F.** Examination of the physiological basis of flowering in plants such as: floral initiation, transition to reproductive growth; floral development; plant response to light, temperature, nutrition, water supply; plant age; chemical growth regulation and in

vitro flowering. Taught first 5 weeks of fall semester. Drop date is last day of 3rd week of the minicourse.

**HS 606 FRUIT DEVELOPMENT AND POSTHARVEST PHYSIOLOGY. Preq.: BO 421. 1(1-0) S.** Theories of plant senescence, both physiological and biochemical, and postharvest changes in all types of plant parts. Emphasis on the physiological principles which underlie current postharvest handling and storage techniques. A study of fruit development from fruit set to senescence. Taught third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**HS(CS,GN) 615 QUANTITATIVE GENETICS IN PLANT BREEDING. 1(1-0) S. Alt. yrs.** (See crop science.)

**HS(CS,GN) 616 BREEDING METHODS. 2(2-0) S. Alt. yrs.** (See crop science.)

**HS(CS,GN) 617 NONCONVENTIONAL PLANT BREEDING. 1(1-0) F. Alt. yrs.** (See crop science.)

**HS(CS,GN,PP) 618 BREEDING FOR PEST RESISTANCE. 2(2-0) F. Alt. yrs.** (See crop science.)

**HS 622 MINERAL NUTRITION IN PLANTS. Preqs.: BO 551, 552. 3(2-3) S. Alt. yrs.** A comprehensive study of the functional roles of nutrients essential to plant growth, their interrelationships and their mode of influence on quality indices of crops. Consideration of the complexity of mineral nutrition experimentation and evaluation of results. A detailed look at the establishment and application of foliar analysis, foliar fertilization and slow-release fertilizers. A general view of the nutrient uptake process in plants.

**HS(CS,SSC) 625 HERBICIDE CHEMISTRY. 1(3-0) S.** (See crop science.)

**HS(CS) 626 HERBICIDE BEHAVIOR IN PLANTS. 1(3-0) S.** (See crop science.)

**HS(CS,SSC) 627 HERBICIDE BEHAVIOR IN SOIL AND WATER. 1(3-0) S.** (See crop science.)

**HS 691 SEMINAR. 1(1-0) F,S.** Required of all graduate students with a minor in horticultural science. Optional for all horticultural science graduate students. Preparation of scientific articles and special lectures. Students required to present one or more papers.

**HS 695 GRADUATE TOPICS IN HORTICULTURAL SCIENCE. Preq.: CI. 1-6 F,S,Sum.** Investigation of theoretical problems at the 600 level in horticultural science not related to a thesis problem; new 600-level courses during the development phase.

**HS 699 RESEARCH. Preqs.: Grad. standing in HS, consent of advisory committee chair. Credits Arranged.** A maximum of six credits allowed toward the Master of Science degree; no limitation on credits in doctoral program. Original research on specific problems in fruit, vegetable and ornamental crops.

# Immunology

**Degrees Offered: Ph.D., M.S.**

**GRADUATE FACULTY**

*Professor* W. A. Tompkins, *Coordinator*
Box 8401, (919) 515-7394

*Professors:* P. F. Agris, T. T. Brown Jr., P. B. Carter, L. Coggins, E. V. De Buysscher, B. Hammerberg, M. G. Levy;
*Professor Emeritus:* J. G. Lecce;
*Associate Professors:* E. J. Noga, M. A. Qureshi, M. B. Tompkins, S. L. Tonkonogy;
*Visiting Associate Professor:* S. Kennedy-Stoskopf;
*Assistant Professors:* S. M. Laster, B. Sherry, D. Weinstock

Course offerings or research facilities are available in the following areas: immunogenetics, immunopathology, immunotoxicology, immunoparasitology, mucosal immunology, molecular and infectious disease immunology, advanced immunology and biotechnology, aquatic immunology and environmental immunology.

**Admission Requirements**
Students will be accepted into the immunology program based on their academic records (GPA) as undergraduates and/or veterinary or medical students, results of the General Test of the Graduate Record Exam (required of applicants who do not hold a DVM or MD degree) and expression of interest in immunology. For the Ph.D. program, particular emphasis will be given to students who have had research experience (either an M.S. degree or other laboratory experience), especially in immunology, microbiology, biochemistry, or genetics, or students completing strong clinical residency programs.

To be admitted, a student should be a graduate of a major accredited biological science or medical science program. Students lacking appropriate courses may be considered for admission, but will be required to make up certain undergraduate deficiencies without graduate credit.

**Master's Degree Requirements**
Courses must include at least two 500-600 series immunology courses and two 500-level core biochemistry courses.

**Doctoral Degree Requirements**
Generally, Ph.D. students should take 22 credit hours to satisfy the course requirements of the program. These include at least two 500-600 level immunology courses, two 600-level core biochemistry courses and the core course in biotechnology (BIT 660). Additional courses in the biotechnology series are recommended. The remaining credit hours (8-10) should include journal club (IMM 691), seminar (IMM 695A) and research credits.

**Student Financial Support**
Graduate assistantships are available to students in the immunology program through the affiliated departments. In addition, there are graduate research assistantships provided by individual faculty of the program.

**Other Relevant Information**
The immunology program is an interdepartmental graduate program with faculty drawn from the College of Veterinary Medicine and the College of Agriculture and Life Sciences' Departments of Biochemistry, Microbiology and Poultry Science. For administrative purposes, all students accepted into the program will also have to be student members of one of the participating departments.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**IMM(MB) 551 IMMUNOLOGY. 3(3-0) S.** (See microbiology.)

**IMM(VMS) 555 IMMUNOPARASITOLOGY. 2(2-0) S. Alt. yrs.** (See veterinary medical sciences.)

**IMM(MB,PHY,PO,VMS) 556 IMMUNOGENETICS. 3(2-2) F. Alt. yrs.** (See poultry science.)

**IMM(PO) 557 AVIAN IMMUNOLOGY. 2(1-2) F. Odd yrs.** (See poultry science.)

*FOR GRADUATES ONLY*

**IMM(TOX) 605 IMMUNOTOXICOLOGY. 1(1-0) S.** (See toxicology.)

**IMM(MB,VMS) 653 ADVANCED IMMUNOLOGY. 3(3-0) F. Alt. yrs.** (See veterinary medical sciences.)

**IMM(VMS) 691 ADVANCED TOPICS IN IMMUNOLOGY AND BIOTECHNOLOGY. 1(1-0) F,S,Sum.** (See veterinary medical sciences.)

**IMM(VMS) 695A SEMINAR IN VETERINARY MICROBIOLOGY/ IMMUNOLOGY. 1(1-0) F,S.** (See veterinary medical sciences.)

# Industrial Design

**Degree Offered: Master of Industrial Design**

**GRADUATE FACULTY**

*Associate Professor* G. E. Lewis, *Head of the Department*
*Professor* H. Khachatoorian, *Director of Graduate Programs*
Box 7701, (919) 515-2208

*Professor:* V. M. Foote;
*Associate Professor:* A. V. Cooke;
*Assistant Professor:* P. Hooper

Industrial Design is the professional service of creating and developing concepts and specifications that optimize the value, function and appearance of products and product systems to the mutual benefit of both user and manufacturer. This service is often provided in the context of a cooperative working relationship with other members of a development group.

Typical groups include management, marketing, engineering, and manufacturing specialists. Industrial designers place special emphasis on human characteristics, needs and interests. These require particular understanding of visual, tactile, safety and convenience criteria. Industrial designers combine these considerations with practical concern for technical processes and requirements for manufacture; marketing opportunities and economic constraints; and distribution, sales, and servicing arrangements. Industrial designers are guided by the awareness of their obligations to protect and promote public safety and well-being; to respect the environment; and to observe ethical business practices.

Graduates with a Master of Industrial Design have career opportunities in four general areas; corporate design offices in manufacturing companies, independent design consulting firms, governmental agencies and educational institutions.

### Admissions Requirements

Applicants will be considered for admission on an individual basis and plans of study will be developed to take into account previous academic and professional experiences. In addition to other forms, applications must include a departmental personal data forms and a portfolio (required of students with design backgrounds).

### Student Financial Support

Priority is given to students in the major science, social science and technology areas.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

ID 400 INDUSTRIAL DESIGN STUDIO.
ID 418 IDEATION II
ID 415 MICROCOMPUTER GRAPHICS FOR DESIGNERS.
ID 492 SPECIAL TOPICS
ID 494 DESIGN INTERNSHIP
ID 495 INDEPENDENT STUDY

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ID 511 INDUSTRIAL DESIGN MATERIALS AND PROCESSES I. Preq.: Grad. standing. 3(3-0) S.** An analysis of paper, wood, metal and manufacturing processes utilized in the production of mass-produced products. Advanced studies in mass production processes and their influence on design and development of products. Emphasis on material search and process selection in relation to product safety, cost, function, human factors, form, finishes and joining methods.

**ID 512 INDUSTRIAL DESIGN MATERIALS AND PROCESSES II. Preq.: Grad. standing. 3(3-0) S.** An analysis of plastics and rubber and the related manufacturing processes utilized in the production of mass-produced products. Advanced studies in mass production processes and their influence on design and development of products. Emphasis on material search and process selection in relation to cost, product safety, function, human factors, form, finishes and joining methods.

**ID 541, 542 ADVANCED GRAPHIC DESIGN I, II. Preqs.: ARC 400, LAR 400, ID 400 or GD 400; waiver of preq. is at discretion of instructor. 6(3-9) F,S.** Application of previous studies in design and visual communications to a wide variety of visual problems presented by our physical environment.

**ID 582 SPECIAL TOPICS IN INDUSTRIAL DESIGN. Preq.: Grad. standing. 203 F,S.** Topics of current interest to the program/option offered by faculty in the School. Subjects offered under this number normally used to test and develop new courses.

**ID 591 SPECIAL PROJECT IN INDUSTRIAL DESIGN. Preq.: Grad. standing. 1-3 F,S.** Seminars on subjects of current interest in industrial design which are presented by persons not part of the regular faculty.

**ID 595 INDEPENDENT STUDY IN INDUSTRIAL DESIGN. Preq.: Grad. standing. Max. 6. F,S.Sum.** Special problems in various aspects of industrial design developed under the direction of a faculty member on a tutorial basis.

*FOR GRADUATES ONLY*

**ID 600 ADVANCED INDUSTRIAL DESIGN (SERIES). Preq.: Portfolio review. 6(0-12) F,S.** Advanced studies in industrial design. Special emphasis given to problem identification, program formulation and application of advanced design methods. All problems of an individual nature leading to a synthesis of previous design experience.

**ID 632 ADVANCED CONCEPTS IN PRODUCT ENGINEERING. Preq.: ID 600. 3(3-0) F,S.** Group investigation of advanced concepts in industrial design with emphasis on engineering. Engineering principles an important role in the design of useful products. The scope of this course includes mass movement of persons as well as the designs of consumer products. The field of transportation and consumer products fast-changing to satisfy the needs of present and future generations. To make designers aware of these needs by special investigations into future technologies and new material developments.

**ID 670 ADVANCED INDUSTRIAL DESIGN-TEXTILES (SERIES). Preq.: Portfolio review. 6(0-12) F,S.Sum.** Advanced studies in textile styling. Special emphasis given to problem indentification, program formulation and application of advanced design methods. All problems of an individual nature.

**ID 681 INDUSTRIAL DESIGN PROJECT PREPARATION. 3(3-0) S.** A seminar course designed to assist students in preparing the groundwork for the final project to be conducted in the design studio.

**ID 688 FINAL PROJECT STUDIO IN INDUSTRIAL DESIGN. Preq.: ID 681. 6(0-12).** Final project for graduate students supervised by members of their graduate advisory committees.

**ID 691 SPECIAL SEMINAR IN INDUSTRIAL DESIGN. 1-6 S.** An investigation of special topics in industrial design of a particular interest to advanced students under the direction of the chair of the graduate committee on a tutorial basis. Credit and content vary with each student.

# Industrial Engineering

**Degrees Offered: Ph.D, M.S., Master of Industrial Engineering**

## GRADUATE FACULTY

*Professor* S. D. Roberts, ***Head of the Department***
*Professor* R. G. Pearson, ***Director of Graduate Programs***
Box 7906, (919) 515-6410, pearson@eos.ncsu.edu

***University Professor:*** S. E. Elmaghraby

***Professors:*** M. A. Ayoub, R. H. Bernhard, S. Fang, T. J. Hodgson, W. L. Meier Jr., H. L. Nuttle, P. J. O'Grady, W. A. Smith Jr., J. R. Wilson;
***Professors Emeriti:*** R. Alvarez, C. A. Anderson, J. R. Canada, R. W. Llewellyn, A. L.Prak;
***Associate Professors:*** C. T. Culbreth Jr., Y. Fathi, R. E. King, E. T. Sanii, R. E. Young;
***Assistant Professors:*** H. Damerdji, M. G. Kay, G. A. Mirka, R. O. Mittal, J. Trevino

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** T. Johnson, R. C. Luo;
***Associate Professor:*** T. L. Honeycutt

The graduate faculty in industrial engineering supports academic and research interests in four areas: manufacturing systems (manufacturing processes, CAM, CIM, robotics, automation, and concurrent engineering); production systems (planning, scheduling, routing, inventory control, materials handling, facility design, and quality control); systems analysis and optimization (stochastic processes, simulation, and modeling); and ergonomics (human performance, occupational safety, and biomechanics). The department faculty actively supports independent graduate degree programs in operations research, integrated manufacturing systems engineering and management.

### Admission Requirements

Applications are accepted from undergraduate majors in engineering and in the behavioral, physical, and mathematical sciences who meet prerequisites in calculus and matrix/linear algebra, computer science, and statistics.

### Master's Degree Requirements

The Master of Science degree involves depth of study in a specified area of concentration, nine hours in a minor and six hours of research credit. The Option B Master of Industrial Engineering (MIE) may be obtained by course work only; project work is optional. A minimum of 33 hours is required for the MIE.

### Doctoral Degree Requirements

This degree requires 60 hours of coursework beyond the B.S. degree. Undergraduate students with superior credentials may apply directly to the doctoral program and bypass the M.S. degree. For students who have completed the M.S. degree, typically 30 to 36 hours of additional coursework are required. A departmental written qualifying examination in two areas is required.

### Student Financial Support

Research and teaching assistantships are available on a competitive basis to early applicants. Fellowships of $3,000 and $6,000 which supplement assistantship stipends are available to U.S. applicants with superior credentials. Award priority is given to Ph.D., then M.S. applicants. The department does not make assistantship or tuition waiver awards to foreign applicants.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

IE 401 STOCHASTIC MODELS IN INDUSTRIAL ENGINEERING.
IE(CSC) 441 INTRODUCTION TO SIMULATION.
IE 443 QUALITY CONTROL.
IE 452 ERGONOMICS.
IE 453 FACILITIES DESIGN.

### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**IE(MA,OR) 505 LINEAR PROGRAMMING. Preq.: MA 405. 3(3-0) F,S.** Application of mathematical methods to problems of planning. Detailed coverage of linear programming. Course for those desiring to study this subject in depth and detail. Rigorous and complete development of theoretical and computational aspects of this technique as well as discussion of a number of applications.

**IE 506 DESIGN OF FLEXIBLE MANUFACTURING SYSTEMS. Preqs.: IE 307, IE 351; Coreq.: IE 516. 3(3-0) F.** Operational characteristics, information requirements, control structures and application of flexible manufacturing systems

(FMS). Integration of technologies including computer numerical control (CNC) machining, robotics, intelligent sensors, automated material handling, and real-time computer control. Methodologies for design and evaluation of physical systems and associated control systems.

**IE 507 REAL-TIME CONTROL OF AUTOMATED MANUFACTURING. Preq.: IE 516. 3(3-0) S. Alt. yrs.** Concepts and application of real-time control of automated manufacturing systems. Development of prototype manufacturing control applications involving introductions to the following topics: computer architecture; real-time, multi-tasking operating systems; data modeling; multi-processing systems; local area networks; inter-task communication; and development of multi-tasking control systems. Design development of the control system.

**IE(OR) 509 DYNAMIC PROGRAMMING. 3(3-0) S.** (See operations research.)

**IE 510 APPLIED ENGINEERING ECONOMY. Preqs.: Undergrad. courses in engineering economics and ST or CI.** 3(3-0) F. Engineering economy analysis of alternative projects including tax and inflation aspects, sensitivity analysis, risk assessment, decision criteria. Emphasis on applications.

**IE 511 CAPITAL INVESTMENT ECONOMIC ANALYSIS. Preqs.: IE 311, ST 371. 3(3-0) F.** Analysis of economic merits of alternatives including interest and income tax considerations. Risk and sensitivity exploration techniques. Introduction to analytical techniques for multiple objectives or criteria. Use of mathematical programming and computers for capital budgeting.

**IE 512 BAYESIAN DECISION ANALYSIS FOR ENGINEERS AND MANAGERS. Preq.: ST 371 or ST 421. 3(3-0) S.** The Bayesian approach to decision making, with numerous applications in engineering and business. Expected value maximization, decision trees, Bayes' theorem, value of information, sequential procedures and optimal strategies. Axiomatic utility theory and controversies, utility of money, theoretical and empirical determination of utility functions and relationship to mean-variance analysis. Brief introduction to multi-attribute problems, time streams and group decisions.

**IE 516 COMPUTER-AIDED MANUFACTURING. Preq.: IE 351. 3(3-0) F,S.** General principles of CAD/CAM integration. Elements of computer graphics. Engineering data base. Computer Process Control. Group Technology concepts and applications. Flexible manufacturing systems.

**IE 518 MANUFACTURING OPERATIONS MANAGEMENT. Preqs.: MA 242; ST(EB) 350 or ST 372. 3(3-0) F,S. Not for IE majors.** Concepts, problems and procedures for the management of manufacturing operations. Emphasis on fore-

casting, capacity planning, material requirements planning, scheduling, inventory control and related computer-based control systems.

**IE 519 CIM SYSTEM DESIGN. Preq. or Coreq.: IE 516. 3(2-3) F.** Tools and methods for the design of computer-integrated manufacturing (CIM) systems in the context of the CIM development life-cycle. Emphasis on automation of information flow supporting the process and assembly operations. Process flow techniques, hierarchical decomposition techniques, information structure analysis techniques; and methods to apply them to produce an integrated system.

**IE(MAE) 520 INDUSTRIAL ROBOTICS. Preqs.: IE 351; MA 301 or MA 303. 3(3-0) F.** Development, structure, specifications and capabilities of industrial robots. Robot control fundamentals. Kinematics of manipulators. Applications, selection, economics and implementation of robotic systems. Safety considerations, end-of-arm tooling and design of robotic workplace. Acutators, sensors including vision and tactile sensory systems for robots.

**IE 521 MANAGEMENT DECISION AND CONTROL SYSTEMS. Preqs.: CSC 421 or equivalent. 3(3-0) F.** Planning and development of comprehensive computer-based information systems to support management decisions. Formal systems concepts; management information requirements. Management science and organizational behavior influences. Data bases and advanced system techniques and concepts. System evaluation and cost effectiveness.

**IE 523 PRODUCTION PLANNING, SCHEDULING AND INVENTORY CONTROL. Preqs.: OR 501 and ST 515 or equivalents. 3(3-0) F,S.** An analysis of Production-Inventory systems. Discussion of commonly used planning and scheduling techniques. Introduction to the use of math modeling for solution of planning and scheduling problems. Interface with quality control and information systems.

**IE 525 ORGANIZATIONAL PLANNING AND CONTROL. Preq.: Three hrs. in operations management (such as EB 325, IE 308). 3(3-0) S.** Organization theory and systems approaches to administrative functions. Human and social influences of management systems for planning and control of activity. Policy, structure and procedure related to industrial engineering activities. Effects of automation.

**IE(PSY) 540 HUMAN FACTORS IN SYSTEMS DESIGN. Preq.: IE 452 or PSY 340; Coreq.: ST 507 or 515. 3(3-0) F.** Introduction to the systems development cycle. Man-machine function allocation, design standards, display and control systems, workspace layout, the personnel sub-system concept, anthropometry and maintainability design.

**IE 541 SYSTEMS SAFETY ENGINEERING. Preqs.: IE 452, ST 371. 3(3-0) S.** Problems in occupational safety and health; OSHA standards; preventive aspects involving product and work design and personnel selection. Consideration of the methods used in accident-injury study, including field investigation, experimental engineering and biomedical research, and statistical and epidemiological studies. Managerial aspects of safety accountability. Product liability and forensics.

**IE 542 PHYSIOLOGICAL CRITERIA IN WORK MEASUREMENT. Preq.: Grad. status. 3(3-0) F. Alt. yrs.** Basic endocrine and autonomic nervous system anatomy and physiology; measures reflecting sympathetic nervous system activity; concepts applicable to work measurement studies including a discussion of arousal theory and the concept of autonomic balance; and survey of current literature on equipment design and use.

**IE 544 OCCUPATIONAL BIOMECHANICS. Preq.: Grad. standing in engineering. 3(2-2) F.** General concepts and techniques of understanding the anatomical and physiological bases of human motion. Characteristics and limitations of human motor capabilities, body mechanics and use of biomedical instrumentation for monitoring and quantifying human performance. Applications of biomechanics in work, industry, rehabilitation, sports, space research and safety.

**IE(PSY) 545 HUMAN PERFORMANCE. Preqs.: Grad. standing; ST 507 or equivalent. 3(3-0) S. Alt. yrs.** Fundamentals of human perceptual and motor abilities basic to skilled operator performance. Theoretical models of the human as an operator. The human as an information processing mechanism. Motor skills learning, performance decrement and information feedback. Channel capacity, stress, fatigue, arousal theory. Attention, time-sharing and workload. Sustained performance, vigilance, monitoring, search, inspection and tracking. Circadian rhythms; sleep loss; shiftwork.

**IE 547 RELIABILITY ENGINEERING. Preq.: ST 515 or equivalent. 3(3-0) F. Alt. yrs.** Basic concepts of reliability engineering. Application of probability and statistics to estimate reliability of industrial systems; development of reliability measures; analysis of static and dynamic reliability models; development and analysis of fault trees; analysis of Markovian and non-Markovian models; and optimization of reliability models.

**IE 548 QUALITY ENGINEERING. Preqs.: OR 501, ST 515. 3(3-0) S. Alt. yrs.** An introduction to basic concepts of quality engineering. Statistical process control (SPC) methods, acceptance sampling techniques, concept of parameter design and statistical as well as analytical techniques for its implementation, tolerance analysis and design, components of cost of poor quality and an introduction to quality management.

**IE 549 TOLERANCES IN DESIGN AND MANUFACTURING. Preqs.: IE 516, ST 372. 3(3-0) S. Alt. yrs.** Tolerancing of discrete parts and assemblies. Limit tolerancing and geometric tolerancing techniques. American National Standard and its applications. Methods of tolerance analysis and synthesis including computer implementation. Tolerance representation in CAD systems. Relationship between tolerances and cost. Functional tolerancing.

**IE 550 CONCURRENT ENGINEERING. Preq.: IE 516. 3(3-0) F.** Concurrent engineering, concurrent engineering of printed wiring boards, design for testability, design for assembly, process selection, interface to feature-based computer-aided design systems, concurrent engineering of metal parts, concurrent engineering performance measurement, concurrent engineering and computer-integrated manufacturing.

**IE 553 MATERIAL HANDLING SYSTEMS. Preq.: IE 453. 3(3-0) S.** Analysis, design, evaluation and implementation of material handling systems. Principles, functions, equipment, concepts and traditional approaches of material handling. Impact of facilities design on material handling and application of quantitative techniques to material handling systems design. Description of factors and approaches to material handling management and the criticality of properly designed and operated material flow systems.

**IE 555 THE JUST-IN-TIME PRODUCTION SYSTEM. Preqs.: IE 523; OR 501. 3(3-0) F.** Concepts, requirements, limitations, examples and implementation procedures of the Just-In-Time Production System (JIT). Relationship between JIT and total quality assurance, total employee involvement and computer integrated manufacturing systems. Organizational changes under JIT. Mathematical programming models, simulation-animation models and object-oriented knowledge systems supporting the design of JIT.

**IE 560 APPLIED STOCHASTIC MODELS IN INDUSTRIAL ENGINEERING. Preqs.: MA 303, ST 371. 3(3-0) F.** Formulation and analysis of stochastic models with particular emphasis on applications in industrial engineering; univariate, multivariate and conditional probability distributions; unconditional and conditional expectations; elements of stochastic processes; moment-generating functions; concepts of stochastic convergence; limit theorems; homogeneous, nonhomogeneous and compound Poisson processes; basic renewal theory; transient and steady-state properties of Markov processes in discrete and continuous time.

**IE(OR) 561 QUEUES AND STOCHASTIC SERVICE SYSTEMS. 3(3-0) S.** (See operations research.)

**IE(CSC,ECE,OR) 562 COMPUTER SIMULATION TECHNIQUES. 3(3-0) F.** (See computer science.)

**IE(CSC,ECE) 575 VOICE INPUT/OUTPUT COMMUNICATION SYSTEMS. Preqs.: IE 307 or CSC 312. 3(3-0) F.** (See computer science.)

**IE(MA,OR) 586 NETWORK FLOWS. 3(2-2) S. Alt. yrs.** (See operations research.)

**IE 588 DIRECTED STUDY IN INDUSTRIAL ENGINEERING. Preq.: CI. 1-6 F,S, Sum.** Independent study providing an opportunity for individual students to explore topics of special interest under the direction of a member of the faculty.

**IE 589 SPECIAL TOPICS IN INDUSTRIAL ENGINEERING. Preq.: CI. 3(3-0) F,S.** Special developments in some phase of industrial engineering using traditional course format. Identification of various specific topics and prerequisites for each section from term to term.

**IE 591 INDUSTRIAL ENGINEERING PROJECTS. Preq.: MIE candidates only. 1-6 F,S,Sum.** Investigation and written report on assigned problems germane to industrial engineering. Maximum of six credits to be earned for the MIE degree.

**IE(PSY) 593 AREA SEMINAR IN ERGONOMICS. 1(0-2) F.** (See psychology.)

**IE 594 SEMINAR IN PRODUCT SAFETY AND LIABILITY. Preq.: Grad. standing. 1(1-0) S. Alt. yrs.** Consumer product safety, laws and standards. Products liability, negligence, due care, strict liability and foreseeability. Product defects, design flaws and liabilities, hazard control, ergonomics design, warnings and labels. Product safety programs for manufacturers; management guidelines. Litigation process, forensic investigation and expert witnessing. Accident case studies.

*FOR GRADUATES ONLY*

**IE 611 THE DESIGN OF PRODUCTION SYSTEMS. Preqs.: IE 523, OR 501. 3(3-0) F. Alt. yrs.** The structure and operation of production planning, scheduling and control systems; emphasis on system structure, capacity planning, master production scheduling and shop loading; investigation of current trends in the field.

**IE(OR) 612 ADVANCED SCHEDULING AND ROUTING. Preqs.: IE 523, OR 501, OR(MA) 504. 3(3-0) S. Alt. yrs.** In-depth study of analytical models of problems arising in the scheduling of single and parallel processors, flow shops and job shops and in routing and scheduling of delivery vehicles. Emphasis on analysis,

solution methodologies and underlying theory. Discussion of recent trends and outstanding problems from both theoretical and applied points of view.

**IE 616 COMPUTER INTEGRATION OF MANUFACTURING SYSTEMS. Preq.: IE 516. 3(3-0) S.** In-depth study of computer integration of manufacturing systems. CIM elements (CAD, CAPP, CNC, industrial robotics), manufacturing control, communication and networking, interfacing, database design, material handling and computer hardware requirements in automated manufacturing systems. Emphasis on the integration of the components involved in computerized manufacturing environments.

**IE 617 COMPUTERIZED PROCESS PLANNING. Preq.: IE 516. 3(3-0) S.** In-depth study of automated and Computer Aided Process Planning (CAPP). Analysis of the process planning task and its various functions and stages; need for automation; approaches to CAPP system development; interrelationship of process planning with design and manufacturing, and their integration. Applications of CAPP and discussion of significant CAPP systems methodologies.

**IE 619 CONSTRAINT MODELING OF MANUFACTURING SYSTEMS. Preq.: IE 550 or CI. 3(3-0) S. Alt. yrs.** The formal basis for constraint-based modeling applied to manufacturing systems. Representing constraints, constraint propagation and detecting constraint violations. Applicability to modeling manufacturing problem-solving.

**IE 621 ADVANCED PROBLEMS IN MANAGEMENT SYSTEMS ENGINEERING. Preq.: CI. 1-4 F.** Coverage of advanced techniques, current research and contemporary problems in analysis, design and operation of management systems. Varied topics cover aspects of economic decision analysis, cost effectiveness, information flow, system performance evaluation and modern organization concepts.

**IE 631 MULTI-ATTRIBUTE DECISION ANALYSIS. Preqs.: IE 511 or IE 512; OR 501 or OR 505. 3(3-0) S.** Specification of attributes/criteria/objectives for complex decisions. Determination of alternatives, attribute weights and decision-making process. Graphical and weighted evaluation techniques. Multi-attribute utility, multi-objective/goal programming and analytic hierarchy process methodologies. Computer applications and case studies.

**IE(PSY) 640 SKILLED OPERATOR PERFORMANCE. Preqs.: PSY 545, ST 507, or ST 515. 3(3-0) S. Alt. yrs.** Consideration of theories of the human operators with regard to the classical problems of monitoring, vigilance and tracking. Factors such as biological rhythm, sleep loss, sensory restriction, environmental stress and time-sharing as they interact with and determine overall systems efficiency.

**IE 641 ENVIRONMENTAL FACTORS AND HUMAN PERFORMANCE. Preqs.: IE(PSY) 540 and IE 542 or other equivalent. 3(3-0) S. Alt. yrs.** Major problem areas, methodology, theory and experimental work in biotechnology; interaction among engineering, biological and behavioral factors in design for safety and survival; physiology and biomechanics of acceleration, deceleration and pressure altitude; consideration of operator effectiveness in submarine, extra-terrestrial, arctic and desert environments; techniques in evaluation of crash dynamics and pathology; closed-ecological systems.

**IE 646 HUMAN FACTORS IN VISUAL DISPLAY SYSTEMS. Preq.: IE (PSY) 540. 3(3-0) S. Alt. yrs.** Electronic visual display systems; integration of photometry, vision and image quality metrics with human factors design concepts associated with standard and advanced display technology options (*e.g.*, CRT, flat panels and virtual image displays); applications and research issues.

**IE(OR) 662 STOCHASTIC SIMULATION DESIGN AND ANALYSIS. 3(3-0) S.** (see operations research.)

**IE(CSC,ECE) 675 ADVANCES IN VOICE INPUT/OUTPUT COMMUNICATIONS SYSTEMS. Preq.: IE(CSC,ECE) 575. 3(2-3) S.** (See computer science.)

**IE 688 ADVANCED DIRECTED STUDY IN INDUSTRIAL ENGINEERING. Preq.: CI. 1-6 F,S,Sum.** Independent study providing an opportunity for individual graduate students to explore advanced topics of special interest under the direction of a member of the faculty.

**IE 689 ADVANCED SPECIAL TOPICS IN INDUSTRIAL ENGINEERING. Preq.: CI. 3(3-0) F,S.** Advanced topics in some phase of industrial engineering using traditional course format. Identification of various specific topics and prerequisites for each section from term to term.

**IE(OR,MA) 692 SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING. Preq.: IE(MA,OR) 505. 3(3-0) S. Alt. yrs.** Special advanced topics in the area of mathematical programming. New techniques and current research in this area. The faculty responsible for this course select areas to be covered during the semester according to their preference and interest. Not necessarily taught by an individual faculty member but can, on occasion, be joint effort of several faculty members from this university as well as visiting faculty from other institutions.

**IE 693 SEMINAR IN APPLIED ERGONOMICS. Preqs.: IE(PSY) 540; ST 515. 1(1-0) On demand.** Discussion of contemporary issues involving ergonomic approaches to the design of work, products and systems. Survey of current ergonomics research and methodologies and their application to areas of faculty and

student interest, such as: industrial ergonomics, occupational safety, manufacturing, transportation, computer systems and process control.

**IE 694 ADVANCED PROBLEMS IN ERGONOMICS. Preqs.: IE(PSY) 540, ST 515. 3(3-0) F.** Exploration in depth of a problem area of contemporary interest involving the man-machine-environment interface. Class discussion and analysis of research and theory, with special focus on the human factors aspects of systems design and operation.

**IE 695 SEMINAR. 1(1-0) F,S.** Seminar discussion of industrial engineering problems for graduate students. Case analyses and reports.

**IE 699 INDUSTRIAL ENGINEERING RESEARCH. Credits Arranged. F,S, Sum.** Graduate research in industrial engineering for thesis credit.

# Instructional Technology - Computers

For a listing of graduate faculty and program information, see curriculum and instruction.

# Integrated Manufacturing Systems Engineering

**Degree Offered: Master of Integrated Manufacturing System Engineering**

**GRADUATE FACULTY**

*Associate Professor* E. Sanii, *Interim Director of Graduate Programs*
Box 7915, (919) 515-3808, Fax: (919) 515-7968

*Professors:* R. L. Barker, R. E. Carawan, R. M. Felder, P. L. Grady, T. J. Hodgson, T. Johnson, R. Luo, C. J. Maday, W. L. Meier Jr., H. L. Nuttle, P. J. O'Grady, W. A. Smith Jr., K. Tai, J. R. Wilson, S. C. Winchester;
*Associate Professors:* D. R. Bahler, T. G. Clapp, C. T. Culbreth Jr., Y. Fathi, R. E. King, R. D. Rodman, J. P. Roise, R. E. Young;
*Assistant Professors:* Y. A. Chen, H. Damerdji, T. K. Ghosh, G. L. Hodge, W. J. Jasper, M. G. Kay, R. O. Mittal, P. I. H. Ro, J. P. Rust, A. M. Seyam, J. Trevino;
*Lecturer:* J. C. Sutton III

The IMSE Institute was established in 1984 as a University response to national productivity and competitiveness concerns. Its purpose is to assist industry in strengthening the country's capability to produce goods of improved quality at lower cost. It provides the basis for a university/industry cooperative program in modern manufacturing systems.

### Admission Requirements

Admission to the IMSE master's program requires a BS degree from an accredited institution, preferably in engineering, physics, mathematics or computer science.

### Master's Degree Requirements

This degree requires a minimum of 27 hours of graduate course work and 6 hours of research project. The research requirement may be completed while serving as a graduate assistant on an Institute project. Credit hours for core courses total 15, concentration electives, 12, and research project, 6 for a total of 33 credit hours.

### Student Financial Support

Assistantships and fellowships are available to qualified students. First-year support is generally provided by the Institute. Students are encouraged to seek support through funded projects for the remainder of their program. United States citizens, non-North Carolina residents with graduate assistantships qualify for in-state tuition rates.

### Other Relevant Information

The Institute is supported by an industrial affiliates group of member companies. They include CP&L, GE, IBM, and R.J. Reynolds Tobacco. The Institute interacts with member companies through an Industry Advisory Board and a Technical Monitors Group.

Basic generic research program is funded by the membership fees of the industrial affiliates supports individual faculty projects aimed at the development of new manufacturing systems technology. Member companies help define areas of generic research.

Both member and non-member companies also fund application projects that apply the results and technology from the generic research to problem-specific applications.

*Core Courses (15 credit hours)*

**IE 511 CAPITAL INVESTMENT AND ECONOMIC ANALYSIS**
or
**BUS 520 MANAGERIAL FINANCE**
**IE 516 COMPUTER-AIDED MANUFACTURING**

*One of the following:*
IE 518 MANUFACTURING OPERATIONS MANAGEMENT
IE 523 PRODUCTION, PLANNING, SCHEDULING AND INVENTORY CONTROL

*One of the following:*
CSC(ECE) 510 SOFTWARE ENGINEERING
CSC(ECE) 542 DATABASE MANAGEMENT
CSC(ECE,IE,OR) 562 COMPUTER SIMULATION TECHNIQUES

MAE 542, MECHANICAL DESIGN FOR AUTOMATED ASSEMBLY

*Concentration Electives (12 credit hours)*
Manufacturing Automation, Manufacturing Operations Management, Mechanical Product Design, Sensors, Control and Robotics, Quality Design and Engineering, and Artificial Intelligence and Information Handling.

*Research Project (6 credit hours)*

*FOR GRADUATES ONLY*

**IMS 698 MANUFACTURING SYSTEMS ENGINEERING PROJECT. Preqs.: Grad. standing in IMSE; CI. 1-3 F,S.** Individual or team project work in integrated manufacturing systems engineering resulting in an engineering report. Required of all degree candidates in IMSE master's program. Forms the basis for IMSE student's final oral examination.

# International Development

**Degree Offered: Master of Technology for International Development**

## GRADUATE FACULTY

*Professor* E. W. Erickson, *Coordinator*
Box 7112, (919) 515-3201, Fax (919) 515-6835, ed_erickson@ncsu.edu

*Professors:* M. K. Beute, R. I. Bruck, S. W. Buol, C. H. Carlton, D. K. Cassel, J. G. Laarman, M. H. M. Mohamed, R. L. Moxley, C. H. Proctor, J. C. C. H. Shih, R. W. Slatta, M. S. Soroos, D. W. Stewart;
*Professors Emeriti:* J. L. Apple, A.J. Coutu, C. B. Davey, H. D. Gross, R. A. King;
*Associate Professors:* R. H. Dorff, T. N. Hammond, H. G. Kebschull, A. C. Malinowski, J. K. Ocko, K. R. Pond, M. D. Schulman, S. E. Simonsen, T. J., Smyth, G. D. Surh, J. M. Wallace;
*Assistant Professor:* J. C. Beghin

**Admission Requirements**
See the general requirements for admission to the Graduate School.

**Degree Requirements**
The program of work requires:

1. 36 semester credits, half in the relevant professional area and the remainder in internationalizing areas. The MTID colloquium (TID 501) is required.
2. a work experience of a minimum of 12 weeks in a foreign country and a substantial report on that field experience.
3. conversational facility in one foreign language as determined by an oral examination.
4. a comprehensive written examination, which may be required at the discretion of the advisory committee.

The MTID program has curricular flexibility. The professional specialization may be done in any of the 72 departments in the 10 substantive NCSU colleges and schools. The internationalizing courses may be drawn from a wide variety of applicable courses offered throughout NCSU. The internationalizing courses may focus on a particular area such as Latin America or Europe; the international applications of principles of law, economics, management or administration; or a combination of the foregoing. The professional courses may be drawn from more than one department. The plan of graduate work for an MTID student must be a coherent intellectual whole with the requisite disciplinary integrity to satisfy the student's committee and the MTID coordinator, but it may be drawn from the whole breadth of NCSU.

The program of study is tailored to the student's individual needs rather than following a prescribed course; therefore, the student is expected to be able to demonstrate maturity and assume initiative in planning his/her own course of study. The relevant department assists in choosing a set of courses which provide grounding in the professional area, and the Office of International Programs assists in identifying appropriate "internationalizing" courses which satisfy the student's particular needs and interests.

***FOR GRADUATES AND ADVANCED UNDERGRADUATES***

**TID 501 COLLOQUIUM IN INTERNATIONAL DEVELOPMENT. Preq.: Grad. standing or CI. 3(3-0).** An interdisciplinary survey of the process and institutions of international development. Systematic review of comparisons and contrasts of selected countries and regions. Specific topics drawn from technological and institutional innovations in development contexts.

**TID 598 TOPICAL PROBLEMS IN INTERNATIONAL DEVELOPMENT. Preq.: MTID standing. 1-6 F,S,Sum.** Investigation of topics of particular interest to advanced students under faculty direction on a tutorial basis. Credits and content vary with student/faculty discretion and needs.

**TID 599 INTERNSHIP IN INTERNATIONAL DEVELOPMENT. Preq.: MTID standing. 1-6 F,S,Sum.** Exposure of student to the value systems and technological environment of cultures other than his/her own through a supervised work experience. The application of technological knowledge to development problems. Required technical paper summarizing and analyzing this experience.

# Landscape Architecture

**Degree Offered: Master of Landscape Architecture**

## GRADUATE FACULTY

*Professor* A. R. Rice, *Head of the Department*
Box 7701, (919) 515-2208

*Professors:* R. C. Moore, R. R. Wilkinson, D. Wood;
*Professors Emeriti:* R. E. Stipe, E. G. Thurlow;
*Associate Professor:* A. R. Abbate;
*Adjunct Associate Professors:* D. Bartelt, C. E. Roe, L. R. Zucchino;
*Assistant Professors:* F. H. Magallanes, S. R. Raval

## ASSOCIATE MEMBER OF THE PROGRAM

*Professors:* W. E. Hooker, J. C. Raulston;
*Lecturer:* M. E. Traer

Course offerings or research facilities are available in the following areas: site planning, landscape architecture, community design, regional planning and design, and resource management.

### Admission Requirements

The best-qualified applicants will be accepted up to the number of spaces that are available for new students. Exceptions to the minimum 3.00 grade-point average may be made for students with special backgrounds, abilities, and interests.

### Master's Degree Requirements

A minimum of 36 course credits is required with a minimum of nine 500- or 600-series landscape architecture courses taken at the university. Students without

previous professional degrees in landscape architecture are required to take additional hours of instruction up to 72 course credit hours. Programs of study are developed by the department's Director of Graduate Programs for all incoming graduate students. These programs outline a general course of study and state the number of course credits required for graduation. A final project is required.

**Other Revelant Information**

Students have the option of including a graduate minor in their course of studies. Minors can be in any other graduate program offered at NCSU. Some examples of graduate minors are: architecture, education, horticultural science, civil engineering, and parks, recreation and tourism management. Special programs and labs in the Department of Landscape Architecture and the School of Design include the Coalition for Community Conservation, the Virtual Environments Laboratory and their program in environment visualization and simulation.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

LAR 400 LANDSCAPE ARCHITECTURE STUDIO.
LAR 421 ENVIRONMENTAL COGNITION FOR DESIGNERS.
LAR 423 CONCEPTS OF SPACE.
LAR 430 SITE PLANNING.
LAR 433 NATIVE PLANTS IN ENVIRONMENTAL DESIGN.
LAR 444 HISTORY OF LANDSCAPE ARCHITECTURE.
LAR 457 LANDSCAPE CONSTRUCTION MATERIALS, METHODS AND DOCUMENTATION.
LAR 494 INTERNSHIP IN LANDSCAPE ARCHITECTURE.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**LAR 510 GRAPHICS FOR LANDSCAPE ARCHITECTS. Preq.: Grad. standing or CI; Coreq.: LAR 600 or CI. 3(3-0) F.** A series of demonstrations and exercises to give students exposure to and experience with conventional techniques of graphic representation and presentation.

**LAR 511 COMMUNITY DESIGN POLICY. Preq.: Grad. standing or CI. 3(3-0) S.** Exploration of theory and practices of the social policy impact on designed environment and users of that environment. Study of public community development process studied in relation to the built environment.

**LAR 512 LANDSCAPE RESOURCE MANAGEMENT. Preq.: CI. 3(1-4) S.** Laboratory techniques course in the methodology of analysis and management of natural resources as related to landscape architecture. Case study approach to managed resource systems using spatial mapping and analysis techniques.

**LAR 521 VALUES, THEORY AND METHODS OF LANDSCAPE ARCHITECTURE. Preq.: Grad. standing. 3(3-0) F.** Radical change in profession of landscape architecture in the past decade. New and emerging roles for the landscape architect include regional analysis, landscape assessment, land development, urban planning, recreation planning, etc. Development of the core values and theories from which each emerged and survey of the techniques and methods of their development.

**LAR 530 ADVANCED SITE PLANNING. Preq.: LAR 430. 3(2-2) S.** Expansion of fundamental site planning techniques applied to development of design proposals including grading, utilities, layout plans, hydrologic calculations, details and specifications.

**LAR 533 PLANTS AND DESIGN. 3(2-2) S.** Examination of three landscape types: natural landscapes, landscapes altered by man and designed landscapes. Investigation of relevant plant materials and planting design processes utilized to reveal natural principles as the basis for a design theory and methodology. Course assignments range from an analysis of actual plant materials and landscapes to the preparation of contract documents.

**LAR 551 ETHICS OF PROFESSIONAL PRACTICE IN LANDSCAPE ARCHITECTURE. 3(3-0) S.** An examination of place of the professional in society, the contents and philosophies of various professional codes of ethics, the relationship of the practitioner with clients, peers and the public interest. Preparation of proposals, conduct as an expert witness, office organization and contracts.

**LAR 564 MANAGEMENT AND MARKETING TECHNIQUES IN COMMUNITY DESIGN. 3(3-0) S. Alt. yrs.** Methods for effective management of community design processes. Emphasis on personal management skills, group process techniques, publicity materials, public relations and marketing strategies. A technical assistantship with a local agency/organization required.

**LAR 573 HISTORIC PRESERVATION. Preqs.: Grad. standing and CI. 3(3-0) F.** Seminar covering the legal, administrative, fiscal and political aspects of preserving and conserving buildings, sites, districts, objects and landscapes of architectural, historical and design significance as related to community design and planning considerations. Subjects to be treated include federal, state and local statutes and ordinances; federal and state court decisions and administrative processes.

**LAR 574 LANDSCAPE AND TOWNSCAPE CONSERVATION. Preq.: LAR 511. 3(3-0) S.** Examination of local, state and federal law affecting the visual quality of large-unit natural and built environments such as landscapes and town-

scapes, as expressed in local ordinances, state statutes, executive orders, administrative regulations and court decisions. Emphasis on the legal, administrative, fiscal and governmental tools and processes for maintaining and enhancing visual environmental quality.

**LAR 575 DEVELOPMENT PLANNING. Preq.: Grad. standing or CI. 3(3-0) F,S.** Seminar presentation of concepts, processes and principles used in the design and development of communities. Focus discussions focus on a general development process, the development team and the role of the designer in the context of the team. Discussion of wide range of project types. The relationships of public regulatory policies and programs to the community design and development process.

**LAR 576 MASTER PLANNING AND DESIGN MANAGEMENT. Preq.: Advanced undergrad. or grad. standing. 3(3-0) S. Alt. yrs.** Case studies in master planning and design management of "multi-designer" environments such as planned communities, historic districts, urban centers, college campuses, retail centers, expos, and corporate and governmental building programs. Analysis of design review procedures. Emphasis on collaborative design methods. Student preparation and implementation of master plan and design management system.

**LAR 582 SPECIAL TOPICS IN LANDSCAPE ARCHITECTURE. Preq.: Grad. standing. 2-3 F,S.** Topics of current interest to the programs in the School of Design offered by faculty in the School. Subjects offered under this number are normally used to test and develop new courses.

**LAR 595 INDEPENDENT STUDY. Preq.: Grad. standing. Max. 6. F,S,Sum.** Special problems in various aspects of design developed under the direction of a faculty member on a tutorial basis.

*FOR GRADUATES ONLY*

**LAR 600 LANDSCAPE DESIGN STUDIO. 6(0-12) F,S.** The application of information and skills developed in course work to environmental design problems. A process of site selection, activity programming, site planning, and program evaluation followed employing the creation of interactive communication systems between the designer, clients and users. Goals include the design of satisfying new landscapes as well as conservation and design strategies for existing culturally important landscapes and townscapes.

**LAR 611 ADVANCED COMMUNITY DESIGN AND DEVELOPMENT CONTROL. Preq.: LAR 511. 3(1-3) S.** Advanced work in design and application of governmental planning and development control techniques to built environments, and impact of such controls on design solutions at varying scales. Emphasis on

design implications of complex control systems: development rights transfer, land use intensity rating systems, planned unit development regulations and other zoning and non-zoning site planning regulations.

**LAR 612 SOCIAL FACTORS ANALYSIS IN SITE PLANNING. Preq.: LAR 511 or CI. 3(2-1) S.** Exploration of social factors techniques and research applications to the design of the landscape. Interaction, neighborhood theory and user preference analysis techniques presented through discussion and development of research and case studies.

**LAR 681 FINAL PROJECT RESEARCH IN LANDSCAPE ARCHITECTURE. Preqs.: 3 LAR 600 studios. 0(0-0) F,S.** Each student in his or her terminal semester not registered in any other courses and in conjunction with the terminal case study will prepare and submit to his or her committee a presentation on the relevance of one's minor to design process with particular reference to individual's case study.

**LAR 688 FINAL PROJECT STUDIO IN LANDSCAPE ARCHITECTURE. Preq.: LAR 681. 2-6 F,S.** Graduate students sufficiently prepared may undertake selected research investigations. A proposal for such investigations must be submitted prior to consent for enrollment.

# Liberal Studies

**Degree Offered: M.A.**

**GRADUATE FACULTY**

*Professor* C. D. Korte, *Director*
Box 7107, (919) 515-2479

The Master of Arts in Liberal Studies (MALS) program is an interdisciplinary graduate program which is administered by the Division of Multidisciplinary Studies and offered by the College of Humanities and Social Sciences. This is a broad, interdisciplinary program of part-time graduate study that integrates and expands awareness and that is geared to the student's personal interests. Each student, in consultation with an academic advisor, designs an individual program of study around an interdisciplinary theme or topic that is of intrinsic interest to the student or that relates to the student's professional or vocational interests. Students take graduate courses across a range of NCSU departments as well as MALS seminars designed specifically for the program.

**Admissions Requirements**
Students entering the master's program in liberal studies must have an undergraduate degree. In addition to the material required by the Graduate School, students applying are asked to submit a statement describing their objectives in doing a degree in liberal studies and a writing sample. GRE scores are not required. All applicants are interviewed.

**Master's Degree Requirements**
Thirty hours of course work made up of (1) a minimum of three MALS seminars, (2) eighteen hours representing the student's interdisciplinary theme or concentration, and (3) a three-hour culminating project. Examples of concentrations that are well supported by graduate courses in the NCSU curriculum are: science, technology and society; national and international issues; and the American experience.

*FOR GRADUATES ONLY*

*NOTE: The prerequisite to all 600-level MALS courses is admission to M.A. in liberal studies.*

**MLS 601 SEMINAR IN LIBERAL STUDIES. 3(3-0) F,S,Sum.** Intensive study of an interdisciplinary issue or area. Seminars, which vary each semester, address such topics as arts studies, history and literature, sociobiology and the social sciences, world trade and world conflict, and technology and social change.

**MLS 696 INDEPENDENT STUDY IN LIBERAL STUDIES. 1-6 F,S,Sum.** Advanced independent study of an interdisciplinary topic under the supervision of a faculty member.

**MLS 697 INDEPENDENT PROJECT IN LIBERAL STUDIES. 3(3-0) F,S, Sum.** Advanced independent research on an interdisciplinary project under the supervision of a faculty member.

# Life Sciences

Several departments in the College of Agriculture and Life Sciences offer programs leading to the Master of Agriculture and/or the Master of Life Sciences. These are non-thesis degrees that are designed for students who wish to emphasize course work in a graduate program. As such they require a total of 36 semester hours. A minimum of four semester hours in special problems is required and not more than six semester hours will be allowed. A minimum of 20 credit hours of 500- or 600-level course work is required.

# Management

**Degree Offered: M.S.**

## GRADUATE FACULTY

*Professor* S. G. Allen, ***Director of Graduate Programs***
Box 7229, (919) 515-5584, steve_allen@ncsu.edu

***Professors:*** R. L. Clark, J. D. Hess, D. M. Holthausen Jr., T. Johnson, C. P. Jones, S. E. Margolis, R. B. Palmquist, D. K. Pearce, W. A. Smith Jr., J. W. Wilson;
***Associate Professors:*** A. Agrawal, D. L. Baumer, J. C. Dutton Jr., A. E. Headen Jr., T. L. Honeycutt, J. S. Lapp, E. A. McDermed, M. B. McElroy, K. Mitchell, A. Padilla, J. C. Poindexter Jr., W. J. Wessels, G. J. Zuckerman;
***Assistant Professors:*** C. C. Bozarth, S. N. Chapman, Y. A. Chen, L. A. Craig, K. S. Davis, S. K. Markham, V. L. Mitchell, Y. E. Tang, G. S. Young

NCSU has long provided leadership in the development, application, and management of science and technology. The Master of Science in Management (MSM) program brings this long-established tradition to graduate education in management. The MSM program provides students with the knowledge, skills and experience to make managerial decisions in today's environment of global competition and rapidly changing technology. The MSM degree combines North Carolina State's historical strengths in technology with disciplines in management including accounting, economics, finance, human resources, information systems, marketing, operations, total quality management and entrepreneurship.

The MSM is an innovative program, offering both general management education and routes to advanced training in a wide range of technical areas. The breadth of faculty expertise and courses from a wide range of disciplines distinguishes the MSM from other graduate programs in management. The range of electives and concentrations in the MSM go far beyond the traditional focus on finance, marketing and strategy in Master of Business Administration programs.

### Admission Requirements

Students should have one semester of calculus, two semesters of economics including both microeconomics and macroeconomics, a semester of accounting (both financial and managerial accounting are recommended), one course in statistics, and knowledge of personal computers including word processing and spreadsheet software. All applicants to the MSM program must take the Graduate Management Admissions Test (GMAT). Specific technical options have additional prerequisites. Admissions decisions will be based on academic performance and potential, GMAT

scores, work and volunteer experience, recommendations, and an essay by the applicant indicating how the MSM degree will further their development.

### Master's Degree Requirements

The MSM degree consists of a core curriculum in management, plus additional work in a focus area called a "technical option." Students interested in advanced training in a technical field beyond the basic business management curriculum may choose to specialize in one of the technical options including:

Biotechnology
Civil Engineering/Construction Management
Computer Studies
Forest Resource Management
Industrial Engineering
Management Information Systems
Operations Research
Statistics
Textile Management
Telecommunications Systems Engineering
Total Quality Management

Students in one of these technical options take 7 required courses and 5 electives in their field of specialization to complete a 36-hour program. The core courses for these options are:

**BUS 520 MANAGERIAL FINANCE**
**BUS 560 MARKETING MANAGEMENT AND STRATEGY**
**ECG 505 APPLIED MICROECONOMIC ANALYSIS**
**ECG 506 APPLIED MACROECONOMIC ANALYSIS**
**OR 501 INTRODUCTION TO OPERATIONS RESEARCH**
**ST 514 STATISTICAL METHODS**
**ACC 520 ADVANCED MANAGEMENT ACCOUNTING**
or
**BUS 530 HUMAN RESOURCE MANAGEMENT**
or
**BUS 625 LONG-RANGE PLANNING IN BUSINESS AND INDUSTRY**

In addition to the courses listed above, students in the business management option take the following courses:

**ACC 520 ADVANCED MANAGEMENT ACCOUNTING**
**BUS 505 LEGAL ENVIRONMENT OF BUSINESS**
**BUS 530 HUMAN RESOURCE MANAGEMENT**
**BUS 555 MANAGERIAL ECONOMICS**
or
**OR 501 INTRODUCTION TO OPERATIONS RESEARCH**

IE 518 MANUFACTURING OPERATIONS MANAGEMENT
or
CSC 421 INTRODUCTION TO MANAGEMENT INFORMATION SYSTEMS

A project paper is an additional graduation requirement for all MSM students. The paper may be an extension of a course paper, new research on a technical or management subject, or an analysis of a problem faced by a business concern. For students in the Textile Management option, the thesis and oral defense substitute for this requirement.

**Other Relevant Information**
Day and evening courses are available; students can attend on either a part-time or full-time basis.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ACC 520 ADVANCED MANAGEMENT ACCOUNTING. 3(3-0) S.** (See accounting.)

**BUS 505 LEGAL ENVIRONMENT OF BUSINESS. Credit in both BUS 405 and BUS 505 is not allowed. 3(3-0) S.** Analysis of the major laws affecting business in the areas of products liability, worker safety, antitrust, securities regulation, environmental laws and antidiscrimination regulations. Examination of economic consequences, policy discussion, ethical analyses. Numerous case studies.

**BUS(ECG) 512 LAW AND ECONOMICS. Preq.: EC 301 or EC 401. 3(3-0) F. Alt. yrs.** An economic analysis of the sources and effects of law, including common law, statutory law and regulation. Topics discussed include property rights and contracts, liability rules, crime and punishment, statutory enactment, bureaucratic behavior and institutional reform.

**BUS 520 MANAGERIAL FINANCE: THEORY AND APPLICATIONS. Preqs.: BUS 420 and EC 301 or 401. 3(3-0) F,S.** The foundations of finance theory and the empirical evidence available regarding the theory. Applications of basic finance theory, including capital budgeting, markets, valuation, cost of capital, financing alternatives, dividend policy and management of liquid assets. The micro-finance decisions made by a firm, primarily the investment, financing and dividend decisions.

**BUS 522 PORTFOLIO AND CAPITAL MARKET THEORY. Preqs.: ECG 501 and BUS(ST) 350 or ST 311. 3(3-0) F.** Portfolio theory and its applications, plus capital market theory and the equilibrium pricing of financial assets. The role of securities, utility theory and analysis of secondary markets and their efficiency

and the definition and measurement of returns and risks. Valuing securities, including options contracts.

**BUS 524 FINANCIAL MARKETS. Preq.: ECG 501. 3(3-0) S.** The economic characteristics of financial markets and instruments: determination of interest rates; structure of domestic financial markets; flow of funds; nature of financial institutions; nature of financial instruments; and financial market behavior.

**BUS 530 HUMAN RESOURCE MANAGEMENT. Preq.: EC 301. 3(3-0) F.** Application of decision-making techniques and economic models to problems of human resource management. Problems, causes and solutions analyzed in relationship to maximizing profits. Nature and impact of government regulations on human resource management.

**BUS 546 INTERNATIONAL BUSINESS. Preq.: EC 301. 3(3-0) S.** Conduct of international business. Commercial and financial environment of firms. Types of international operations and relative competitive advantages and disadvantages. Issues of export-import management, financial management, accounting, marketing, technology transfer and other aspects of international operations.

**BUS 555 MANAGERIAL ECONOMICS. Preq.: EC 301 or 401. 3(3-0) S.** Applications of economic theory to the study of selected business practices in realms of finance, marketing and management decision making. Specific topics have included: capital budgeting, financial structure, government regulation of industry, pricing strategies, tie-in sales, contractual arrangements between manufacturers and retailers, comparisons of managerial behavior in nonprofit or government enterprise to that in for-profit firms.

**BUS 560 MARKETING MANAGEMENT AND STRATEGY. Preq.: EC 401 or ECG 501. 3(3-0) F.** Analytical approach to marketing problems facing business firms and nonprofit organizations. Emphasis on management decision making and societal issues. Topics include marketing concepts, economic environment, marketing strategy and research, buyer behavior, market segmentation and target marketing, product development and management, marketing and public policy, pricing strategies, channels of distribution, advertising and sales promotions.

**BUS 562 RESEARCH METHODS IN MARKETING. Preqs.: BUS(ST) 350, BUS 360, ECG 501. 3(3-0) S.** A systematic approach to the structure, implementation and analysis of marketing research for decision making. Models of consumer demand and firm behavior analyzed in a marketing context.

**BUS 575 MANAGING FOR QUALITY. Preqs.: EC 301 and ST 350. 3(3-0) S.** The concepts and basic tools of managing quality from a total quality perspec-

tive; emphasis on service operations. Dimensions of quality, voice of the customer, planning for quality, employee involvement, process variation and capability, role of inspection, statistical process control, continuous improvement, case studies.

**BUS(TAM) 585 MARKET RESEARCH IN TEXTILES. 3(3-0) S.** (See textile materials and management.)

**BUS 590 SPECIAL TOPICS IN BUSINESS MANAGEMENT. Preq.: CI. 1-6.** Presentation of material not normally available in regular courses offerings or offering of new courses on a trial basis.

**BUS 598 INDEPENDENT STUDY IN BUSINESS MANAGEMENT. Preq.: CI. 1-6 F,S,Sum.** Detailed investigation of topics of particular interest to graduate students under faculty direction on a tutorial basis. Determination of credits and content by faculty member in consultation with department head.

*FOR GRADUATES ONLY*

**BUS 625 LONG RANGE PLANNING IN BUSINESS AND INDUSTRY. Preq.: ECG 501. 3(3-0) S.** Theory and practice of long-range planning in business and industry. Case discussions and intensive readings dealing with techniques for identifying opportunities and risks in the environment of the firm, determining corporate strengths and weaknesses, specifying long-range strategy. Special attention to the roles of management and the internal processes of large organizations as the organizations respond to changes in external conditions.

**BUS(ECG) 650 ECONOMIC DECISION THEORY. Preq.: ECG 501. 3(3-0) S. Alt. yrs.** Study of general theories of choice. Structure of decision problems, the role of information; formulation of objectives. Current research problems.

# Marine, Earth and Atmospheric Sciences

**Degrees Offered: Ph.D., M.S.**

**GRADUATE FACULTY**

*Professor* L. J. Pietrafesa, ***Head of the Department***
*Professor* G. S. Janowitz, ***Director of Graduate Programs***
Box 8208, (919) 515-7776, janowitz@ncsumeas

***Distinguished University Scholar:*** T. F. Malone
***Scholar in Residence:*** R. R. Braham

*Professors:* S. P. S. Arya, V. V. Cavaroc Jr., J. M. Davis, D. J. DeMaster, R. V. Fodor, D. Kamykowski, S. Raman, V. K. Saxena, T. G. Wolcott;
*Visiting Professor:* T. S. Hopkins;
*Adjunct Professors:* A. H. Hines, R. V. Madala, W. H. Snyder;
*Professors Emeriti:* M. Amein, C. E. Anderson, H. S. Brown, L. J. Langfelder, C. J. Leith, J. M. Parker III, W. J. Saucier, C. W. Welby;
*Associate Professors:* M. G. Bevis, N. E. Blair, S. Businger, M. M. Kimberley, C. E. Knowles, S. E. Koch, E. L. Leithold, Y. Lin, J. M. Morrison, A.J. Riordan, F. H. M. Semazzi, P. Shaw, W. J. Showers, E. F. Stoddard, G. F. Watson;
*Research Associate Professor:* V. P. Aneja;
*Visiting Associate Professors:* M. L. Kaplan, D. L. Wolcott;
*Adjunct Associate Professors:* M. DeMaria, L. Levin, C. J. Nappo, J. F. Parnell;
*Assistant Professors:* D. B. Eggleston, D. G. Evans, J. P. Hibbard, J. A. Speer;
*Visiting Assistant Professor:* L. Xie;
*Adjunct Assistant Professors:* D. M. Checkley Jr., J. R. Pawlik, M. H. Posey

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* B. J. Copeland, E. B. Cowling, J. M. Miller, F. Y. Sorrell Jr., C. C. Tung

## INTERINSTITUTIONAL ADJUNCT GRADUATE FACULTY

E.G. Bolen, L. B. Cahoon, W. J. Cleary, R. M. Dillaman, D. G. Linquist, R. D. Roer, R. K. Sizemore, W. D. Webster, J. D. Willey

Graduate majors in atmospheric science, geology, geophysics, and marine sciences are offered. Within marine sciences the subdisciplines of biological, chemical, geological, and physical oceanography are recognized by the profession.

### Admission Requirements

An M.S. degree is required for entry into the Ph.D. program. The Graduate Record Subject Test scores are required for applicants in geology and biological oceanography. A B.S. degree in a basic or applied science, mathematics, or engineering is required for entry into the M.S. program in atmospheric science, geology or geophysics, biological oceanography, chemical oceanography, geological oceanography, or physical oceanography. Field camp is required of all applicants for the M.S. program in geology. An M.S. degree with a non-thesis option for students on leave for a fixed period from government positions is available and admission to this option must be requested at the time of application.

### Master's Degree Requirements

Specific course requirements are determined by the advisory committee of each stu-

dent. However, MEA 695 SEMINAR is required of all M.S. students no later than the third semester in residence. Marine science students are required to take core courses in two of the three subdisciplines other than their own.

**Doctoral Degree Requirements**
Specific courses are determined by the students advisory committee. Registration in seminar, MEA 695, is required of all Ph.D. students no later than the fourth semester in residence. Marine Science students are required to take core courses in all three subdisciplines other than their own; this requirement may be fulfilled at the M.S. level.

**Student Financial Support**
Research and teaching assistantships are available.

**Other Relevant Information**
Students are assigned advisors upon admission, and thesis research should commence as soon as possible.

*GRADUATE COURSES IN COMMON TO ALL MEA STUDENTS*

**MEA 695 SEMINAR. 1(1-0) F,S.** Presentation by each student of one seminar on his/her current research.

**MEA 699 RESEARCH. Preq.: Consent of advisor. Credits Arranged. F,S,Sum.**

## *Atmospheric Science*

*SELECTED ADVANCED UNDERGRADUATE COURSES*

MEA 412 ATMOSPHERIC PHYSICS.
MEA 421 AIR PROCESSES AND MOTIONS I.
MEA 422 AIR PROCESSES AND MOTIONS II.
MEA 443 WEATHER ANALYSIS AND FORECASTING I.
MEA 444 WEATHER FORECASTING PRINCIPLES.
MEA 455 MICROMETEOROLOGY.
MEA 493 SPECIAL TOPICS IN METEOROLOGY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MEA 501 ENVIRONMENTAL FLUID MECHANICS. Preqs.: MA 241, PY 208. 3(3-1) F.** Basic concepts and the laws governing the motion of the atmosphere and oceans developed from first principles, including approximations valid for envi-

ronmental flows, the kinematics, dynamics and thermodynamics of fluid flows as well as an introduction to environmental turbulence.

**MEA 512 SATELLITE METEOROLOGY. Preq.: MA 241; Coreq.: MEA 443. 3(3-0) S. Alt. yrs.** Basic background in satellite orbits, coordinate systems and image navigation; description of sensors and techniques for quantitative measurement of atmospheric variables. Applications of satellite data in analysis of weather systems; evolution of convective systems, tropical disturbances and mid-latitude cyclones as revealed by visible and infrared imagery; current research in satellite applications.

**MEA 514 ADVANCED PHYSICAL METEOROLOGY. Preqs.: MEA 412, 421. 3(3-0) F.** The fundamental laws and concepts of thermodynamics and electromagnetic radiative transfer considered in an atmospheric context. These principles then applied to a number of meteorological problems, including those of radiative climate models, the global energy balance, atmospheric aerosols, lidar/radar backscatter and remotely sensed temperature fields.

**MEA 524 DYNAMIC METEOROLOGY. Preq.: MEA 422 or equivalent. 3(3-0) F.** Classical and physical hydrodynamics; scale analysis of dynamic equations; atmospheric instabilities; dynamics of tropical convections; perturbation theory and approximations for atmospheric wave motions.

**MEA 525 NUMERICAL WEATHER PREDICTION. Preqs.: MEA 524, CSC (MA) 427 or equivalent and some FORTRAN programming experience. 3(3-0) F,S. Alt. yrs.** Physical and mathematical basis of numerical weather prediction with computer experiments to demonstrate principles and techniques. Derivation of sets of prediction equations consistent with scale analysis and dynamical constraints; atmospheric waves and filtered equations; numerical methods and computational instabilities; filtered and primitive equation models; NWS operational models.

**MEA 526 AIR-SEA INTERACTION. Preq.: MEA 422 or MEA 560 or CI. 3(3-0) S. Alt. yrs.** Basic equations and concepts of turbulent transfer in geophysical flows, air-sea interaction processes and their importance to man's activities, theory and observation of wind-generated ocean surface waves, turbulent transfers in the planetary boundary layer of the marine atmosphere, oceanic mixed layer, development of thermocline and inversion.

**MEA 527 PLANETARY BOUNDARY LAYER. Preq.: MEA 455 or MEA 526 or CI. 3(3-0) F,S. Alt. yrs.** basic equations and concepts of planetary boundary layers. The closure problem and semi-empirical theories of turbulence, buoyancy effects on mean flow and turbulence, instrumentation and observational platforms for PBL experiments, observed characteristics of atmospheric boundary layers,

numerical and physical modeling of PBL and its parameterization in large-scale atmospheric circulation models.

**MEA 528 COASTAL METEOROLOGY. Preq.: MEA 455. 3(3-0) Alt. yrs.** Importance and complexity of coastal meteorological processes; modification induced by surface inhomogeneities; development of internal boundary layers; thermally induced internal boundary layers; coastal fumigation processes; structure and development of sea and land breezes; analytical and numerical modeling of sea breezes; coastal fronts; storm surges; prediction models for storm surges; cold air outbreaks; baroclinic boundary layer processes near coastal areas.

**MEA 530 MESOSCALE MODELING. Preq.: MEA 524. 3(3-0) F. Alt. yrs.** Modeling mesoscale weather phenomena including midlatitude cyclones, mesoscale convective complexes and squall lines. Application of finite difference, spectral and implicit methods and coordinate transforms to these problems. Utilization of explicit representations of moist processes. Development of parameterizations of convective clouds, the planetary boundary layer and moist processes.

**MEA 555 METEOROLOGY OF THE BIOSPHERE. Preqs.: PY 205 or 211; CH 103 or 107; MA 101 or 111. 3(3-0) F. Alt. yrs.** Designed for graduate students in the life sciences, presenting the physical principles governing the states and processes of the atmosphere in contact with earth's surface of land, water and life. Exchanges of heat, mass and momentum analyzed for various conditions of the atmosphere and surface and as a function of season, time and geographic location.

**MEA 556 AIR POLLUTION METEOROLOGY. Preqs.: MAE 308 or MEA 455 or MEA 501 or equivalent. 3(3-0) S.** Wind structure in the atmospheric surface layer and planetary boundary layer; temperature structure and stability; mixed layer and inversions; turbulence intensity and scale; meteorological factors affecting the dispersion of pollutants; diffusion theories and models; diffusion and transport experiments; plume rise, fumigation and trapping; removal processes; effects of buildings and hills; effects of local winds.

**MEA 557 ADVANCED CLOUD AND PRECIPITATION PHYSICS. Preq.: MEA 421 or MEA 412. 3(3-0) F. Alt. yrs.** Analysis of the microstructure of warm and cold clouds and precipitation, cloud microphysics-dynamics interactions, formation of cloud droplets, growth of cloud droplets by condensation, initiation of rain in nonfreezing clouds, formation and growth of ice crystals, precipitation theories, planned and inadvertent weather modification, and the problem of acid rain.

**MEA 558 ATMOSPHERIC AEROSOLS. Preqs.: CH 103 or 107 and PY 205 or 211; Coreq.: MEA 412. 3(3-0) S. Alt. yrs.** Aerosols as primary air pollutants, indoor versus outdoor pollution, transformation processes, prediction of atmospheric

concentrations, scavenging of aerosols, transport of air pollutants on a regional scale, discussion of national experiments to characterize and study the impact of urban-industrial pollution, tropospheric aerosol and weather, stratospheric aerosol, effect of aerosols on atmospheric warming and cooling and air-quality models.

**MEA(MAE) 563 GEOPHYSICAL FLUID MECHANICS. 3(3-0) F. Alt. yrs.** (See *Marine Science.*)

**MEA 593 SPECIAL TOPICS. Preq.: CI. 1-6 F,S,Sum.** Special topics in atmospheric science, provided to groups or to individuals.

*FOR GRADUATES ONLY*

**MEA 627 ATMOSPHERIC TURBULENCE. Preq.: MAE 550 or MEA 501 or MEA 527 or equivalent. 3(3-0) S. Alt. yrs.** Statistical description of turbulence, including probability, correlation and spectrum functions. Statistical theory of homogeneous turbulence, spectral dynamics and Kolmogorov's local similarity hypotheses. Effects of shear, thermal stratification and earth's rotation. Observed structure and scales of turbulence in the PBL and free atmosphere. Higher-order closure models and large eddy simulations of atmospheric turbulence.

**MEA 635 ADVANCED WEATHER ANALYSIS. Preqs.: MEA 444, MEA 524. 3(2-2) F. Alt. yrs.** Evolution of the physical and dynamic structure of synoptic and sesoscale storm systems occurring in the middle and high latitudes. Recent advances in understanding these storm systems through intensive field experiments and computer modeling. Contemporary analysis techniques through laboratory exercises shedding light on storm structure, dynamics and scale interaction.

**MEA 640 MESOSCALE DYNAMICS. Preqs.: MEA 501 and MEA 524 or equivalent. 3(3-0) F. Alt. yrs.** Inertia-gravity waves. Mechanical and thermally forced waves. Generation, circulation and maintenance of mesoscale convective storms and systems. Symmetric instability. Wave-CISK, quasi-geostrophic and semi-geostrophic fronts and frontogenesis. Meso-B/Y frontogenesis. Lee and coastal cyclogenesis.

**MEA 656 ATMOSPHERIC DISPERSION. Preq.: MAE 550 or MEA 501 or MEA 556; Coreq.: MEA 556. 3(3-0) F. Alt. yrs.** Lagrangian vs. Eulerian descriptions of turbulence and diffusion. Statistical theories of absolute and relative diffusion from continuous and instantaneous releases. Effects of shear, thermal stratification and earth's rotation on atmospheric dispersion. Lagrangian similarity theories of diffusion in the surface layer and mixed layer. Random walk, Monte Carlo and large eddy simulations of atmospheric dispersion. Urban and regional dispersion models.

**MEA(MAE) 663 ADVANCED GEOPHYSICAL FLUID MECHANICS. 3(3-0) S. Alt. yrs.** (See *Marine Science.*)

## *Earth Science*

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

MEA 415 GEOLOGY OF METALLIFEROUS DEPOSITS.
MEA 423 INVERTEBRATE PALEONTOLOGY AND BIOSTRATIGRAPHY.
MEA 440 IGNEOUS AND METAMORPHIC PETROLOGY.
MEA 452 SEDIMENTARY PETROLOGY AND STRATIGRAPHY.
MEA 461 ENGINEERING GEOLOGY.
MEA 465 GEOLOGIC FIELD CAMP I.
MEA 466 GEOLOGIC FIELD CAMP II.
MEA 470 PRINCIPLES OF GEOPHYSICS.
MEA 471 EXPLORATION AND ENGINEERING GEOPHYSICS.
MEA 475 GEOPHYSICAL FIELD METHODS.
MEA 476 SEISMIC EXPLORATION FOR OIL.
MEA 481 PRINCIPLES OF GEOMORPHOLOGY.
MEA 491 SEMINAR ON SELECTED GEOLOGIC TOPICS.

### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MEA 500 REGIONAL GEOLOGY OF NORTH AMERICA. Preqs.: MEA 101 or 120, sr. standing. 1-6 F,S.** Field study of classic geologic localities and geomorphic processes not indigenous to North Carolina. Typical areas: New England and adjacent Canada, northern Mexico and southwestern United States and the Pacific Northwest. Representative subjects include the Canadian Shield, Precambrian mineral deposits, the San Andreas fault, desert geomorphology, Grand Canyon stratigraphy, modern and ancient reefs and glaciated volcanoes. Mineral, rock and fossil collecting. Required student reports.

**MEA 510 GEOLOGICAL OCEANOGRAPHY. 3(3-0) F.** (See *Marine Science.*)

**MEA 515 TOPICS IN APPALACHIAN GEOLOGY. Preqs.: MEA 440, 450 and 451. 3(3-0) F. Alt. yrs.** Examination of the geology of areas within Appalachian orogenic belt. Lectures, discussions, reading and review of current literature and consideration of ideas concerning geological evolution of region. Required field trips.

**MEA 522 PETROLEUM GEOLOGY. Preq.: MEA 450. 3(3-0) S. Alt. yrs.** Properties, origin and modes of occurrence of petroleum and natural gas. Geologic and economic features of principal oil and gas fields, mainly in the United States.

**MEA 523 INTRODUCTION TO SUBSURFACE WELL EVALUATION. Preqs.: CH 103 or 107, PY 212, MEA 101. 3(2-3) F. Alt. yrs.** Principles, uses and interpretation of commonly used wireline technique for structural, lithologic and fluid evaluation of wells. Oriented towards petroleum reserve/evaluations.

**MEA 545 ADVANCED IGNEOUS PETROLOGY. Preq.: MEA 440. 3(2-2) S. Alt. yrs.** Physicochemical principles related to igneous petrogenesis. General principles and specific problems including the origin, differentiation and emplacement of magmas and the possible relationships of igneous processes to global tectonics.

**MEA 546 ADVANCED METAMORPHIC PETROLOGY. Preq.: MEA 440. 3(2-2) S. Alt. yrs.** The petrogenesis of metamorphic rocks including conditions of metamorphism, metamorphic facies and facies series, the petrogenetic grid, contact and regional metamorphism, metamorphism and plate tectonics. Heterogeneous chemical equilibrium and application of Gibbs Phase Rule to metamorphic rocks. Thermodynamically valid algebraic and graphical analysis of equilibrium mineral assemblages. Chemical zoning. Petrographic studies of selected metamorphic suites.

**MEA 551 ADVANCED STRUCTURAL GEOLOGY. Preq.: MEA 451. 3(2-3) F. Alt. yrs.** Principles of rock mechanics and their application in solving geologic problems; finite strain analysis of deformed rocks; advanced techniques of structural analysis; petrofabrics; development of various geologic structures. Course designed to emphasize the application of principles and techniques in the field.

**MEA 562 APPLIED SEDIMENTARY ANALYSIS. Preqs.: MEA 450, ST 361. 3(2-2) F. Alt. yrs.** Extension of MEA 450, with emphasis on coarser grained clastic sedimentary rocks. Sampling of sedimentary population, critical study of assumptions underlying standard measurement techniques; treatment, testing and evaluation of sedimentary data; application to problems in sedimentology.

**MEA 564 DEPOSITIONAL ENVIRONMENTS AND LITHOSTRATIGRAPHY. Preq.: MEA 450 or grad. standing. 3(2-3) S.** Fabric of large sedimentary basins in terms of the spatial distribution of component major rock facies; current litho-genetic models based upon comparison with recent equivalents; field trips.

**MEA 565 HYDROGEOLOGY. Preq.: MEA 452. 3(3-0) S. Alt. yrs.** Occurrence and sources of surface and subsurface water. Relationships of surface water to subsurface water. Rock properties affecting infiltration, movement, lateral and vertical distribution and quality of ground water. Determination of permeability, capacity, specific yield and other hydraulic characteristics of aquifers. Principles of well design, legal aspects of water supplies.

**MEA 566 HYDROGEOLOGY OF GROUNDWATER POLLUTION AND PROTECTION. Preq.: MEA 565 or CE 584 or equivalent. 3(3-0) S. Alt. yrs.** Hydrogeologic factors associated with protection of groundwater; use of geologic principles and materials to protect groundwater quality; geologic evaluation and monitoring of waste disposal sites, including appropriate models.

**MEA 567 GEOCHEMISTRY. Preq.: CH 331 or 431. 3(3-0) F. Alt. yrs.** Quantitative distribution of elements in earth's crust, hydrosphere and atmosphere. Application of laws of chemical equilibrium and resultant chemical reactions to natural earth systems. Geochemical application of Eh-pH diagrams. Geochemical cycles. Isotope geochemistry.

**MEA 570 EXPLORATION AND ENGINEERING GEOPHYSICS. Preq.: MEA 470 or PY 208. Credit in both MEA 470 and MEA 570 is not allowed. 3(3-0) S.** Geophysical methods as applied to exploring the earth's mineral and energy resources and to investigating subsurface geological structure and physical properties. Principles, measurements, analyses, and interpretations of gravity, magnetic, electric, electromagnetic, seismic methods. Required research paper.

**MEA 572 LABORATORY AND FIELD METHODS FOR INVESTIGATION OF THE SEABED. 3(2-3) S. Alt. yrs.** (See *Marine Science.*)

**MEA 573 ORGANIC GEOCHEMISTRY. 3(3-0) F. Alt. yrs.** (See *Marine Science.*)

**MEA 574 BIOGEOCHEMISTRY. 3(3-0) F. Alt. yrs.** (See *Marine Science.*)

**MEA 575 GEOPHYSICAL FIELD METHODS. Preq.: MEA 570. Credit in both MEA 475 and MEA 575 is not allowed. 2(2-week summer camp) Sum. Alt. yrs.** Two-week summer field course. Practical geophysical field measurements using instruments for gravity, magnetic, electric, electromagnetic and radioactivity methods. Data interpretation in terms of subsurface geological structures and their physical properties, locations, sizes and shapes. Students required to register for the course in the second summer session. Location: within the state of North Carolina. Estimated expense: $150.00. Research paper required.

**MEA 576 SEISMIC EXPLORTION FOR OIL. Preqs.: PY 208 and knowledge of FORTRAN language. Credit in both MEA 476 and MEA 576 is not allowed. 3(3-0) S.** Comprehensive introduction to reflection seismic method as applied to exploring oil and gas resources. Seismic instrumentation, field data acquisition, common-depth-point method, deconvolution, digital filtering, migration and seismic stratigraphy of hydrocarbon depositional environments, along with computer-oriented exercises. Research paper required.

**MEA 577 SEDIMENTARY GEOCHEMISTRY. Preq.: CH 331 or CH 431 or MEA 567 or equivalent background. 3(3-0) S. Alt. yrs.** Application of thermodynamic data to the calculation of reactions in natural waters at or near the earth's surface. Topics include weathering to form clay minerals, precipitation of economic minerals and carbonate sedimentology.

**MEA 583 PHOTOGEOLOGY AND REMOTE SENSING. Preqs.: MEA 101 or 120, MEA 481 or equivalent. 3(2-3) S.** Study and interpretation of aerial photographs and other remotely sensed data for geological information relating to mineral resource exploration and evaluation and geological controls on environmental problems.

**MEA 588 REGIONAL TECTONICS. Preqs.: MEA 440, 450, 451. 3(3-0) S. Alt. yrs.** Methods of study of the tectonic history of major geologic regions in North America and other areas of the world through the application of stratigraphy, petrology and structural geology. Synthesizing regional tectonic patterns and events.

**MEA 592 SPECIAL TOPICS. Preq.: CI. 1-6 F,S,Sum.** Special topics in earth sciences, provided to groups or to individuals.

*FOR GRADUATES ONLY*

**MEA 610 MARINE SEDIMENTOLOGY. 3(3-0) S. Alt. yrs.** (See *Marine Science.*)

**MEA 630 GEOTECTONICS. Preqs.: MEA 440, 450, 451. 3(3-0) F. Alt. yrs.** In-depth examination of current ideas in plate tectonic theory. Plate tectonic controls on orogeny, orogenic belts, magmatism and metallogeny.

**MEA 670 ADVANCED GEOPHYSICS I. Preqs.: MEA 570 and MA 401. 3(3-0) F. Alt. yrs.** Advanced geophysical theories and applications: topics chosen from the potential field theory of Laplace and Poisson, gravity, heatflow, magnetism, electric and electromagentic fields as means of investigating the earth's internal structure. Understanding geodynamic principles and applications to exploring for mineral and hydrocarbon resources.

**MEA 671 ADVANCED GEOPHYSICS II. Preqs.: MEA 570 and MA 401. 3(3-0) F. Alt. yrs.** Advanced geophysical theories and applications: topics chosen from scalar and vector wave propagation phenomena in geophysics, earthquake seismology, focal mechanisms, propagation of body and surface waves, plate tectonics, advanced reflection seismology for oil and gas exploration, electromagnetic waves as applied to mineral exploration.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MEA 501 ENVIRONMENTAL FLUID MECHANICS. 3(3-1) F.**(See *Atmospheric Science.*)

**MEA 510 GEOLOGICAL OCEANOGRAPHY. Preq.: MEA 450 or equivalent. 3(3-0) F.** Comprehensive overview of the geological aspects of oceanography. Topics: a) marine geophysics and evolution of ocean basins, b) sedimentological processes and formation of marine deposits, c) marine geochemistry and authigenic sedimentation, d) paleoceanography and interpretation of marine stratigraphy.

**MEA 516 DYNAMICS OF SHELF CIRCULATION. Preq.: MEA 501. 3(3-0) F. Alt. yrs.** Description and models of dynamic processes on the shelf, including seiches and tides in gulfs, propagation of tides and storm surges, wind-induced coastal upwelling, continental shelf waves and coastally trapped waves. Steady circulation driven by winds, river plumes and density forcing, formation of shelf-break fronts; and influence from deep-ocean currents.

**MEA(ZO) 520 PRINCIPLES OF BIOLOGICAL OCEANOGRAPHY. Preqs.: BS 100 and either BO(ZO) 360 or grad. standing. 3(3-0) S.** Biological productivity and trophic relationships in Plankton, Nekton and Benthos; community ecology of selected habitats (estuaries, intertidal zones, coral reefs, deep sea) and adaptation of organisms to the marine environment.

**MEA 526 AIR-SEA INTERACTION. 3(3-0) S. Alt. yrs.** (See *Atmospheric Science.*)

**MEA (ZO) 534 MARINE BENTHIC ECOLOGY. Preqs.: ZO 402, ZO 509 or ZO 560 or MEA (ZO) 520. 3(3-0) F.** Marine benthic systems in deep sea and in shallow waters, focusing upon the abiotic and biotic processes regulating density, diversity and taxonomic and functional composition. Discussions of benthic-pelagic coupling, predation, interspecific competition, biogeography, sampling problems, evolutionary trends, trophic structure and community organization.

**MEA 540 FOURIER ANALYSIS OF GEOPHYSICAL DATA. Preqs.: MA 341 and ST 511. 3(3-0) S. Alt. yrs.** Application of Fourier analysis techniques to interpretation of low-frequency motions in the ocean and atmosphere. Review of Fourier method. Filtering of tidal signals. Spectral estimates and calculation of current ellipses. Identification of coherent motions and their empirical orthogonal modes. Data from field experiments used in lectures and homework assignments.

**MEA (CE) 541 GRAVITY WAVE THEORY I. Preq.: MAE 308, PY 411 or MEA 501. 3(3-0) S.** Classical gravity wave theory with emphasis on basic mechanics of wave motions, mass transport induced by waves and various conservation laws with their applications in wave study.

**MEA 559 SYNOPTIC PHYSICAL OCEANOGRAPHY. Preq.: MEA 560 or MEA 561. 3(3-0) S. Alt. yrs.** Techniques and terminology of synoptic physical oceanography; focus on water characteristics and their relationship to currents in the individual oceans; a systematic quantitative description of the character of ocean waters and their movements.

**MEA 560 PRINCIPLES OF PHYSICAL OCEANOGRAPHY. Preqs.: MA 231 and PY 212 or equivalent. 3(3-0) S.** Principles and practice of physical oceanography. The equation of state of seawater; energy transfer to the ocean by thermal, radiative and mechanical processes; the heat budget; oceanic boundary conditions; the geographical distribution of oceanic properties; observational methods; conservation equations; simple waves and tides; physical oceanography of the North Carolina coastal zone.

**MEA 561 INTRODUCTION TO PHYSICAL OCEANOGRAPHY. Preqs.: MA 301, PY 208 or CI. 3(3-0) F.** Descriptive and dynamical features of ocean circulation. Physical properties of seawater, oceanic heat budget, fluid mechanics, dynamics of ocean currents, descriptive oceanography, tides and other waves.

**MEA(MAE) 563 GEOPHYSICAL FLUID MECHANICS. Preq.: MAE 501 or equivalent. 3(3-0) F. Alt. yrs.** Principles of fluid mechanics applied to geophysical systems. Special emphasis on those features of these systems, such as almost rigid rotation and stable stratification, producing unique and important effects. Detailed examination of effects of almost rigid rotations on homogeneous and stratified flows.

**MEA 568 OCEAN CIRCULATION. Preq.: MEA 501 or PY 411. 3(3-0) F.** Basic study of the mechanics of ocean circulation with emphasis on various simple models of circulation systems.

**MEA 569 THE PHYSICAL DYNAMICS OF ESTUARIES. Preqs.: MA 121 or 212; PY 208 or 212 or CI. 3(3-0) S. Alt. yrs.** A physical/dynamical description of estuaries and estuarine processes occurring as a function of tides, atmospheric forcing, river runoff and topography. Includes classification schemes; the development of salt, heat energy and momentum balances; a discussion of biological modeling and sediment transport processes as a function of the physical dynamics; conservative and non-conservative pollution dispersion prediction; and the theoretical, mathematical modeling of estuaries, including those in North Carolina.

**MEA 571 PRINCIPLES OF CHEMICAL OCEANOGRAPHY. Preq.: CH 107 or equivalent. 3(3-0) F.** Chemical processes controlling the composition of oceans, including discussions of chemical equilibria, biological cycling of nutrients and the use of chemical tracers in the marine environment; the origin and chemical history of the oceans also considered.

**MEA 572 LABORATORY AND FIELD METHODS FOR INVESTIGATION OF THE SEABED. Preqs.: MEA 510 and CH 107 or MEA 571. 3(2-3) S. Alt. yrs.** An initial lecture and laboratory phase acquaints students with the use of advanced techniques and instrumentation for chemical and geological oceanographic investigations. A field project in the coastal waters of North Carolina then allows application of these tools to a specific marine problem.

**MEA 573 ORGANIC GEOCHEMISTRY. Preq.: CH 223. 3(3-0) F. Alt. yrs.** Sources and fates of organic material in the geochemical environment. Microbial transformations of organic compounds. The use of biomarkers to study depositional environments. Petroleum, natural gas and coal formation. Extraterrestial organic geochemistry.

**MEA 574 BIOGEOCHEMISTRY. Preqs.: BCH 451 and CH 223. 3(3-0) F. Alt. Yrs.** Processes involved in the biogeochemical cycling of C, N, S and related biogenic elements. Stable isotopic and other geochemical signatures of biological processes. Modeling chemical distributions in sediments. The impact of biogeochemical processes on atmospheric chemistry.

**MEA 593 SPECIAL TOPICS. Preq.: CI. 1-6 F,S, Sum.** Special topics in marine science, provided to groups or to individuals.

*FOR GRADUATES ONLY*

**MEA 610 MARINE SEDIMENTOLOGY. Preq.: MEA 510. 3(3-0) S. Alt. yrs.** Quantitative examination of sedimentology with specific reference to marine environment including introduction to fluid mechanics, sediment transport theory, quantitative models of sedimentation and dynamic stratigraphy.

**MEA 613 CONTINENTAL MARGIN SEDIMENTATION. Preq.: MEA 510. 3(3-0) S. Alt. yrs.** The processes and sedimentation active along continental margins. Specific environments of continental shelf, slope and rise.

**MEA 622 MARINE PLANKTON ECOLOGY. Preqs.: BCH 451 and MA 121 and ZO 419 or equivalents. 3(3-0) F. Alt. yrs.** Worldwide relationships between physical-chemical environment and planktonic organisms. Organism descriptions; effects of light, temperature, salinity, density, water motion and chemical consti-

tuents on organisms; interactions among different organisms emphasizing competition and predation; community structure, distribution and succession; and mathematics models of distribution, production and interaction.

**MEA(ZO) 623 ADVANCES IN MARINE COMMUNITY ECOLOGY. Preqs.: ZO 402 and ZO 517 or ZO 560 or MEA(ZO) 534. 3(3-0) S. Alt. yrs.** Current research and biological and physical processes structuring shallow and deep water benthic communities. Recent research on competition, predation, disturbance, succession, animal-sediment-flow interactions, life history tactics and experimental design in marine benthic biology. Student discussion of current issues and critique of recent papers.

**MEA(ZO) 624 ECOLOGY OF FISHES. Preq.: BO(ZO) 360 or 560 or equivalent. 3(3-0) F.** Physiological ecology of fishes emphasizing energetics, production and adaptations to aquatic mediums. Ecological classification of fishes and theory of resource partitioning in freshwater, estuarine and marine realms.

**MEA(MAE) 663 ADVANCED GEOPHYSICAL FLUID MECHANICS. Preq.: MAE 563 or equivalent. 3(3-0) S. Alt. yrs.** Principles of fluid mechanics applied to geophysical systems. The role of stable stratification on the flows in these systems. Generation, interaction, propagation and dissipation of internal gravity waves. Other geophysically important flows.

**MEA(MAE) 664, 665 PERTURBATION METHOD IN FLUID MECHANICS I, II. Preqs.: MA 401, MAE 308. 3(3-0) F,S. Alt. yrs.** Basic theory and application of perturbation methods in fluid mechanics including: regular and singular perturbations, matching principles, method of strained coordinate, two variable expansion and applications to partial differential equations.

**MEA 674 MARINE GEOCHEMISTRY. Preqs.: CH 331, MEA 571 or equivalent. 3(3-0) S. Alt. yrs.** Chemical processes occurring in marine environment. Chemical evolution of the oceans, continental and submarine weathering, particle scavenging of reactive elements from water, column, formation of biogenic and metalliferous deposits, sediment diagenesis and marine geochronology.

# Marketing Education

For a listing of graduate faculty and program information, see occupational education.

# Master of Engineering

For program information, see engineering.

# Materials Science and Engineering

**Degrees Offered: Ph.D., M.S., Master of Materials Science and Engineering**

## GRADUATE FACULTY

*Professor* J. J. Hren, *Head of the Department*
*Professor* A. A. Fahmy, *Director of Graduate Programs*
Box 7907, (919) 515-3858, fahmy@mte.ncsu.edu

*Distinguished University Professor:* J. Narayan
*Distinguished University Research Professor:* J. J. Cuomo
*Kobe Steel Distinguished University Professor:* R. F. Davis

*Professors:* K. J. Bachmann, J. R. Beeler Jr., R. B. Benson Jr., A. I. Kingon, C. C. Koch, H. I. Palmour, G. A. Rozgonyi, P. E. Russell, R. O. Scattergood;
*Research Professor:* D. M. Maher;
*Adjunct Professors:* O. Auciello, G. E. McGuire, J. L. Routbort, F. Shimura;
*Professors Emeriti:* W. W. Austin Jr., H. Conrad, J. K. Magor, K. L. Moazed, H. H. Stadelmaier, V.T. Stannett, R. F. Stoops;
*Associate Professors:* C. M. Balik, N. A. El-Masry, J. T. Glass;
*Research Associate Professor:* J. Kasichainula;
*Visiting Associate Professors:* D. P. Griffis, J. C. Russ;
*Adjunct Associate Professors:* K. Das, J. T. Prater, I. Turlik;
*Associate Professor Emeritus:* J. V. Hamme;
*Assistant Professor:* R. J. Spontak;
*Visiting Assistant Professor:* H. A. West II;
*Lecturer:* R. L. Porter

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* J. A. Bailey, S. M. Bedair, K. S. Havner, Y. Horie, G. Lucovsky, R. J. Nemanich, A. Reisman;
*Assistant Professor:* H. H. Lamb

Materials and materials limitations pervade all of the engineering and high technology fields that are an integral part of our society. Graduate programs in this department focus on understanding the structure, structure modification and proper-

ties of materials and the development of new or improved materials and advanced processing methods which are critical links between the design and the realization of new systems.

### Admission Requirements

In addition to the general admission requirements as set by the Graduate School, the department requires submission of GRE scores or convincing evidence of the competence of the applicant and his/her ability to satisfy the requirements for the graduate degree for which he/she is seeking admission. In addition, for applicants whose native tongue is other than English, the minimum TOEFL score acceptable is 575.

### Master's Degrees Requirements

The minimum requirements for the Master of Materials Science and Engineering degree are 33 credit hours not including seminar credit but including 3 credit hours for a project course and 9 to 12 hours in one or more supporting fields as approved by the director of graduate programs of which no more than 3 credit hours may be at the 400 level. The M.S. degree has the minimum requirement of 30 credit hours not including seminar credit but including six credit hours for research, a minimum of 3 credit hours at the 600 level, excluding research credit, and 9 credit hours in one or more supporting fields of which no more than 3 credit hours may be at the 400 level.

### Doctoral Degree Requirements

The minimum requirements for the doctoral degree are 51 credit hours including 9 credit hours for research, a minimum of 9 credit hours at the 600 level, excluding research credit, and 12 credit hours in one or more supporting fields of which no more than 3 credit hours may be at the 400 level.

### Student Financial Support

In recent years more than three quarters of students in the graduate program have received financial support in one form or another. The department offers a number of teaching and research assistantships on a competitive basis to qualified students. Also available are a number of federal-, state- and industry-funded fellowships and supplements which generally pay for the tuition in addition to a stipend.

### Other Relevant Information

The department reflects the interdisciplinary nature of the field of materials science and engineering. A substantial number of current graduate students majored in fields other than but related to materials, and the department has a significant number of associated graduate faculty from other departments supervising thesis and dissertation research.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

MAT 400 METALLIC MATERIALS IN ENGINEERING DESIGN.
MAT 423 MATERIALS FACTORS IN DESIGN.
MAT 431 PHYSICAL METALLURGY I.
MAT 432 PHYSICAL METALLURGY II.
MAT 435 PHYSICAL CERAMICS I.
MAT 440 PROCESSING OF METALLIC MATERIALS.
MAT 445 CERAMIC PROCESSING.
MAT 450 MECHANICAL PROPERTIES OF MATERIALS.
MAT 460 MICROELECTRONIC MATERIALS.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MAT 500 MODERN CONCEPTS IN MATERIALS SCIENCE. Preq.: Grad. standing. 3(3-0) F.** Fundamentals of structure, structure modification and properties of materials with emphasis on structure-property relationships and the modern theory of solids.

**MAT 501 DIFFUSION AND MASS TRANSPORT PROCESSES IN SOLIDS. Preq.: CI. 3(3-0) F.** Interatomic forces and crystal structure, basic concepts in diffusion theory, diffusion and mass transport in metals and alloys, semiconductors, ionic crystals (ceramics) and amorphous materials. Diffusion along dislocations and grain boundaries, surface and interface diffusion, electromigration and thermomigration, concentration-enhanced diffusion, transient diffusion, stress-induced diffusion, mass and heat transport during rapid solidification, radiation damage and defect diffusion.

**MAT 502 DEFECTS IN SOLIDS. Preq.: CI. 3(3-0) S.** Defect structure in ionic, covalent and metallic solids of either a crystalline or an amorphous nature. Effects of defects on the mechanical, electrical, magnetic, chemical and optical properties of solids. Provision of computer software for the exploration of defect interactions via computer simulation.

**MAT 504 ELECTRICAL, OPTICAL AND MAGNETIC PROPERTIES OF MATERIALS. Preqs.: MAT 500, 510. 3(3-0) S.** Electron theory of materials, band theory; electrical behavior of metals, semiconductors, dielectrics and noncrystalline materials; theory of optical behavior and applications; foundations of magnetic properties and applications of ferrites and permanent magnetic materials.

**MAT 505 MECHANICAL BEHAVIOR OF ENGINEERING MATERIALS. Preqs.: MAT 450, MAT 502. 3(3-0) F.** Fundamental and engineering aspects of mechanical behavior of materials. Elasticity, plasticity and dislocation theory concepts used to describe phenomenological behavior and micro-mechanical mechanisms. Strengthening mechanisms in crystals, high-temperature deformation,

fracture mechanics, fracture toughening mechanisms and cyclic deformation. Also various aspects of deformation of noncrystalline solids.

**MAT 506 PHASE TRANSFORMATIONS AND KINETICS. Preqs.: MAT 500, 510. 3(3-0) S.** Homogeneous and heterogeneous nucleation, spinodal decomposition, interface and diffusion-controlled growth, formal theory of transformation kinetics, growth of crystals from the vapor, precipitation, coarsening, order-disorder, and martensitic transformations.

**MAT(CH) 507 CHEMICAL CONCEPTS IN MATERIALS SCIENCE AND ENGINEERING. Preq.: CI. 3(3-0) F.** Structure, symmetry and chemical bonding; spectroscopic methods and their utilization in trace analysis and pollution control; phase equilibria, crystal growth and materials purification; vapor phase equilibria and kinetics of chemical reactions and transport; electrochemical thermodynamics and kinetics with applications to batteries, solar cells, electrorefinement, plating and corrosion processes.

**MAT 508 THERMODYNAMICS OF MATERIALS. Preq.: MAT 301 or equivalent. 3(3-0) F.** Review of first and second laws of thermodynamics, equilibrium and irreversible processes, open and closed systems, partition functions and particle distribution functions. Applications include extension of the thermodynamic potentials to situations where electrical, magnetic and stress fields present, heat capacity of crystals, electron gas in metals, solution models, binary phase diagrams and rubber elasticity in polymers.

**MAT 510 ELEMENTS OF CRYSTALLOGRAPHY AND DIFFRACTION. Preq.: MAT 411. 3(3-0) F.** Crystal symmetry, lattices and space groups; elementary diffraction by crystalline matter; experimental methods of x-ray diffraction.

**MAT 511 STEREOLOGY AND IMAGE ANALYSIS. Preq.: Grad. standing. 3(3-0) S. Alt. yrs.** Development of principles and their practical application to measurement of images from microscopy (primarily materials) to describe three-dimensional structure of specimens viewed in transverse sections or projection. Includes basic statistics, manual and automatic (computerized) image analysis methods. Basic stereological parameters (volume fraction, surface density, curvature) plus object size and shape parameters, fractal and stereoscopic description of surfaces.

**MAT 512 SCANNING ELECTRON MICROSCOPY. Preq.: Grad. standing. 3(3-0) F.** Electron optics, sources and detectors. Beam specimen interactions, secondary and backscattered electrons, EDS and WDS. Resolution limits, experimental conditions, related techniques, beam-induced damage and materials modification.

**MAT 515 FUNDAMENTALS OF TRANSMISSION ELECTRON MICROSCOPY. Preq.: MAT 510 or equivalent. 3(2-3) S.** Electron optics, electron solid interactions, basic electronic diffraction, contrast from amorphous materials, diffraction contrast, defect characterization, introduction to analytical electron microscopy. Laboratory experiments illustrating these concepts.

**MAT(NE) 525 NUCLEAR MATERIALS. 3(3-0) F.** (See nuclear engineering.)

**MAT(MAE) 531 MATERIALS PROCESSING BY DEFORMATION. 3(3-0) F.** (See mechanical and aerospace engineering.)

**MAT(MAE) 532 FUNDAMENTALS OF METAL MACHINING THEORY. 3(3-0) S.** (See mechanical and aerospace engineering.)

**MAT 533 ADVANCED CERAMIC ENGINEERING DESIGN. Preq.: MAT 417. 3(2-3) F.** Advanced studies in analysis and design of ceramic products, processes and systems leading to original solutions of current industrial problems and the development of new concepts of manufacturing.

**MAT 541 PRINCIPLES OF CORROSION. Preqs.: MAT 201 and CH 431 or MAT 301. 3(2-3) F.** Fundamentals of metallic corrosion and passivity. The electrochemical nature of corrosive attack, basic forms of corrosion, corrosion rate factors, methods of corrosion protection. Laboratory work included.

**MAT 556 COMPOSITE MATERIALS. Preq.: MAT 450. 3(3-0) F.** Basic principles underlying the properties of composite materials as related to properties of the individual constituents and their interactions. Emphasis on the design of composite systems to yield desired combinations of properties.

**MAT 560 MATERIALS SCIENCE IN PROCESSING OF SEMICONDUCTOR DEVICES. Preq.: MAT 460. 3(3-0) S. Alt yrs.** Ion implantation and doping of semiconductor devices, thin films and epitaxy, silicides, ohmic contacts and interconnection metallurgy, oxidation and nitridation, gettering of impurities and dopant segregation phenomena, electromigration, electronic packaging materials science, advanced device concepts.

**MAT(TC) 561 ORGANIC CHEMISTRY OF POLYMERS. 3(3-0) S.** (See textile chemistry.)

**MAT(TC) 562 PHYSICAL CHEMISTRY OF HIGH POLYMERS–BULK PROPERTIES. 3(3-0) F.** Alt. yrs. (See textile chemistry.)

**MAT(NE) 573 COMPUTER EXPERIMENTS IN MATERIALS AND NUCLEAR ENGINEERING. Preq.: Advanced undergrad. standing. 3(3-0) S.** Monte Carlo and dynamical computer experiments covered from the standpoint of how to design and use them in materials and nuclear engineering work.

**MAT 575 STRUCTURE OF SEMICRYSTALLINE POLYMERS. Preq.: MAT 325 or equivalent. 3(3-0) S. Alt. yrs.** Structure and organization of semicrystalline polymers, from the molecular scale to the bulk state, including chain configuration, unit cell geometries, polymer crystallography, single crystals, spherulites, epitaxial crystallization, morphology, crystal defects, annealing and deformation mechanisms. Emphasis on analysis of x-ray diffraction, electron diffraction and electron microscopy data for structural characterization.

**MAT 595 ADVANCED MATERIALS EXPERIMENTS. Preq.: Sr. or grad. standing. 1-3.** Advanced engineering principles applied to a specific experimental project dealing with materials. A seminar period provided; required written report.

*FOR GRADUATES ONLY*

**MAT 610 ADVANCED CRYSTALLOGRAPHY AND DIFFRACTION. Preq.: MAT 510. 3(3-0) F.** Symmetry in crystals and space group determination. Kinematic and dynamical scattering theories. Experimental methods involving single crystals. Image formation in x-ray topography and electron microscopy. Disorder and defects. Methods of crystal structure analysis. Residual stresses and preferred orientation in polycrystals.

**MAT 612 ADVANCED SCANNING ELECTRON MICROSCOPY AND SURFACE ANALYSIS. Preq.: MAT 512 or equivalent. 3(3-0) S. Alt. yrs.** Beam specimen interactions, voltage contrast, electron spectrometers, stroboscopy, EBIC, cathodoluminescence, channeling, backscattering, magnetic contrast, vacuum science, instrumentation, ion sputtering, Auger electron spectroscopy, SIMS, quantitative EDS, ESCA, FIM, STM.

**MAT 621 THEORY AND STRUCTURE OF AMORPHOUS MATERIALS. Preq.: MAT 500. 3(3-0) S.** Bond types and structure of amorphous solids, relations of bond types and structure to flow mechanisms, electrical, optical and thermal properties.

**MAT 623 THEORY AND STRUCTURE OF METALLIC MATERIALS. Preq.: MAT 500. 3(3-0) F.** The metallic state, its atomic and electronic structure. Electron theory of metals and alloys. Advanced methods of determining electronic structure in metallic materials. Solid solutions and intermediate phases, superconducting and magnetic alloys.

**MAT 631 THIN FILM AND COATING SCIENCE AND TECHNOLOGY I. Preq.: MAT 500. 3(3-0) F.** Vacuum science and technology including gas kinetics, gas flow calculations, system design and use of various pumps, materials and components. Atomistics of solid surfaces. Nucleation and growth of films and coatings.

**MAT 632 THIN FILM AND COATING SCIENCE AND TECHNOLOGY II. Preq.: MAT 631. 3(3-0) S. Alt yrs.** Techniques for thin films and coatings deposition and their applications. Interfaces, adhesion and surface modification. Artifically structured and chemically modulated layered materials. Pseudomorphic structures. Characterization of thin films and coatings.

**MAT 633 ADVANCED MECHANICAL PROPERTIES OF MATERIALS. Preq.: MAT 630. 3(3-0) F.** The theories of yield strength, work hardening, creep, fracture and fatigue of crystalline materials developed in terms of dislocation theory.

**MAT 660 DEFECTS, DIFFUSION AND ION IMPLANTATION IN SEMICONDUCTORS. Preq.: MAT 501 or equivalent. 3(3-0) F. Alt yrs.** Thermodynamics of vacancies and interstitials, defect complexes, electronic defects, defect annealing processes, self diffusion, dopant and impurity diffusion, substitutional/interstitial diffusion, diffusion in amorphous solids, electro transport, fundamentals of ion-solid interactions, atomic structure of defects, damage annealing processes, supersaturated alloys, laser annealing, ion beam mixing phenomena.

**MAT(CH,TC) 662 PHYSICAL CHEMISTRY OF HIGH POLYMERS--SOLUTION PROPERTIES. 3(3-0) S. Alt. yrs.** (See textile chemistry.)

**MAT 691, 692 ADVANCED TOPICS IN MATERIALS SCIENCE AND ENGINEERING. 1-3.** Special studies of advanced topics in materials science and engineering.

**MAT 695 MATERIALS SCIENCE AND ENGINEERING SEMINAR. 1(1-0) F,S.** Reports and discussion of special topics in materials science and engineering and allied fields.

**MAT 699 MATERIALS SCIENCE AND ENGINEERING RESEARCH. Credits Arranged.** Independent investigation of an appropriate research problem. A report on this investigation required as a graduate thesis.

# Mathematics

**Degrees Offered: Ph.D., M.S.**

## GRADUATE FACULTY

*Professor* R. H. Martin Jr., *Head of the Department*
*Professor* M. Shearer, *Director of Graduate Programs*
*Professor* J. D. Cohen, *Associate Director of Graduate Programs*
Box 8205, (919) 525-3744, shearer@math.ncsu.edu, cohen@math.ncsu.edu

*Drexel Professor and University Professor:* H. T. Banks

*Professors:* J. W. Bishir, E. E. Burniston, S. L. Campbell, R. E. Chandler, M. T. Chu, E. N. Chukwu, L. O. Chung, J. M. Danby, J. C. Dunn, A. C. Fauntleroy, R. O. Fulp, R. E. Hartwig, C. T. Kelley, K. Koh, J. Luh, J. A. Marlin, L. B. Martin Jr., C. D. Meyer, C. Pao, E. L. Peterson, M. S. Putcha, S. Schecter, J. F. Selgrade, C. E. Siewert, M. F. Singer, E. L. Stitzinger, R. E. White;
*Adjunct Professor:* R. J. Plemmons;
*Professors Emeriti:* R. C. Bullock, J. M. Clarkson, W. J. Harrington, J. Levine, P. A. Nickel, H. V. Park, N. J. Rose, H. Sagan, R. A. Struble, J. B. Wilson;
*Associate Professors:* G. D. Faulkner, J. E. Franke, D. E. Garoutte, I. Ipsen, K. Ito, T. J. Lada, D. M. Latch, X. Lin, K. C. Misra, L. K. Norris, L. B. Page, R. T. Ramsay, J. Rodriguez, F. H. Semazzi, R. Silber, J. W. Silverstein, D. F. Ullrich;
*Assistant Professors:* H. J. Charlton, B. G. Fitzpatrick, F. J. Garaizar, D. J. Hansen, A. G. Helminck, P. Hitczenko, A. Kheyfets, W. R. McKinney, S. O. Paur, J. S. Scroggs, H. T. Tran;
*Adjunct Assistant Professor:* W. E. Spooner

The Department of Mathematics offers programs leading to the degrees of Master of Science and Doctor of Philosophy in mathematics and in applied mathematics. Students may opt for the concentration in computational mathematics, which is attached to the program in applied mathematics. There are also opportunities for students to be associated with the Center for Research in Scientific Computation, which is housed in the Department of Mathematics.

### Admissions Requirements

Applicants for admission should have an undergraduate or masters degree in mathematics or the equivalent. This should include courses in advanced calculus, modern algebra, and linear algebra. Applicants with degrees in other subjects may be admitted but may be required to take certain undergraduate courses in mathematics with-

out receiving graduate credit. It is recommended that applicants take the GRE Advanced Test in Mathematics.

### Master of Science Requirements

In addition to course requirements, the M.S. degree requires a written master's project for 3 hours credit.

### Ph.D. Requirements

A student will typically take 50-60 semester hours of course credits for the Ph.D. These courses include one semester of modern algebra and one semester of mathematical analysis. The written preliminary examination consists of examinations in three selected areas of mathematics. Prior to taking the preliminary oral examination, the student must demonstrate a working knowledge of a foreign language. The research dissertation should represent a substantial contribution to an area of mathematics or its applications.

### Student Financial Support

Several teaching assistantships and some fellowships and research assistantships are available. For full consideration, complete applications should be submitted before January 15th.

### Other Information

The Department of Mathematics is well equipped with computing facilities for undergraduate and graduate students. There are two computer laboratories with SUN and IBM workstations and Macintosh computers. Some graduate student offices are equipped with desktop computers. The graduate student laboratory and several graduate student offices are linked through the department's ethernet network to other facilities in the university and elsewhere, including the North Carolina Supercomputer Center.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

MA 401 APPLIED DIFFERENTIAL EQUATIONS II.
MA 403 INTRODUCTION TO MODERN ALGEBRA.
MA 405 INTRODUCTION TO LINEAR ALGEBRA AND MATRICES.
MA 407 INTRODUCTION TO MODERN ALGEBRA FOR MATHEMATICS MAJORS.
MA 408 FOUNDATIONS OF EUCLIDEAN GEOMETRY.
MA 410 THEORY OF NUMBERS.
MA 414 INTRODUCTION TO DIFFERENTIAL GEOMETRY.
MA(CSC) 416 INTRODUCTION TO COMBINATORICS.
MA 421 INTRODUCTION TO PROBABILITY.
MA 425 MATHEMATICAL ANALYSIS I.
MA 426 MATHEMATICAL ANALYSIS II.
MA(CSC) 427 INTRODUCTION TO NUMERICAL ANALYSIS I.
MA(CSC) 428 INTRODUCTION TO NUMERICAL ANALYSIS II.

MA 430 MATHEMATICAL MODELS IN THE PHYSICAL SCIENCES.
MA 432 MATHEMATICAL MODELS IN LIFE SCIENCES AND SOCIAL SCIENCES.
MA 433 HISTORY OF MATHEMATICS.
MA 437 APPLICATION OF ALGEBRA.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MA 501 ADVANCED MATHEMATICS FOR ENGINEERS AND SCIENTISTS I. Preq.: MA 301 or equivalent. Credit for this course and MA 401 is not allowed. 3(3-0) F,S,Sum.** Survey of mathematical methods for engineers and scientists. Ordinary differential equations and Green's functions; partial differential equations and separation of variables; special functions, Fourier series. Applications to engineering and science. Not for credit by mathematics majors.

**MA 502 ADVANCED MATHEMATICS FOR ENGINEERS AND SCIENTISTS II. Preq.: MA 301 or equivalent. Any student receiving credit for MA 502 may receive credit for, at most, one of the following: MA 405, MA 512, MA 513. 3(3-0) F,S,Sum.** Determinants and matrices; line and surface integrals, integral theorems; complex integrals and residues; distribution functions of probability. Not for credit by mathematics majors.

**MA(OR) 504 INTRODUCTION TO MATHEMATICAL PROGRAMMING. 3(3-0) S.** (See operations research.)

**MA(IE,OR) 505 LINEAR PROGRAMMING. 3(3-0) F,S.** (See industrial engineering.)

**MA 507 ANALYSIS FOR SECONDARY TEACHERS. Preq.: Grad. standing. 3(3-0) F,Sum. Alt. yrs.** A course designed to update and broaden the secondary teacher's capability and point-of-view with respect to topics in analysis. Historical development, logical refinement and applications of concepts such as limits, continuity, differentiation and integration. May be taken for graduate credit for certificate renewal by secondary school teachers. Credit towards a graduate degree may be allowed only for students in mathematics education.

**MA 508 GEOMETRY FOR SECONDARY TEACHERS. Preq.: Grad. standing. 3(3-0) S,Sum. Alt. yrs.** Study of topics in geometry of concern to secondary teachers in their work and provision for background and enrichment. Various approaches to the study of geometry, including vector geometry, transformational geometry and axiomatics. Course may be taken for graduate credit and for certificate renewal by secondary school teachers. Credit towards a graduate degree may be allowed only for students in mathematics education.

**MA 509 ABSTRACT ALGEBRA FOR SECONDARY TEACHERS. Preq.: Grad. standing. 3(3-0) F,Sum. Alt. yrs.** From advanced viewpoint, an investigation of topics in algebra from the high school curriculum. Theory of equations, polynomial rings, rational functions and elementary number theory. Course may be taken for graduate credit for certificate renewal by secondary school teachers. Credit towards a graduate degree may be allowed only for students in mathematics education.

**MA 510 SELECTED TOPICS IN MATHEMATICS FOR SECONDARY TEACHERS. Preq.: Grad. standing. 3(3-0) S,Sum. Alt. yrs.** Designed to cover various topics in mathematics of concern to secondary teachers. Topics selected from areas such as mathematics of finance, probability, statistics, linear programming and theory of games, intuitive topology, recreational math, computers and applications of mathematics. Course may be taken for graduate credit for certification renewal by secondary school teachers. Credit towards a graduate degree may be allowed only for students in mathematics education.

**MA 511 ADVANCED CALCULUS I. Preq.: MA 301. Credit for both MA 425 and MA 511 is not allowed. 3(3-0) F,S,Sum.** Fundamental theorems on continuous functions; convergence theory of sequences, series and integrals; the Riemann integral.

**MA 512 ADVANCED CALCULUS II. Preq.: MA 301. Credit for both MA 426 and MA 512 is not allowed. 3(3-0) F,S,Sum.** General theorems of partial differentiation; implicit function theorems; vector calculus in 3-space; line and surface integrals; classical integral theorems.

**MA 513 INTRODUCTION TO COMPLEX VARIABLES. Preq.: MA 242. 3(3-0) F,S,Sum.** Operations with complex numbers, derivatives, analytic functions, integrals, definitions and properties of elementary functions, multivalued functions, power series, residue theory and applications, conformal mapping.

**MA 514 METHODS OF APPLIED MATHEMATICS. Preq.: MA 511 or 425. 3(3-0) S.** Introduction to integral equations, the calculus of variations and difference equations.

**MA 515 ANALYSIS I. Preq.: MA 425. 3(3-0) F,S.** Metric spaces: contraction mapping principle, Tietze extension theorem, Ascoli-Arzela lemma, Baire category theorem, Stone-Weierstrass theorem, $L^p$ spaces. Banach spaces: linear operators, Hahn-Banach theorem, open mapping and closed graph theorems. Hilbert spaces: projection theorem, Riesz representation theorem, Lax-Milgram theorem, complete orthonormal sets.

**MA 517 INTRODUCTION TO TOPOLOGY. Preq.: MA 426. 3(3-0) F.** Sets and functions, metric spaces, topological spaces, compactness, separation, connectedness.

**MA 518 CALCULUS ON MANIFOLDS. Preq.: MA 426. 3(3-0) F.** Calculus of several variables from a modern viewpoint. Differential and integral calculus of several variables, vector functions, integration of manifolds, Stokes' and Green's theorems, vector analysis.

**MA 519 NONLINEAR DYNAMICS AND CHAOS. Preqs.: MA 341 and MA 405. 3(3-0) F.** Usage of computer experiments for demonstration of nonlinear dynamics and chaos and motivation of mathematical definitions and concepts. Examples from finance and ecology as well as traditional science and engineering. Difference equations and iteration of functions as nonlinear dynamical systems. Fixed points, periodic points and general orbits. Bifurcations and transition to chaos. Symbolic dynamics, chaos, Sarkovskii's Theorem, Schwarzian derivative, Newton's method and fractals.

**MA 520 LINEAR ALGEBRA. Preq.: MA 405. 3(3-0) F.** Vector spaces, linear mappings and matrices, determinants, inner product spaces, bilinear and quadratic forms, canonical forms, spectral theorem.

**MA 521 FUNDAMENTALS OF MODERN ALGEBRA. Preqs.: MA 405 and MA 407. 3(3-0) F,S.** Groups, normal subgroups, quotient groups, Cayley's theorem, Sylow's theorem. Rings, ideals and quotient rings, polynomial rings. Fields, extension fields, elements of Galois theory.

**MA 524 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES I. Preqs.: MA 405, 511 and either MA 401 or 501. 3(3-0) F.** Green's functions and two-point boundary value problems; elementary theory of distributions; generalized Green's functions. Finite and infinite dimensional inner product spaces; Hilbert spaces; completely continuous operators; integral equations; the Fredholm alternative; eigenfunction expansions; applications to potential theory. Nonsingular and singular Sturm-Liouville problems; Weil's theorem.

**MA 525 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES II. Preq.: MA 524. 3(3-0) S.** Distribution theory in n-space; Fourier transforms; partial differential equations, generalized solutions, fundamental solutions, Cauchy problem, wave and heat equations, well-set problems. Laplace's equations, the Dirichlet and Neumann problems, integral equations of potential theory. Green's functions, eigenfunction expansions.

**MA(CSC) 529 NUMERICAL ANALYSIS I. Preqs.: MA 405, MA 511, high-level computer language. 3(3-0) F.** For students in the engineering, physical and mathematical sciences. Illustrations of algorithm behavior and applicability. The effect of roundoff errors, systems of linear equations and direct methods, least squares via Givens and Householder transformations, iterative methods, convergence for SOR with symmetric positive definite matrices, the conjugate gradient method, eigenvalue problems, Newton's method, initial value problems and partial differential equations.

**MA(CSC) 530 NUMERICAL ANALYSIS II. Preq.: MA 529. 3(3-0) S.** Approximation, quadrature, Newton's method, roots of polynomials, minimization problems, ordinary differential equations with boundary conditions and variational methods.

**MA(E,OR) 531 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL I. 3(3-0) F.** (See operations research.)

**MA 532 THEORY OF ORDINARY DIFFERENTIAL EQUATIONS. Preqs.: MA 341, 405, 425 or 511. 3(3-0) F.** Existence and uniqueness theorems, systems of linear equations, fundamental matrices, matrix exponential, nonlinear systems, plane autonomous systems, stability theory.

**MA 534 INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS. Preqs.: MA 425 or MA 511, MA 341. 3(3-0) F.** Linear first order equations, method of characteristics. Classification of second order equations. Solution techniques for the heat equation, wave equation and Laplace's equation. Maximum principles. Green's functions and fundamental solutions.

**MA 535 STABILITY AND TIME OPTIMAL CONTROL OF HEREDITARY SYSTEMS I. Preqs.: MA 341 or MA 531 or MA 532 and MA 425 or MA 511. 3(3-0) F.** The theory of stability and of time optimal control of hereditary systems. Lyapunov stability theory, time optimal, minimum fuel and effort control synthesis of systems. Applications: spread of epidemics, growth of global economy, automatic steering of aircraft, control of wind tunnels, and of flexible structures.

**MA(ST) 541 THEORY OF PROBABILITY I. Preq.: MA 425 or 511. 3(3-0) F,Sum.** Axioms, combinatorial analysis, conditional probability, independence, random variables, expectation, special discrete and continuous distributions, probability and moment generating functions, central limit theorem, laws of large numbers, branching processes, recurrent events, random walk.

**MA(ST) 542 INTRODUCTION TO STOCHASTIC PROCESSES. 3(3-0) S.** (See statistics.)

**MA 544 COMPUTER EXPERIMENTS IN MATHEMATICAL PROBABILITY. Preq.: MA 421. 3(3-0) S.** Exposure of the student to the practice of performing mathematical experiments on the computer, with emphasis on probability. Programming in an interactive language such as APL, MATLAB or Mathematica. Mathematical treatment of random number generation and application of these tools to mathematical topics in Monte Carlo method, limit theorems and stochastic processes for the purpose of gaining mathematical insight.

**MA 545 SET THEORY AND FOUNDATIONS OF MATHEMATICS. Preq.: MA 407. 3(3-0) S.** Logic and the axiomatic approach, the Zermelo-Fraenkel axioms and other systems, algebra of sets and order relations, equivalents of the Axiom of Choice, one-to-one correspondences, cardinal and ordinal numbers, the Continuum Hypothesis.

**MA(PY) 555 MATHEMATICAL INTRODUCTION TO CELESTIAL MECHANICS. Preq.: MA 301. 3(3-0) F.** Central orbits, N-body problem, 3-body problem, Hamilton-Jacobi theory, perturbation theory, applications to motion of celestial bodies.

**MA(PY) 556 ORBITAL MECHANICS. Preqs.: MA 301, 405, knowledge of elementary mechanics and computer programming. 3(3-0) S.** Keplerian motion, iterative solutions, numerical integration, differential corrections and space navigation, elements of probability, least squares, sequential estimation, Kalman filter.

**MA(BMA,ST) 571 BIOMATHEMATICS I. 3(3-0) F.** (See biomathematics.)

**MA(BMA,ST) 572 BIOMATHEMATICS II. 3(3-0) S.** (See biomathematics.)

**MA 581 SPECIAL TOPICS. Preq.: Consent of department. 1-6 F,S.**

**MA 583 NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS. Preq.: MA 511 or 512. 3(3-0) S.** Numerical methods for initial value problems including predictor-corrector, Runge-Kutta, hybrid and extrapolation methods; stiff systems; shooting methods for two-point boundary value problems; weak, absolute and relative stability results.

**MA 584 NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS--FINITE DIFFERENCE METHODS. Preqs.: MA 501; knowledge of a high level programming language. 3(3-0) F.** Finite difference methods for partial differential equations including elliptic, parabolic and hyperbolic PDE's. Both linear and nonlinear problems considered. Theoretical foundations described; however, emphasis on algorithm design and implementation.

**MA(CSC,OR) 585 GRAPH THEORY. 3(3-0) F.** (See computer science.)

**MA(IE,OR) 586 NETWORK FLOWS. 3(2-2) S.** (See industrial engineering.)

**MA 587 NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS--FINITE ELEMENT METHOD. Preqs.: MA 501; knowledge of a high-level programming language. 3(3-0) S.** The finite element method. Applications to both linear and nonlinear elliptic and parabolic partial differential equations. Theoretical foundations described; however, emphasis on algorithm design and implementation.

*FOR GRADUATES ONLY*

**MA 600 ADVANCED DIFFERENTIAL EQUATIONS I. Preqs.: MA 513, 518, 520. 3(3-0) S.** Analytical theory of ordinary differential equations, stability theory, perturbations, asymptotic behavior, nonlinear oscillations.

**MA 601 ADVANCED DIFFERENTIAL EQUATIONS II. Preq.: MA 600. 3(3-0) S. Alt. yrs.** Qualitative theory of ordinary differential equations, general properties of dynamical systems, limit sets, integral invariants, global theory.

**MA 602 PARTIAL DIFFERENTIAL EQUATIONS. Preqs.: MA 501 or 534 and MA 511. 3(3-0) S.** Linear second order parabolic, elliptic and hyperbolic equations. Initial value problems and boundary value problems. Iterative and variational methods. Existence, uniqueness and regularity. Nonlinear equations and systems.

**MA 604 TOPOLOGY. Preq.: MA 517. 3(3-0) S.** Topological spaces: separation axioms, compactness, connectedness, local topological properties; continuous mappings and convergence; product and quotient spaces; compactification; homotopy equivalence of mappings, fundamental groups.

**MA(ST,OR) 606 NONLINEAR PROGRAMMING. 3(3-0) S.** (See statistics.)

**MA(NE) 607 EXACT AND APPROXIMATE SOLUTIONS IN PARTICLE TRANSPORT THEORY. 3(3-0) S.** (See nuclear engineering.)

**MA 608 NUMERICAL NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS. Preqs.: MA 405 or 520 and MA 501 or 534; knowledge of a high-level programming language. 3(3-0) S. Alt. yrs.** Nonlinear discrete equations; Newton and monotone methods for nonlinear equations; computational algorithms and applications; finite difference method - convergence, stability and error estimates; multiplicity of solutions and bifurcation; asymptotic behavior of solutions; and coupled systems of equations.

**MA(BMA,OR,ST) 610 STOCHASTIC MODELING. 3(3-0) S. Alt. yrs.** (See biomathematics.)

**MA 611 ANALYTIC FUNCTION THEORY I. Preq.: MA 426. 3(3-0) F.** Rigorous introduction to theory of functions of a complex variable. Complex plane, functions, Mobius transformations, exponential and logarithmic functions, trigonometric functions, infinite series, integration in the complex plane, Cauchy's theorem and its consequences.

**MA 612 ANALYTIC FUNCTION THEORY II. Preq.: MA 611. 3(3-0) S.** A continuation of MA 611. Taylor and Laurent series. The residue theorem, the argument principle, harmonic functions and the Dirichlet problem, analytic continuation and the monodromy theorem, entire and meromorphic functions, the Weierstrass product representation and the Mittag-Leffler partial fraction representation, special functions, conformal mapping and the Picard theorem.

**MA 613 TECHNIQUES OF COMPLEX ANALYSIS. Preq.: MA 513 or 611. 3(3-0) S.** The applications of complex analysis to mathematical problems in physical science in the setting of the potential equation and other partial differential equations: contour integrals, special functions of mathematical physics from the line integral point of view, solution of problems in potential theory, asymptotic methods including WKB and Wiener-Hopf techniques.

**MA(OR) 614 INTEGER PROGRAMMING. 3(3-0) S. Alt. yrs.** (See operations research.)

**MA(ST) 617, 618 MEASURE THEORY AND ADVANCED PROBABILITY. 3(3-0) F,S.** (See statistics.)

**MA 620 MODERN ALGEBRA I. Preq.: MA 521. 3(3-0) S.** Field extensions, Galois theory, modules, tensor products, exterior products.

**MA 621 MODERN ALGEBRA II. Preq.: MA 620. 3(3-0) S.** Advanced topics in groups, rings, fields and modules.

**MA 622 LINEAR TRANSFORMATIONS AND MATRIX THEORY. Preq.: MA 405. 3(3-0) F.** Vector spaces, linear transformations and matrices, orthogonality, orthogonal transformations with emphasis on rotations and reflections, matrix norms, projectors, least squares, generalized inverses, definite matrices, singular values.

**MA 623 THEORY OF MATRICES AND APPLICATIONS. Preq.: MA 520 or 622. 3(3-0) S.** Canonical forms, functions of matrices, variational methods, per-

turbation theory, numerical methods, nonnegative matrices, applications to differential equations, Markov chains.

**MA 625 LIE ALGEBRAS. Preqs.: MA 520, MA 521. 3(3-0) S.** Definition of Lie algebras and examples. Nilpotency, solvability and semi-simplicity. The Killing form and Cartan's criterion. Weyl's theorem on complete reducibility. Representations of sl(2,F). The classification of finite dimensional simple Lie algebras over the complex numbers.

**MA 626 ALGEBRAIC TOPOLOGY. Preq.: MA 517. 3(3-0) S. Alt. yrs.** Simplicial and singular homology and cohomology, Eilenberg-Steenrod axioms, duality, cohomology operations; higher homotopy groups, Hurewicz homomorphisms.

**MA(OR) 629 VECTOR SPACE METHODS IN SYSTEM OPTIMIZATION. 3(3-0) F.** (See operations research.)

**MA(E,OR) 631 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL II. 3(3-0) S. Alt. yrs.** (See operations research.)

**MA 632 OPERATIONAL MATHEMATICS I. Preq.: MA 513 or 611. 3(3-0) F.** Laplace transforms with theory and application to ordinary and partial differential equations arising from problems in engineering and physics.

**MA 633 OPERATIONAL MATHEMATICS II. Preq.: MA 632. 3(3-0) S.** Extended development of the Laplace and Fourier transforms and their application to the solution of ordinary and partial differential equations, integral equations and difference equations; Z-transforms, other infinite and finite transforms and their applications.

**MA 635 STABILITY AND TIME OPTIMAL CONTROL OF HEREDITARY SYSTEMS II. Preq.: MA 535. 3(3-0) S.** Time optimal control of linear delay systems; minimum fuel control synthesis; nonlinear controllability theory; stability of large-scale systems and applications to growth of the national/global economy.

**MA 637 DIFFERENTIABLE MANIFOLDS. Preqs.: MA 405, 521; Coreq.: MA 604. 3(3-0) F. Alt. yrs.** The topology and geometry of differentiable manifolds, multilinear algebra, exterior differential forms, differentiable manifolds, theory of connexions, Riemannian manifolds.

**MA 647 ANALYSIS II. Preq.: MA 515. 3(3-0) S.** Integration: Lebesgue measure and integration, Lebesgue dominated convergence and monotone convergence theorems, Fubini's theorem, extension of the fundamental theorem of calculus. Banach

spaces: $L^p$ spaces, weak convergence, adjoint operators, compact linear operators, Fredholm-Riesz Schauder theory and spectral theorem.

**MA 648 ADVANCED FUNCTIONAL ANALYSIS. Preq.: MA 647. 3(3-0) S. Alt. yrs.** Advanced topics in functional analysis such as linear topological spaces; Banach algebra, spectral theory and abstract measure theory and integration.

**MA 661 DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS I. Preq.: MA 426 or 512. 3(3-0) S. Alt. yrs.** Classical and modern differential geometry presented from the point of view of tensor analysis and differential forms. Theory of curves, tensor analysis and differential forms, intrinsic geometry of surfaces, Riemannian geometry.

**MA 662 DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS II. Preq.: MA 661. 3(3-0) F. Alt. yrs.** Continuation of MA 661.

**MA 672 ADVANCED NUMERICAL LINEAR ALGEBRA. Preq.: MA 529. 3(3-0) S.** Mathematical and numerical investigation of direct, iterative and semi-iterative methods for the solution of linear systems. Singular algebraic systems and least squares computations. Methods for the calculation of eigenvalues and eigenvectors. Careful mathematical analysis of these techniques.

**MA(CSC) 673 PARALLEL ALGORITHMS AND SCIENTIFIC COMPUTATION. Preq.: MA 529. S.** Multiprocessing and supercomputer architectures including Alliant FX/8, IBM 3090 VF-600, CRAY XMP-48, Intel iPCS and BBN Butterfly. The implementation of standard numerical linear algebra algorithms on vector and multiprocessing computers. Portability of codes from one computer to another. Typical applications to science and engineering.

**MA 674 NONLINEAR EQUATIONS AND UNCONSTRAINED OPTIMIZATION. Preq.: MA 529. 3(3-0) S. Alt. yrs.** Newton's method and Quasi-Newton methods for nonlinear equations and optimization problems, globally convergent extensions, methods for sparse problems, applications to differential equations, integral equations and general minimization problems. Methods appropriate for boundary value problems.

*The subject matter in the following special topics courses varies from year to year. The topics and instructors are announced well in advance by the department.*

**MA 681 SPECIAL TOPICS IN REAL ANALYSIS. 1-6.**

**MA 682 SPECIAL TOPICS IN COMPLEX ANALYSIS. 1-6.**

**MA 683 SPECIAL TOPICS IN ALGEBRA. 1-6.**

**MA 684 SPECIAL TOPICS IN COMBINATORIAL ANALYSIS. 1-6.**

**MA 685 SPECIAL TOPICS IN NUMERICAL ANALYSIS. 1-6.**

**MA 686 SPECIAL TOPICS IN TOPOLOGY. 1-6.**

**MA 687 SPECIAL TOPICS IN GEOMETRY. 1-6.**

**MA 688 SPECIAL TOPICS IN DIFFERENTIAL EQUATIONS. 1-6.**

**MA 689 SPECIAL TOPICS IN APPLIED MATHEMATICS. 1-6.**

**MA(IE,OR) 692 SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING. 3(3-0) F,S,Sum.** (See industrial engineering.)

**MA 697 MASTER'S PROJECT. 3(3-0) F,S,Sum.** Investigation of some topic in mathematics to a deeper and broader extent than typically done in a classroom situation. For the applied mathematics student the topic usually consists of a realistic application of mathematics to the student's minor area. A written and oral report on the project required.

**MA 699 RESEARCH. Credits Arranged.** Individual research in mathematics.

# Mathematics Education

For a listing of graduate faculty and program information, see mathematics and science education.

# Mathematics and Science Education

**Degrees Offered: Ph.D., M.S., M.Ed.**

**GRADUATE FACULTY**

*Professor* J. R. Kolb, *Head of the Department*
*Associate Professor* W. M. Waters Jr., *Director of Graduate Programs, Mathematics Education*
*Assistant Professor* J. C. Park, *Director of Graduate Programs, Science Education*
Box 7801, (919) 515-2239, waters@poe.coe,ncsu.edu (Mathematics Ed.); (919) 515-2238, park@poe.coe.ncsu.edu (Science Ed.)

*Professors:* N. D. Anderson, L. M. Clark;
*Associate Professors:* S. B. Berenson, L. V. Stiff, L. W. Watson, J. H. Wheatley;
*Research Associate Professor:* H. S. Stubbs;
*Associate Professor Emeritus:* H. A. Shannon;
*Assistant Professors:* K. S. Norwood, S. L. Westbrook;
*Visiting Assistant Professors:* G. S. Carter, J. M. Gleason

The Department of Mathematics and Science Education offers graduate work leading to the degrees of Master of Science, Master of Education, and Doctor of Philosophy with majors in mathematics education or science education. A sixth-year program leading to certification is available. Students take courses in both professional education and in their teaching speciality. Areas of specialization include mathematics, statistics, computer science, biological sciences, earth science, chemistry and physics.

**Admission Requirements**
Recent scores from the Graduate Record Examination (General Test) or, in the case of the master's degree, the Miller's Analogy Test are required for admission. Academic and professional background necessary for admission differs by specific program.

**Master's Degree Requirements**
A minimum of 36 semester hours is required of which a minimum of 18 semester hours must be in the teaching field.

**Doctoral Degree Requirements**
A minimum of 45 semester hours of course work, a minimum of 12 semester hours of research and one foreign language is required.

**Student Financial Support**
Teaching assistantships and research assistantships are available to students in the program.

**Other Relevant Information**
Programs are offered that lead to graduate level(G) certification as a teacher of mathematics or a teacher of science at grades 6-9 or grades 9-12 for those who have earned initial(A) certification. A program is available to prepare teachers of science and mathematics for careers in post-secondary education.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**EMS 511 IMPLICATIONS OF MATHEMATICAL CONTENT, STRUCTURE, AND PROCESSES FOR THE TEACHING OF MATHEMATICS IN**

**THE ELEMENTARY SCHOOL. Preq.: Bachelor's degree in elementary educ. or CI. 3(3-0) S,Sum. Alt. yrs.** For teachers and supervisors of mathematics in the elementary or middle school. Special emphasis on implications of mathematical content, structure, and processes in teaching arithmetic and geometry.

**EMS 512 TEACHING MATHEMATICS IN ELEMENTARY AND JUNIOR HIGH SCHOOL. Preq.: EMS 471 or equivalent. 3(3-0) S,Sum. Alt. yrs.** Comprehensive study of teaching mathematics in elementary and junior high schools. Major emphasis on building skills in teaching arithmetic, elementary algebra and intuitive geometry. Thorough search of the literature relative to the mathematics curricula conducted, designing and sequencing of learning activities, teaching mathematical concepts and relationships, building skill in computation, reading mathematics, problem solving and measurement covered.

**EMS 526 TEACHING IN COLLEGE. 3(3-0) Sum.** Development of competencies to perform the fundamental tasks of a college teacher as well as consideration of more long-range tasks such as course development and the university responsibilities of a professor. In addition to attending lectures and other types of presentations, students make video tapes of their teaching, develop tests, design introductory courses in their teaching fields and consider current issues related to university and college teaching.

**EMS 570 FOUNDATIONS OF MATHEMATICS EDUCATION. Preq.: EMS 471 or equivalent. 3(3-0) S.** Current status of mathematics education with special emphasis on the study and critical analysis of current practices in mathematics instruction from elementary school through college.

**EMS 575 FOUNDATIONS OF SCIENCE EDUCATION. Preq.: EMS 475 or equivalent. 3(3-0). S. Alt. yrs.** Philosophical, historical, sociological, political and economic factors affecting science education in the schools of the United States. Implications for science education of various learning theories examined along with models for curriculum development and program planning. Critical analysis of current trends, issues and problems in science education in terms of multiple perspectives.

**EMS 577 IMPROVING CLASSROOM INSTRUCTION IN SCIENCE. Preq.: EMS 475 or equivalent. 3(3-0) S. Alt. yr.** Application of major principles of education and psychology to improvement of science teaching in elementary, middle and secondary schools. Critical analysis of research and the development of research-based classroom applications. Goals and objectives of science teaching, instructional strategies, development or selection of science materials, evaluation of achievement and elements of a desirable classroom climate.

**EMS 592 SPECIAL PROBLEMS IN MATHEMATICS TEACHING. Preq.: EMS 471 or equivalent. 1-3 F,S,Sum.** An in-depth investigation of topical problems in mathematics teaching chosen from the areas of curriculum, methodology, technology, supervision and research.

**EMS 594 SPECIAL PROBLEMS IN SCIENCE TEACHING. Preq.: EMS 476 or equivalent. 1-6 F,S,Sum.** An in-depth investigation of topics in science education not covered in existing courses. Includes critical analysis of research and may include field work. May be offered on individual basis or as a class.

**EMS 599 RESEARCH PROJECTS IN MATHEMATICS AND SCIENCE EDUCATION. Preqs.: CI; ELP 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. The research chosen on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**EMS 603 TEACHING MATHEMATICS AND SCIENCE IN HIGHER EDUCATION. Preqs.: EMS 570, 592 or 594, CI. 3(3-0) S.** Examination of collegiate mathematics and science instruction with respect to goals and objectives, design of courses and curricula, innovative programs and facilities, and methods and materials for instruction.

**EMS 604 CURRICULUM DEVELOPMENT AND EVALUATION IN SCIENCE AND MATHEMATICS. Preqs.: 500-level statistics, PSY 535, CI. 3(3-0) S. Alt. yrs.** Elements of curriculum design and theory in mathematics education and science education and the examination of evaluation procedures for assessing educational innovations.

**EMS 605 EDUCATION AND SUPERVISION OF TEACHERS OF MATHEMATICS AND SCIENCE. Preqs.: ED 470 or 475 or equivalent, EMS 570 or 592 or 594. 3(3-0) S. Alt. yrs.** Critical analysis of theories, programs and techniques designed to promote interpersonal interactions leading to more effective teaching of science and mathematics.

**EMS 621 INTERNSHIP IN MATHEMATICS AND SCIENCE EDUCATION. Preqs.: Nine hrs. in grad. level courses and CI. 3-9 F,S,Sum.** Utilizing the participant-observer role, required participation in selected educational situations with emphasis upon development of observational skills, ability to record relevant observations by means of written journals, skills in analyzing experiences identifying critical incidents and projection of events and consequences. The student required

to develop possible alternative courses of action in various situations, select one of the alternatives and evaluate the consequences of the selected course of action.

**EMS 641 PRACTICUM IN SCIENCE AND MATHEMATICS EDUCATION. Preq.: EMS 570 or EMS 575. 1-6 F,S.** Supervised practicum in appropriate settings both on- and off-campus. Provision for opportunity for development, implementation and evaluation in science and mathematics in clinical environment under faculty supervision.

**EMS 690 SEMINAR IN MATHEMATICS EDUCATION. Preq.: Departmental major or CI. 2(2-0) F,S.** An in-depth examination and analysis of the literature and research in a particular topic(s) in mathematics education.

**EMS 695 SEMINAR IN SCIENCE EDUCATION. Preq.: Department major or CI. 2(2-0) F,S.** An in-depth examination and analysis of the literature and research in a particular topic(s) in science education.

**EMS 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of ED; CI. Credits Arranged. F,S,Sum.** Individual research on a thesis or dissertation problem.

# Mechanical Engineering

For a listing of graduate faculty and program information, see mechanical and aerospace engineering.

# Mechanical and Aerospace Engineering

**Degrees Offered: Ph.D., M.S., Master of Mechanical Engineering**

**GRADUATE FACULTY**

*Graduate Alumni Distinguished Professor* F. R. DeJarnette, *Interim Head of the Department*
*Professor* J. C. Mulligan, *Director of Graduate Programs*
Box 7910, (919) 515-3026, mulligan@eod.ncsu.edu

*Graduate Alumni Distinguished Professors:* H. A. Hassan, M. N. Ozisik
*R. J. Reynolds Industries Professor:* C. F. Zorowski

*Professors:* E. M. Afify, J. A. Bailey, T. A. Dow, J. A. Edwards, F. D. Hart, T. H. Hodgson, R. F. Keltie, C. Kleinstreuer, G. K. F. Lee, C. J. Maday, D. S. McRae, R. T. Nagel, J. N. Perkins, L. H. Royster, F. O. Smetana, F. Y. Sorrell Jr., J. S. Strenkowski, G. D. Walberg;
*Visiting Professor:* G. V. Candler;
*Adjunct Professors:* J. M. Bownds, D. P. Dewitt, W. D. Erickson, J. N. Juang, D. E. Klett, E. R. McClure, R. A. Whisnant;
*Professors Emeriti:* R. A. Burton, M. H. Clayton, B. H. Garcia Jr., W. C. Griffith, F. J. Hale, M. N. Ozisik, J. K. Whitfield, J. Woodburn;
*Associate Professors:* M. A. Boles, N. Chokani, J. W. David, H. M. Eckerlin, J. W. Eischen, R. D. Gould, R. R. Johnson, E. C. Klang, J. W. Leach, L. M. Silverberg;
*Visiting Associate Professors:* C. P. Young Jr.;
*Adjunct Associate Professors:* J. P. Archie Jr., J. G. Cleland, A. C. Eberhardt, J. H. Hebrank, K. R. Iyer, D. W. Lee, D. L. Margolis, R. M. Potter Jr., H. Singh;
*Assistant Professors:* L. Franzoni, C. E. Hall Jr., P. I. H. Ro, F. Yuan, M. A. Zikry;
*Adjunct Assistant Professors:* J. A. Cooke, J. P. Coulter, S. D. Holland, M. A. Norris, A. L. Patra, S. C. Southward, M. E. Tauber, M. A. Ward, W. J. Yanta

## INTERINSTITUTIONAL ADJUNCT GRADUATE FACULTY

S. Chandra, P. H. Dehoff

Course offerings and research programs are available in the following areas: thermodynamics and energy conversion, heat and mass transfer, fluid mechanics, combustion, acoustics and noise control, machine design, vibration, gas dynamics and aerodynamics, aeroelasticity, CFD, finite elements, structures, controls, precision engineering, materials processing, and tribology.

### Admission Requirements

An applicant to the master's program must be a graduate of an accredited undergraduate program with a B.S. degree in either mechanical or aerospace engineering. Graduates of other accredited programs in engineering, physical sciences and mathematics may be considered but will be required to make up undergraduate deficiencies without graduate credit. Provisional admissions, as well as exceptions, are sometimes granted under special circumstances. The most qualified applicants are accepted first. Applicants to the Ph.D. program must have met the M.S. admission requirements, completed the M.S. degree in mechanical engineering or aerospace engineering and additionally must satisfy the Ph.D. qualifying requirements.

### Master's Degree Requirements

The non-thesis Master of Mechanical Engineering degree requires 27 hours of course credit and a six-hour project.

### PhD Degree Requirements

A minimum of 24 hours of course credit beyond the master's program is required.

### Student Financial Support

Various types of assistantships and fellowships are available. Awards are made to the most qualified applicants first and generally are not available for all students.

### Other Relevant Information

Each new student choses an area of specialty, selects an advisor and committee, customizes a program of study, and begins research in the first semester of residence. The Director of Graduate Programs acts as a temporary advisor initially and should be contacted with questions.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

MAE 403 AIR CONDITIONING.
MAE 404 REFRIGERATION.
MAE 405 MECHANICAL ENGINEERING LABORATORY III.
MAE 406 ENERGY CONSERVATION IN INDUSTRY.
MAE 407 STEAM AND GAS TURBINES.
MAE 408 INTERNAL COMBUSTION ENGINE FUNDAMENTALS.
MAE 409 PARTICULATE CONTROL IN INDUSTRIAL ATMOSPHERIC POLLUTION.
MAE 410 CONVECTIVE HEAT TRANSFER AND FLUID FLOW.
MAE 411 MACHINE COMPONENT DESIGN.
MAE 412 ENERGY SYSTEMS.
MAE 415 MECHANICAL ENGINEERING ANALYSIS.
MAE 416 MECHANICAL ENGINEERING DESIGN.
MAE 431 THERMODYNAMICS OF COMPRESSIBLE FLUID FLOW.
MAE 435 PRINCIPLES OF AUTOMATIC CONTROL.
MAE 442 AUTOMOTIVE ENGINEERING.
MAE 452 AERODYNAMICS OF V/STOL VEHICLES.
MAE 455 BOUNDARY LAYER THEORY.
MAE 456 COMPUTATIONAL METHODS IN AERODYNAMICS.
MAE 462 FLIGHT VEHICLE STABILITY AND CONTROL.
MAE 465 PROPULSION II.
MAE 466 PROPULSION II LABORATORY.
MAE 472 AEROSPACE VEHICLE STRUCTURES II.
MAE 473 AEROSPACE VEHICLE STRUCTURE II LABORABORY.
MAE 478 AEROSPACE VEHICLE DESIGN I.
MAE 479 AEROSPACE VEHICLE DESIGN II.
MAE 495 SPECIAL TOPICS IN MECHANICAL AND AEROSPACE ENGINEERING.

**MAE 501 ADVANCED ENGINEERING THERMODYNAMICS. Preqs.: MAE 302; MA 401 or MA 511. 3(3-0) F.** Classical thermodynamics of a general reactive system; conservation of energy and principles of increase of entropy; fundamental relation of thermodynamics; Legendre transformations; phase transitions and critical phenomena; equilibrium and stability criteria in different representation; irreversible thermodynamics. Statistical thermodynamics.

**MAE 503 ADVANCED POWER PLANTS. Preq.: MAE 412. 3(3-0) F.** A critical analysis of the energy balance of thermal power plants, thermodynamics and economic evaluation of alternate schemes of development; study of recent development in the production of power.

**MAE 504 FLUID DYNAMICS OF COMBUSTION I. Preqs.: MAE 301, MAE 355 or MAE 308. 3(3-0) F.** Gas-phase thermochemistry including chemical equilibrium and introductory chemical kinetics. Homogeneous reaction phenomena. Subsonic and supersonic combustion waves in premixed reactants (deflagration and detonation). Effects of turbulence. Introduction to diffusion flame theory.

**MAE 505 HEAT TRANSFER THEORY AND APPLICATIONS. Preq.: MAE 410 or equivalent. 3(3-0) F.** Development of basic equations for steady and transient heat and mass transfer processes. Emphasis on the application of the basic equations to engineering problems in the areas of conduction, convection, mass transfer and thermal radiation.

**MAE 510 EFFECTS OF NOISE AND VIBRATION ON MAN. Preq.: MA 301. 3(3-0) F.** Effects of noise and vibration and design criteria available to establish acceptability of environments. Auditory and non-auditory response to noise and models available for predicting responses. Guidelines for designing equipment and environments to meet existing ANSI, ISO, ASTM and HVAC standards. Practical experience in using noise-vibration equipment.

**MAE 513 PRINCIPLES OF STRUCTURAL VIBRATION. Preq.: MAE 315. 3(3-0) F.** Principles of structural vibration beginning from single and multi-degree of freedom systems and extending to distributed systems. Forced system response, vibration of strings, bars, shafts and beams and an introduction to approximate methods.

**MAE 514 NOISE AND VIBRATION CONTROL. Preq.: MAE 315. 3(3-0) S.** Noise and vibration design criteria. Noise and vibration survey procedures. The noise and vibration control model. Review of most common equipment noise sour-

ces and ways to achieve adequate control. Room acoustics, acoustics of walls, enclosures, vibration isolation and use of scale models.

**MAE 517 INSTRUMENTATION IN SOUND AND VIBRATION ENGINEERING. Preq.: ECE 331; Coreq.: MAE 513. 3(3-0) S.** Measurement techniques and theory and operation of transducers and amplifiers. Signal analysis techniques such as power spectral density and correlation.

**MAE 518 ACOUSTIC RADIATION I. Preqs.: MA 301 and MAE 308 or MAE 356. 3(3-0) F.** Acoustic radiation from vibrating bodies and their related fields. The radiation of simple sources, the propagation of sound waves in confined spaces and transmission through different media.

**MAE 519 THEORY OF NOISE IN TRANSPORTATION SYSTEMS. Preq.: MAE 550. 3(3-0) S.** Basic noise generating mechanisms encountered in transportation systems. Jet noise, propeller noise, helicopter noise, fan and compressor noise, aircraft induced community noise, surface vehicle noise models and efforts to control noise in transportation systems.

**MAE(IE) 520 INDUSTRIAL ROBOTICS. 3(3-0) F.** (See industrial engineering.)

**MAE 521 LINEAR CONTROL AND DESIGN FOR MINO SYSTEMS. Preqs.: MAE 435 or equivalent; MA 341. 3(3-0) F.** Linear Multivariable control and design for multibody engineering systems (robotics) and aircraft controls and navigation. Multi-input and multi-output (MIMO) system analysis and design using frequency-based approach. Controllability and observability, transmission zeroes and pole-zero cancellation, eigenstructures, singular value decomposition in frequency domain, stability and performance robustness of MIMO systems.

**MAE 524 PRINCIPLES OF STRUCTURAL CONTROL. Preq.: MAE 315; Coreq.: MAE 513. 3(3-0) F.** Structural control beginning with single and two-degree of freedom systems and extending to distributed systems. State feedback, disturbance rejection, mode coupling, state estimation, pole placement. Applications to civil structures, path following in robotic structures, suspensions in automotive structures, flight control systems in aircraft structures and attitude control in space structures.

**MAE 525 ADVANCED FLIGHT VEHICLE STABILITY AND CONTROL. Preq.: MAE 462. 3(3-0) F.** Preliminary analysis and design of flight control systems to include autopilots and stability augmentation systems. Effects of inertial cross-coupling and nonrigid bodies on vehicle dynamics.

**MAE 526 INERTIAL NAVIGATION ANALYSIS AND DESIGN. Preq.: MAE 435 or 462. 3(3-0) S.** Performance analysis and engineering design of inertial navigation components, subsys tems and systems. Development of transfer functions and application of linear system techniques to determine stability, transient response and errors of gyroscopes, accelerometers, stable platforms and inertial alignment systems. Error analysis and its significance. Preliminary analysis and design of typical inertial navigation systems for aircraft and marine vehicles.

**MAE(MAT) 531 MATERIALS PROCESSING BY DEFORMATION. Preq.: Six hrs. of solid mechanics and/or materials. 3(3-0) F.** Mechanical and metallurgical fundamentals of materials processing by deformation. Principles of metal working, friction, forging, rolling, extrusion, drawing, high energy rate forming, chipless forming techniques, manufacturing system concept in production.

**MAE(MAT) 532 FUNDAMENTALS OF METAL MACHINING THEORY. Preq.: Six hrs. of solid mechanics and/or materials. 3(3-0) S.** Mechanical and metallurgical fundamentals of metal machining. Mechanics of machining, temperatures generated, tool life and tool wear, lubrication, grinding process, electrical machining processes, surface integrity, economics, nomenclature of cutting tools.

**MAE 533 FINITE ELEMENT ANALYSIS I. Preq.: MAE 316 or MAE 472. 3(3-0) F.** The finite element method for linear stress and deformation analysis of mechanical components. Development of truss, beam, frame, plane stress, plane strain, axisymmetric and solid elements. Isoparametric formulations. Introduction to structural dynamics. Practical modeling techniques and use of general-purpose codes for solving practical stress analysis problems.

**MAE 536 PHOTOELASTICITY. Preq.: MAE 316 or 371. 3(2-3) S. Alt. yrs.** Theory and experimental techniques of two- and three-dimensional photoelasticity including photoelastic coatings, photoplasticity and an application of photoelastic methods to the determination of stress-strain distributions in loaded members. Laboratory includes an investigation and complete report of a problem chosen by the student under the guidance of the instructor.

**MAE 537 MECHANICS OF COMPOSITE STRUCTURES. Preq.: MAE 316 or MAE 472. 3(3-0) F.** Manufacturing techniques with an emphasis on the selection of those producing the most favorable end result. Classical plate theory, materials properties and failure theories. Micromechanics, repair, plate solutions and elasticity solutions covered as required to meet special interests of students.

**MAE 538 ENGINEERING OPTICS. Preq.: Grad. standing. 3(3-0) S.** Geometric and physical optics as related to problems in engineering design and research. Characteristics of imaging systems including multi-element design, geometric and

chromatic aberrations and effects of apertures. Properties of light sources and optical properties of material also covered. Diffraction, interference and scattering phenomena as related to optical measurements techniques. Introduction to lasers and holography.

**MAE 540 ADVANCED AIR CONDITIONING DESIGN. Preqs.: MAE 403, 404. 3(3-0) S.** Psychrometric process representations. Heating and cooling coil design. Heat pump design. Air washer design. Direct contact heat and mass transfer systems. Ventilation requirements, air dilution calculations. Cooling load calculations; CLTD, CLF and transfer functions methods. Room air distribution.

**MAE 541 ADVANCED MACHINE DESIGN I. Preq.: MAE 416. 3(3-0) F.** Advanced treatment of stress analysis and mechanics of materials devoted to analytical methods of predicting the life of mechanical components. Development of governing differential equations of elasticity. Analyses of beams, stress concentrations, pressurized pipes, rotating disks and contact stresses. The energy approach to elasticity problems also used as well as a brief introduction to plastic failure criteria.

**MAE 542 MECHANICAL DESIGN FOR AUTOMATED ASSEMBLY. Preq.: Grad. standing or PBS status in engineering. 3(3-0) F.** Mechanical design principles important in high volume production using modern automated assembly technology. Production and component design for ease of assembly as dictated by part handling, feeding, orientation, insertion and fastening requirements. Existing product evaluation and redesign for improved assemblage.

**MAE 543 FRACTURE MECHANICS. Preq.: MAE 316. 3(3-0) S.** Elastic stress intensity factor, Griffith energy balance, determination of the elastic field at a sharp crack tip via eigenfunction expansion methods, J integrals analysis, experimental determination of fracture toughness, fatigue crack growth, elastic-plastic crack tip fields. Modern numerical methods for determination of stress intensity factors, critical crack sizes and fatigue crack propagation rate predictions.

**MAE 544 REAL TIME ROBOTICS. Preq.: Pascal, C, Fortran or Assembly language experience. 3(3-0) F.** Real-time programming for servo control using an embedded controller. Software and hardware interfacing for control of a D.C. servo device. Introduction of multi-tasking to establish concurrent control of several processes, transforming servo loop into a process executing concurrently on single board computer. Provision for hands-on development systems and software emulators.

**MAE 550 FOUNDATIONS OF FLUID DYNAMICS. Preqs.: MAE 301, MAE 355 or MAE 308. 3(3-0) F.** Basic thermodynamics pertinent to gas dynamics. Detailed development of the general equations governing fluid motion in

both differential and integral forms. Simplification of the equations to those for specialized flow regimes. Similarity parameters. Applications to simple problems in various flow regimes.

**MAE 551 AIRFOIL THEORY. Preq.: MAE 355. 3(3-0) S.** Development of fundamental aerodynamic theory. Mathematical analysis and derivation of equations of motion, airfoil theory and comparison with experimental results. Introduction to super sonic flow theory.

**MAE 552 TRANSONIC AERODYNAMICS. Preq.: MAE 356. 3(3-0) S.** The latest theoretical and experimental findings in transonic aerodynamics, including two-dimensional and axisymmetric flows.

**MAE 553 COMPRESSIBLE FLUID FLOW. Preq.: MAE 356 or MAE 431 or MAE 550. 3(3-0) F. Alt. yrs.** Equations of motion in supersonic flow; unsteady wave motion, velocity potential equation; linearized flow; conical flow. Slender body theory. Methods of characteristics. Shockwave/ boundary layer interactions.

**MAE 554 HYPERSONIC AERODYNAMICS. Preq.: MAE 553. 3(3-0) S.** Inviscid and viscous hypersonic flowfields. Classical and modern techniques for calculating shock wave shapes, expansions, surface pressures, heat transfer and skin friction. Applications to high speed aircraft, rockets and spacecraft.

**MAE 555 AERODYNAMIC HEATING. Preq.: MAE 356. 3(3-0) F.** The latest theoretical and experimental findings of the compressible laminar and turbulent boundary layers with special attention to the aerodynamic heating problem. Application of theory in the analysis and design of aerospace hardware.

**MAE 556 MECHANICS OF IDEAL FLUIDS. Preq.: MAE 355 or MAE 308. 3(3-0) S.** Mass, momentum and energy conservation laws, flow kinematics and special forms of the governing equations (*e.g.*, Euler equations and Bernoulli's equation). Solutions of Laplace's equation for the velocity potential. Applications of complex analysis for two-dimensional potential flows. Study of three-dimensional potential flows. Introduction to the effects of viscosity.

**MAE 557 DYNAMICS OF INTERNAL FLUID FLOW. Preq.: MAE 356 or MAE 308. 3(3-0) F.** A general development of the governing equations of fluid motion with subsequent restriction to incompressible flow. Exact and approximate solutions of the Navier-Stokes equations for internal laminar flow and elementary boundary layer theory. Applications include: hydrodynamic lubrication, converging-diverging channel flows, entrance flows and turbulent internal flow.

**MAE 558 PLASMAGASDYNAMICS I. Preqs.: MAE 356, PY 414. 3(3-0) F.** Study of basic laws governing plasma motion for dense and rarefied plasmas, hydromagnetic shocks, plasma waves and instabilities, simple engineering applications.

**MAE 559 MOLECULAR GAS DYNAMICS I. Preq.: MAE 550. 3(3-0) F.** Statistical mechanics as applied to the derivation of the equations of gas dynamics from the microscopic view point. Collision processes, treatments of viscosity, heat conduction and electrical conductivity.

**MAE 560 COMPUTATIONAL FLUID MECHANICS AND HEAT TRANSFER. Preqs.: MA 501 or MA 512, MAE 550 or MAE 557, proficiency in the FORTRAN programming language is required. 3(3-0) S.** Integration of the governing partial differential equations of fluid flow and heat transfer by numerical finite difference and finite volume means. Methods for parabolic, hyperbolic and elliptical equations and application to model equations. Error analysis and physical considerations.

**MAE 561 WING THEORY. Preq.: MAE 551. 3(3-0) S. Alt. yrs.** Inviscid flow fields over wings in subsonic flow. Vortex lattice methods, lifting surface theories and panel methods developed for wings with attached flow and leading-edge separation. Calculation of aerodynamic characteristics and determination of the effects of planform and airfoil shapes.

**MAE 562 PHYSICAL GAS DYNAMICS. Preq.: MAE 550. 3(3-0) F.** Kinetic theory, statistical mechanics and chemical thermodynamics. Law of Action. Vibrational and chemical rate processes. Application to equilibrium and nonequilibrium flows.

**MAE(MEA) 563 GEOPHYSICAL FLUID MECHANICS. 3(3-0) F. Alt. yrs.** (See marine, earth and atmospheric sciences.)

**MAE(ECE) 565 GAS LASERS. Preqs.: MAE 356 or equivalent, PY 407. 3(3-0) F.** Study of the principles, design and potential application of ion, molecular, chemical and atomic gas lasers.

**MAE 570 THEORY OF PARTICULATE COLLECTION IN AIR POLLUTION CONTROL. Preq.: MAE 409 or grad. standing. 3(3-0) S.** Classification of particulate matter and description of its properties. Careful analysis of motion of particles as applied to particulate collection. Development of elements of aerodynamic capture of particles and consideration of applications in filtration and liquid scrubbing. Introduction of fundamentals of acoustical, electrostatic and thermal precipitation. Consideration of sampling techniques and instrumentation.

**MAE 586 PROJECT WORK IN MECHANICAL ENGINEERING. 1-6 F,S.** Individual or small group investigation of a problem stemming from a mutual student-faculty interest. Emphasis on providing a situation for exploiting student curiosity.

**MAE 589 SPECIAL TOPICS IN MECHANICAL ENGINEERING. Preq.: Advanced undergrad. or grad. standing. 3(3-0) F,S.** Faculty and student discussions of special topics in mechanical engineering.

*FOR GRADUATES ONLY*

**MAE 601 STATISTICAL THERMODYNAMICS. Preq.: MAE 501. 3(3-0) S.** Analysis and establishment of conclusions of classical thermodynamics from the microscopic viewpoint. Ensemble methods, partition functions, translational, rotational and vibrational energy modes of an ideal gas, chemical equilibrium, imperfect gases, dense fluids, critical-point theories, mean free path concepts, Boltzmann equation, hydrodynamic equations from kinetic theory and properties of disordered composite media.

**MAE 604 FLUID DYNAMICS OF COMBUSTION II. Preq.: MAE 504. 3(3-0) S.** Advanced theory of detonation and deflagration. Ignition criteria. Direct initiation of detonation including blast-wave theory. Transition from deflagration to detonation. Combustion wave structure and stability. Liquid droplet and solid particle combustion.

**MAE 608 ADVANCED CONDUCTIVE HEAT TRANSFER. Preq.: MAE 505 or MA 501. 3(3-0) S.** A comprehensive, unified treatment of methodologies for solving multidimensional transient and steady heat conduction. Approximate and exact methods of solving nonlinear problems, including phase and temperature-dependent thermal properties, nonlinear boundary conditions. Heat conduction in composite media and anisotropic solids. The use of finite integral transform and Green's function techniques.

**MAE 609 ADVANCED CONVECTIVE HEAT TRANSFER. Preq.: MAE 557. 3(3-0) S.** Advanced topics in steady and transient, natural and forced convective heat transfer for laminar and turbulent flow through conduits and over surfaces. Mass transfer in laminar and turbulent flow. Topics on compressible flow with heat and mass transfer.

**MAE 610 ADVANCED RADIATIVE HEAT TRANSFER. Preq.: MAE 505. 3(3-0) F.** A comprehensive and unified treatment of basic theories; exact and approximate methods of solution of radiative heat transfer and the interaction of

radiation with conductive and convective modes of heat transfer in participating and non-participating media.

**MAE 613 ANALYTICAL METHODS IN STRUCTURAL VIBRATION. Preq.: MAE 513. 3(3-0) S.** Classical problems in structural vibration for which analytical solutions are available. Shock response, energy formulations and applications to continuous and discretized systems including curved beams, membranes, plates, shells, cylinders, spheres and cones.

**MAE 614 COMPUTATIONAL METHODS IN STRUCTURAL VIBRATION. Preq.: CE 527 or MAE 513. 3(3-0) S.** Development of computational methods to analyze the field problems in structural vibration for which closed-form solutions generally unavailable. Aimed primarily at linear systems, topics include: linearization and stability, computational methods for the eigensolutions and discretization by local function, global function and hybrid approaches, applications to undampled, damped and spinning assemblages of beams, rods, strings, shafts, membranes and plates.

**MAE 615 NONLINEAR VIBRATIONS. Preq.: MAE 513. 3(3-0) S. Alt. yrs.** A study of free and forced vibrations of non-linear systems with non-linear restoring forces and self-sustained oscillations. Development and usage of various analytical and phase plane methods in obtaining actual solutions. Emphasis on understanding properties unique to non-linear systems.

**MAE 618 ACOUSTIC RADIATION II. Preq.: MAE 518. 3(3-0) S.** Advanced treatment of the theory of sound generation and transmission. Topics include: techniques for solution of the wave equation, radiation from spheres, cylinders and plates, sound propagation in ducts, scattering.

**MAE 619 RANDOM VIBRATION. Preq.: MAE 513. 3(3-0) F. Alt. yrs.** Mathematical description of stochastic processes. The stationary and ergodic assumptions and response analysis of mechanical systems to random excitation. Simulation of and failure due to random environments.

**MAE 623 MECHANICS OF MACHINERY. Preqs.: MAE 315, MA 512. 3(3-0) S. Alt. yrs.** Advanced applications of dynamics to the design and response analysis of dynamic behavior of machines and mechanical devices. Emphasis on developing competence in transforming real problems in dynamics into appropriate mathematical models whose analysis permits performance predictions of engineering value.

**MAE 634 FINITE ELEMENT ANALYSIS II. Preq.: MAE 533. 3(3-0) S.** Advanced treatment of finite element analysis for non-linear mechanics problems, including most recent developments in efficient solution procedures. Plate bending

and shell elements, computational plasticity and viscoplastic materials, large deformation formulations, initial stability and buckling, structural vibrations, incompressible elasticity, contact problems, flow in incompressible media, weighted residuals and field problems. Development of efficient algorithms for practical application.

**MAE 640 ADVANCED MACHINE DESIGN II. Preq.: MAE 541. 3(3-0) S.** Continuation of MAE 541. Problems related to torsion, curved and non-symmetric beams, rings, plates and shells, and a brief introduction to fracture mechanics.

**MAE 642 MECHANICAL DESIGN ANALYSIS. Preq.: Nine hours of graduate credit in MAE. 3(3-0) F.** Lecture and project activity devoted to development of ability to apply knowledge and experience in performing comprehensive design analysis of complete mechanical systems. Critical problem recognition, system modeling, performance determination and optimization and reliability evaluation.

**MAE 650 COMPUTATION OF REACTING FLOWS. Preqs.: MAE 560, MAE 660. 3(3-0) S.** Development of the governing equations for chemically and thermally non-equilibrium flows. Numerical formulation with application to planetary entry flows and supersonic combustion. Numerical examples. Computational problems.

**MAE 653 HYDRODYNAMIC STABILITY AND TRANSITION. Preq.: MAE 550 or MAE 557. 3(3-0) S. Alt. yrs.** Conceptual framework and development of hydrodynamic stability theory. Application of the theory to two-dimensional incompressible and compressible subsonic, transonic, supersonic and hypersonic flows. Results for three-dimensional flows. Mechanisms of transition and discussion of transition models in numerical methods.

**MAE 654 DYNAMICS OF REAL FLUIDS I. Preq.: MAE 550 or 557. 3(3-0) S.** Exact solutions to the Navier-Stokes equations. Approximate solutions for low Reynolds numbers. Approximate solutions for high Reynolds numbers--incompressible boundary layer theory. Laminar and turbulent boundary layers in theory and experiment. Flow separation.

**MAE 655 DYNAMICS OF REAL FLUIDS II. Preq.: MAE 654. 3(3-0) F.** A continuation of MAE 654. Compressible laminar and turbulent boundary layers. Laminar and turbulent jets. The stability of laminar boundary layers with respect to small disturbances, transition from laminar to turbulent flow.

**MAE 656 TURBULENCE. Preq.: MAE 550. 3(3-0) S.** Basic concepts and governing equations for turbulence and turbulent field motion. Formulations of the various correlation tensors and energy spectra for isotropic and nonisotropic turbulence. Turbulent transport processes, "free" turbulence and "wall" turbulence.

**MAE 658 PLASMAGASDYNAMICS II. Preq.: MAE 558. 3(-0) S.** Quantum statistics and ionization phenomena. Charged particle interactions. Transport properties in the presence of electric and magnetic fields and nonequilibrium ionization.

**MAE 659 MOLECULAR GAS DYNAMICS II. Preqs.: MAE 559, 601. 3(3-0) S.** A continuation of MAE 559. Approximate methods of solution to the Boltzmann equation. Modeling of the Boltzmann equation. Results obtained by the various methods of analysis.

**MAE 660 COMPUTATIONAL FLUID DYNAMICS. Preq.: MAE 560; proficiency in the FORTRAN programming language is required. 3(3-0) F.** Advanced computational methods for integrating, by use of finite differences, and finite volume discretizations, non-linear governing equations of fluid flow; the Euler equations and the Navier-Stokes equations. Topics from the current literature.

**MAE 661 INTRODUCTION TO ROCKET PROPULSION. Preq.: MAE 501. 3(3-0) F.** Review of the exterior ballistics and performance of rocket-propelled vehicles. Thermodynamics of real gases at high temperatures. Nonequilibrium flow in rocket nozzles.

**MAE(MEA) 663 ADVANCED GEOPHYSICAL FLUID MECHANICS. 3(3-0) S. Alt. yrs.** (See marine, earth and atmospheric sciences.)

**MAE(MEA) 664, 665 PERTURBATION METHOD IN FLUID MECHANICS I, II. 3(3-0) F,S.** (See marine, earth and atmospheric sciences.)

**MAE 686 ADVANCED TOPICS IN MECHANICAL ENGINEERING. 1-3 F,S.** Faculty and graduate student discussions of advanced topics in contemporary mechanical engineering.

**MAE 695 MECHANICAL ENGINEERING SEMINAR. 1(1-0) F,S.** Faculty and graduate student discussions centered around current research problems and advanced engineering theories.

**MAE 699 MECHANICAL ENGINEERING RESEARCH. Preqs.: Grad. standing in mechanical engineering, consent of adviser. Credits Arranged.** Individual research in the field of mechanical engineering.

# Microbiology

**Degrees Offered: Ph.D., M.S., Master of Life Sciences**

## GRADUATE FACULTY

*Professor* H. M. Hassan, *Interim Head of the Department*
*Associate Professor* T. Melton, *Director of Graduate Programs*
Box 7615, (919) 515-2391, Fax: (919) 515-7867, micro@mbio.ncsu.edu

*Professors:* W. J. Dobrogosz, L. W. Parks, J. J. Perry;
*Professor Emeritus:* G. H. Elkan;
*Professor (USDA):* P. E. Bishop;
*Adjunct Professor:* R. E. Kanich;
*Associate Professors:* G. H. Luginbuhl, J. M. Mackenzie Jr., E. S. Miller, E. K. Tatchell;
*Adjunct Associate Professors:* G. A. Boorman, K. T. Kleeman;
*Assistant Professors:* J. W. Brown, S. M. Laster, I. T. D. Petty;
*Adjunct Assistant Professors:* W. S. Dallas, S. H. Shore

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* P. M. Foegeding, T. R. Klaenhammer, W. E. Kloos;
*Associate Professors:* F. J. Fuller

The Department of Microbiology is in the College of Agriculture and Life Sciences, which has a unique blend of applied and basic research programs. The department offers courses of study and research leading to both the Ph.D. and M.S. degrees. The graduate program is designed to prepare individuals for careers in research and teaching. Research in the department emphasizes study of fundamental biological processes, with several programs having important biotechnological and environmental applications.

### Admission Requirements

Applications are invited from individuals holding baccalaureate degrees in the physical and life sciences. Applications should ideally be received in the department before January 15 to be considered for fall admission.

### Master's Degree Requirements

For students wishing a more general educational background in microbiology without the thesis requirement, the Master of Life Sciences degree is offered.

### Doctoral Degree Requirements

The Ph.D. program is designed for individuals desiring to pursue careers in research and teaching. First-year students enroll in a core curriculum consisting of courses in microbiology, biochemistry and genetics offered in this and other departments on campus. In conjunction with their advisor, the student establishes a four-member faculty advisory committee to guide their research and academic program. At least one semester of laboratory instructorship is required. The final examination also includes a seminar presented by the candidate that is open to the university community.

### Student Financial Support

Financial support for study in the department is available in the form of teaching assistantships, research assistantships and competitive fellowships. All applications to the department are automatically considered for available assistantships. For highly qualified students, supplemental funds are frequently available.

### Other Relevant Information

During the first semester, participation in a laboratory rotation program is encouraged so that students become acquainted with departmental research programs, faculty and other graduate students. A faculty thesis adviser and laboratory research program are usually selected in the first semester and no later than the second term.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

MB 401 GENERAL MICROBIOLOGY.
MB(FS) 405 FOOD MICROBIOLOGY.
MB 411 MEDICAL MICROBIOLOGY.
MB 490 SPECIAL TOPICS IN MICROBIOLOGY.
MB 491 SEMINAR IN MICROBIOLOGY.

### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**MB 503 MICROBIAL DIVERSITY. Preq.: MB 401. 2(2-0) S. Alt. yrs.** Introduction to the theory and practice of bacterial taxonomy. Historical view of significant developments; classification into phrenetic and phylogenetic; modern approaches of chemotaxonomy and numerical taxonomy; identification methods; interactions with biotechnology, ecology, genetics and pathology. The role of microbial culture collections.

**MB 514 MICROBIAL METABOLIC REGULATION. Preqs.: MB 401, BCH 451. Credit in both MB 414 and MB 514 is not allowed. 3(3-0) F.** An integrative perspective on bacterial physiology and metabolism through an analysis of metabolic regulatory functions.

**MB 518 INTRODUCTORY VIROLOGY. Preq.: BCH 451 or GN 411 or MB 401. 3(3-0) S.** Introduction to principles of virology including: classification and nomenclature, epidemiology, structure, genome replication, gene expression strategies and cellular infection cycle. Major groups of viruses including those with DNA genomes and positive-sense or negative-sense RNA genomes.

**MB(FS) 525 FERMENTATION MICROBIOLOGY. 3(3-0) S. Alt. yrs.** (See food science.)

**MB(SSC) 532 SOIL MICROBIOLOGY. 4(3-3) S.** (See soil science.)

**MB(IMM) 551 IMMUNOLOGY. Preq.: BCH 451, GN 411, MB 401. 3(3-0) S.** Introduction to mechanisms of immunity in man and animals. Emphasis on the interactions between the cells of the immune system in the production of immune responses and the molecules in the control of these interactions.

**MB(ZO) 555 PROTOZOOLOGY. 4(2-6) S.** (See zoology.)

**MB(IMM,PHY,PO,VMS) 556 IMMUNOGENETICS. 3(2-2) F. Alt. yrs.** (See poultry science.)

**MB(GN) 558 PROKARYOTIC MOLECULAR GENETICS. Preqs.: BCH 451 or BCH 551, GN 411, MB 401. 3(3-0) S.** Structure and function in prokaryotic molecular genetics, with emphasis on mutations and mutagenic pathways, transcriptional and translational regulation, RNA processing, DNA replication and recombination and characterization of recombinant DNA molecules. Applications of genetic and recombinant DNA techniques to microbial processes, including strain construction and enhancement of gene expression.

**MB(BO) 574 PHYCOLOGY. 3(1-4) S.** (See botany.)

**MB(BO,PP) 575 THE FUNGI. 3(3-0) F.** (See botany.)

**MB(BO,PP) 576 THE FUNGI--LAB. 1(0-3) F.** (See botany.)

**MB 590 TOPICAL PROBLEMS. Preqs.: Grad. standing, CI. Credits Arranged. F,S.**

*FOR GRADUATES ONLY*

**MB 605 BIOLOGICAL SCANNING ELECTRON MICROSCOPY. Preq.: Some biological background. 2(1-2) On demand.** Theory and application of scanning electron microscopy, including specimen preparation, microscope alignment

and operation, performance evaluation, interpretation of problems and darkroom technique. (Limited to 8 students with prior approval of instructor.)

**MB 610 BIOLOGICAL TRANSMISSION ELECTRON MICROSCOPY. Preq.: Some biological background. 3(2-3) On demand.** Theoretical and practical aspects of transmission electron microscopy, including microscope alignment and use, performance evaluation, interpretation of problems and darkroom. (Limited to 8 students with prior approval of instructor.)

**MB 611 ULTRAMICROTOMY FOR LIFE SCIENCES. Preq.: BS 610. 2(1-4) On demand.** An intensive laboratory course covering sample preparative techniques for transmission electron microscopy, including tissue preparation, thick sectioning, staining and ultramicrotomy. (Limited to 8 students with prior approval of instructor.)

**MB(BO,GN,PP) 627 FUNGAL GENETICS AND PHYSIOLOGY. 3(2-3).** (See plant pathology.)

**MB(SSC) 632 ECOLOGY AND FUNCTIONS OF SOIL MICROORGANISMS. 3(3-0) S.** (See soil science.)

**MB(VMS) 653 ADVANCED IMMUNOLOGY. 3(3-0) F. Alt. yrs.** (See veterinary medical sciences.)

**MB(GN) 660 EXPERIMENTAL MICROBIAL GENETICS. Preqs.: BCH 561, GN 411, MB 401. 4(2-6) S.** Laboratory-oriented presentation of current methodologies and concepts in molecular microbial genetics and their application to strain construction, plasmid and phage manipulations, mutagenesis, cloning and genetic engineering of microorganisms.

**MB 671 MOLECULAR VIROLOGY OF ANIMAL VIRUSES. Preqs.: BCH 551, MB 502B. 3(3-0) F.** Animal virus replication. Selected examples from each virus group illustrate the principles underlying lytic, persistent and tumor-inducing viral infection.

**MB 690 MICROBIOLOGY SEMINAR. 1(1-0) F,S.**

**MB 692 SPECIAL PROBLEMS IN MICROBIOLOGY. Credits Arranged. F, S,Sum.**

**MB 699 MICROBIOLOGY RESEARCH. Credits Arranged. F,S,Sum.**

# Middle Grades Education

For a listing of graduate faculty and program information, see curriculum and instruction.

# Natural Resources Administration

**Degrees Offered: M.S., Master of Natural Resources Administration**

**GRADUATE FACULTY**

*Professor* D. L. Holley Jr., ***Director of Graduate Programs, Forestry***
Box 8002, (919) 515-2892
*Associate Professor* B. E. Wilson, ***Director of Graduate Programs, Parks, Recreation and Tourism Management***
Box 8004, (919)515-3276
*Professor* E. J. Kamprath, ***Director of Graduate Programs, Soil Science***
Box 7619, (919) 515-2643

*Professors:* H. A. Devine, J. D. Gregory, E. J. Kamprath, J. D. Wellman;
*Professor (USDA):* F. W. Cubbage;
*Associate Professors:* R. C. Abt, H. J. Kleiss, B. E. Wilson;
*Assistant Professor:* R. L. Moore

The natural resources administration program is an interdepartmental program consisting of faculty from the Departments of Forestry, Parks, Recreation and Tourism Management, and Soil Science and is designed to prepare students for administrative positions in science-based natural resource management organizations. Core training is provided in policy and administration for all students, together with the opportunity for specialization in one of several technical natural resource management options: forest policy and management, outdoor recreation management, spatial information systems, hydrology and soil science.

**Admissons Requirements**
Students should have completed a B.S. in natural resources or related fields, but individuals currently employed in natural resources management desiring further professional training for career advancement will also be considered.

**Master's Requirements**
In four of the five technical options, students may choose between a M.S. and a Master of Natural Resources Administration degree. The soil science option offers a Master of Natural Resources Administration only.

*Core Courses (15 credit hours)*

**ECG 515 ENVIRONMENTAL AND RESOURCE POLICY**
**FOR 672 CURRENT ISSUES IN NATURAL RESOURCE POLICY**
**PA 520 ENVIRONMENTAL POLICY**
**PRT 505 QUANTITATIVE TECHNIQUES FOR RECREATION AND NATURAL RESOURSE MANAGEMENT**

*Advised Elective:*
Graduate Statistics course

*One of the following:* (This is a one-hour seminar for all students in the program. Instruction will rotate among participating departments, and students will enroll in the designated section of the lead department's seminar.)
**FOR 691 GRADUATE SEMINAR**
**PRT 691 RECREATION MANAGEMENT SEMINAR II**
**SSC 690 SEMINAR**

# Nuclear Engineering

**Degrees Offered: Ph.D., M.S., Master of Nuclear Engineering**

**GRADUATE FACULTY**

*Professor* D. J. Dudziak, ***Head of the Department***
*Professor* J. G. Gilligan, ***Director of Graduate Programs***
Box 7909, (919) 515-2301, gilligan@eos.ncsu.edu

***Professors:*** R. P. Gardner, K. L. Murty, P. J. Turinsky, K. Verghese;
***Adjunct Professor:*** M. S. Wechsler;
***Professors Emeriti:*** T. S. Elleman, R. L. Murray, R. F. Saxe, E. Stam, L. R. Zumwalt;
***Associate Professors:*** J. M. Doster, C. W. Mayo;
***Research Associate Professor:*** M. A. Bourham;
***Assistant Professors:*** O. E. Hankins, R. M. Mayo;
***Research Assistant Professor:*** D. J. Kropaczek

The discipline of nuclear engineering is concerned with the development of nuclear processes for energy production and with the applications of radiation for the benefit of society. Representative topics of investigation include analytic, computational and experimental research in the neutronics, materials, thermal-hydraulics and control aspects of fission reactors; radiation detection and measurement of basic physics parameters; waste management and radiological assessment; applications of

radioisotopes and radiation in industry, medicine and science; and plasma, plasma-material surface interactions and design aspects of fusion reactors.

### Admission Requirements

Bachelor's degree graduates in any of the fields of engineering or physical sciences may be qualified for successful advanced study in nuclear engineering. Prior experience or course work in nuclear physics, partial differential equations and basic reactor analysis is helpful but may be gained during the first semester of graduate study. GRE scores (general test) are usually needed for financial aid.

### Master's Degree Requirements

A project is required for the MNE degree. A minor (9 semester hours) must be selected for both the MS and MNE degrees.

### Doctoral Degree Requirements

Typically about 60 semester hours are required beyond the B.S. degree for the Ph.D. (includes research hours). Students must pass a departmental qualifying exam that covers basic nuclear engineering material. Stuents must select a minor (typically 15-18 hours).

### Student Financial Support

Teaching assistantships, research assistantships and fellowships are available for qualified applicants. Opportunities are also available for graduate traineeships with utility companies, reactor manufacturers and national laboratories providing a valuable combination of financial support and learning in the classroom, the research laboratory and on the job.

### Other Relevant Information

The department has many excellent facilities including the one-megawatt PULSTAR fission reactor, the Scaled PWR Facility (SPWRF), neutron activation analysis laboratory, nuclear materials laboratory, plasma and fusion laboratories, instrumentation and controls equipment, radiation analyzers and tomography systms, and computers ranging from workstations to a supercomputer.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

NE 401 REACTOR ANALYSIS AND DESIGN.
NE 402 REACTOR ENGINEERING.
NE 403 NUCLEAR ENGINEERING DESIGN PROJECTS.
NE 404 RADIOLOGICAL, REACTOR, AND ENVIRONMENTAL SAFETY.
NE(MAT) 409 NUCLEAR MATERIALS.
NE 414 NUCLEAR POWER PLANT INSTRUMENTATION.
NE 419 INTRODUCTION TO NUCLEAR ENGINEERING.
NE 491 SPECIAL TOPICS IN NUCLEAR ENGINEERING.

**NE 505 REACTOR SYSTEMS. Preq.: NE 401 or equivalent. Credit for both NE 405 and NE 505 is not allowed. 3(3-0) F.** Nuclear power plant systems: PWR, BWR and advanced concepts. Design criteria, design parameters, economics, primary and secondary loops, safety systems, reactor control and protection systems, containment, accident and transient behaviors, core design, and reactivity control mechanisms. Term-long project.

**NE 508 RADIATION SAFETY. Preq.: NE 401 or NE 520. 3(2-3) S.** The basic concepts of health physics, biological effects of radiation and calculation of radiation exposure. Radiation units, regulatory agencies and allowable limits of radiation, sources of radiation, dose calculations–external and internal, radiation dosimetry, reactor radiation sources and dose reduction with particular emphasis on shielding.

**NE(PY) 511 NUCLEAR PHYSICS FOR ENGINEERS. 3(3-0) F.** (See physics.)

**NE 512 NUCLEAR FUEL CYCLES. Preq.: NE 401 or equivalent. Credit for both NE 412 and NE 512 is not allowed. 3(3-0) S.** Processing of nuclear fuel with description of mining, milling, conversion, enrichment, fabrication, irradiation, shipping, reprocessing and waste disposal. Fuel cycle economics and fuel cost calculation. In-core and out-of-core nuclear fuel management, engineering concepts and methodology. Term-long project.

**NE 520 RADIATION AND REACTOR FUNDAMENTALS. Preqs.: MA 401 and NE 401 or equivalent. 2(2-0) F.** An introduction to radiation physics and reactor physics. Atomic and nuclear decay processes, nuclear reactions, neutron slowing down and diffusion, criticality for bare and reflected reactors and reactor kinetics.

**NE 521 NUCLEAR LABORATORY FUNDAMENTALS. Preqs.: MA 401 and NE 401 or equivalent. 2(1-3) F.** Introduction to nuclear instrumentation and experimental techniques used in nuclear engineering research. Topics include radiation detection and spectroscopy, neutron instrumentation, statistical analysis, use of microcomputers and nuclear reactor operations.

**NE 522 REACTOR DYNAMICS AND CONTROL. Preq.: NE 401 or NE 520. 3(3-0) F.** Methods of describing and analyzing dynamic behavior of systems. These methods applied to reactor systems and the effects of feedbacks studies. Methods of measuring the behavior of reactor systems and development of logic systems for control and safety.

**NE 523 REACTOR ANALYSIS. Preq.: NE 401 or NE 520. 3(3-0) F.** Basic models of neutron motion and methods of calculating neutron flux distributions in nuclear reactors. Emphasis on multigroup diffusion theory. Criticality search, neutron slowing down models, resonance absorption, thermalization and heterogeneous cell calculations. Objective is to enable students to read literature and perform relevant analysis in reactor physics.

**NE 524 REACTOR HEAT TRANSFER. Preq.: NE 401 or NE 520. 3(3-0) S.** Consideration of heat generation and transfer in nuclear power reactors. Topics include reactor heat generation, steady-state and transient heat conduction in reactor fuel elements, boiling heat transfer and single and two-phase flow.

**NE(MAT) 525 NUCLEAR MATERIALS. Preq.: NE 409 or MAT 201, CI. 3(3-0) F.** Properties and selection of materials for nuclear steam systems and to radiation effects on materials. Implications of radiation damage to reactor materials and material problems in nuclear engineering. An overview of nuclear steam systems, crystal structure and defects, dislocation theory, mechanical properties, radiation damage, hardening and embrittlement due to radiation exposure and problems concerned with fission and fusion materials.

**NE 526 RADIOISOTOPE MEASUREMENT APPLICATIONS. Preq.: NE 401 or NE 520. 3(3-0) S.** Introducing the student to measurement applications using radioisotopes and radiation. Discussion of all major tracing, gauging and analyzer principles and treatment of several specific applications in detail. Objective is to familiarize student with design and analysis of industrial measurement systems using radioisotopes and/or radiation.

**NE 527 NUCLEAR ENGINEERING ANALYSIS. Preq.: NE 401 or NE 520. 3(3-0) S.** Fundamental material on: (1) numerical methods for solving the partial differential equations pertinent to nuclear engineering problems, (2) Monte Carlo simulation of radiation transport and (3) data and error analysis techniques including estimation of linear and nonlinear model parameters from experimental data.

**NE 528 PRINCIPLES OF FUSION REACTORS. Preq.: NE 401 or NE 520. 3(3-0) F.** Plasma concepts and fusion reactor design. Basics of thermonuclear reactions, charged particle collisions and radiation, plasma confinement, plasmas as fluids, formation and heating of plasmas and reactor concepts and design.

**NE 550 LABORATORY PROJECTS IN NUCLEAR ENGINEERING. Preq.: NE 521. 3(1-6) F.** Enhancement of laboratory skills that are pertinent to nuclear engineering research sought through projects that require the student to design the experiment, assemble equipment, carry out the measurements and analyze and

interpret data. Students work in groups of two and perform to completion two laboratory projects.

**NE(MAT) 573 COMPUTER EXPERIMENTS IN MATERIALS AND NUCLEAR ENGINEERING. 3(3-0) S.** (See materials science and engineering.)

**NE 580 PLASMA GENERATION AND DIAGNOSTICS LABORATORY. Preq.: NE 528 or PY 508 or PY 509. 3(2-3) F. Alt. yrs.** Experimental plasma generation and plasma diagnostic techniques. Lecture topics include high vacuum techniques, perturbing and non-perturbing probe techniques, and laser and emission spectroscopy. Laboratories utilize various methods of measuring plasma parameters discussed in lectures.

**NE 581 FUSION ENERGY ENGINEERING. Preq.: NE 528. 3(3-0) F. Alt. yrs.** Description and analysis of the technologies of devices necessary to produce fusion energy including vacuum technology, plasma heating and fueling, magnetics, special energy conversion, neutronics, materials, environment and safety. Stress upon design integration and the ensuing technological constraints.

**NE 591, 592 SPECIAL TOPICS IN NUCLEAR ENGINEERING I, II. Preq.: CI. 3(3-0) F,S.**

*FOR GRADUATES ONLY*

**NE 601 REACTOR THEORY AND ANALYSIS. Preqs.: NE 523, 527. 3(3-0) S. Alt. yrs.** Theoretical aspects of neutron diffusion and transport related to the design computation and performance analysis of nuclear reactors. Principal topics: a unified view of the neutron cycle including slowing down, resonance capture and thermalization; reactor dynamics and control; fuel cycle studies; and neutron transport methods. Background provided for research in power and test reactor analysis.

**NE(MA) 607 EXACT AND APPROXIMATE SOLUTIONS IN PARTICLE TRANSPORT THEORY. Preq.: MA 501 or MA 511. 3(3-0) S.** The method of elementary solutions used to solve exactly basic problems in neutron-transport theory and related topics. The development and use of $F_N$ method to establish concise approximate solutions in the realm of particle transport theory.

**NE 610 NUCLEAR REACTOR DESIGN CALCULATIONS. Preq.: NE 523. 3(3-0) S. Alt. yrs.** Application of the digital computer to problems in reactor core nuclear design. Study and exercise of available reactor core physics computer modules. Systems and programs used by industry for power reactor core design and core follow. Relevant analytic and numerical methods facilitates computer program development by the students.

**NE 611 RADIATION DETECTION. Preq.: NE 526. 3(2-2) F.** The advanced aspects of radiation detection such as computer methods applied to gamma-ray spectroscopy, absolute detector efficiencies by experimental and Monte Carlo techniques, the use and theory of solid state detectors, time-of-flight detection experiments and Mössbauer and other resonance phenomena.

**NE 612 THERMAL HYDRAULIC DESIGN CALCULATIONS. Preq.: NE 524. 3(3-0) F. Alt. yrs.** An advanced presentation of thermal-hydraulic analysis of nuclear power systems. Development of single phase and two-phase fluid flow equations, subchannel analysis, interphase phenomena and numerical solution methods relevant to design and safety analysis codes.

**NE 620 NUCLEAR RADIATION ATTENUATION. Preq.: NE 527. 3(3-0) F. Alt. yrs.** The physical theory and mathematical analysis of the penetration of neutrons, gamma-rays and charged particles. Analytical techniques include point kernels, transport theory, Monte Carlo and numerical methods. Digital computers employed in the solution of practical problems.

**NE 621 RADIATION EFFECTS ON MATERIALS. Preq.: NE 525. 3(3-0) F.** Interactions of radiation with matter, with emphasis on the physical effects. Discussion of current theories and experimental techniques. Annealing of defects, radiation induced changes in physical properties and effects in reactor materials.

**NE 631 REACTOR KINETICS AND CONTROL. Preq. NE 522. 3(3-0) S.** A study of the control of nuclear reactor systems. Development of basic control theory including the use of Bode, Nyquist and S-plane diagrams and state-variable methods. Analysis of reactor and reactor systems by these methods and development ofcontrol methods and optimum-control methods. Models of reactors and reactor-associated units, such as heat exchangers. Effects of non-linearities.

**NE 641 RADIOISOTOPE APPLICATIONS. Preq.: NE 526. 3(3-0) F.** Advanced principles and techniques of radioisotope applications. Radiotracer principles; radiotracer applications to engineering processes; radioisotope gauging principles; charged particle, gamma ray and neutron radioisotope gauges.

**NE 680 PLASMA ENGINEERING I. Preq.: NE 528 or equivalent. 3(3-0) S. Alt. yrs.** Fundamental behavior of plasmas as applied to controlled thermonuclear devices and other applications. Energy and particle transport in relevant plasmas. Single particle and collective effects detailed.

**NE 681 PLASMA ENGINEERING II. Preq.: NE 528 or equivalent. 3(3-0) S. Alt. yrs.** Continued study of fundamentals in areas of plasma equilibriums, wave

interactions, plasma heating, fueling, radiation and atomic physics. Stress upon numerical modelling of plasmas.

**NE 691, 692 ADVANCED TOPICS IN NUCLEAR ENGINEERING I, II. Preq.: CI. 3(3-0) F,S.** Recent developments in nuclear engineering theory and practice.

**NE 695 SEMINAR IN NUCLEAR ENGINEERING. 1(1-0) F,S.** Discussion of selected topics in nuclear engineering.

**NE 699 RESEARCH IN NUCLEAR ENGINEERING. Credits Arranged.** Individual research in the field of nuclear engineering.

# Nutrition

**Degrees Offered: Ph.D., M.S.**

**GRADUATE FACULTY**

*Professor* J. W. Spears, *Coordinator*
Box 7621, (919) 515-4008

*Professors:* L. S. Bull, G. L. Catignani, W. E. Donaldson, J. D. Garlich, W. M. Hagler Jr., R. W. Harvey, E. E. Jones, J. R. Jones, C. J. Lackey, J. F. Ort, K. R. Pond, A. H. Rakes, J. C. H. Shih, H. E. Swaisgood, L. W. Whitlow;
*Professors Emeriti:* L. W. Aurand, E. R. Barrick, E. S. Cofer, C. H. Hill, R. D. Mochrie, H. A. Ramsey, F. H. Smith, S. B. Tove, G. H. Wise;
*Associate Professors:* J. C. Allen, B. Alston-Mills, J. H. Eisemann, P. R. Ferket, R. C. Smart;
*Assistant Professors:* J. A. Hansen, B. A. Hopkins, J. W. McClellan, M. H. Poore;
*Visiting Assistant Professor:* S. L. Ash

The interdepartmental nutrition program consist of faculty from four departments (animal science, food science, poultry science and toxicology). Students reside and conduct research in one of these departments under the direction of an appropriate advisor. Research in the nutrition program may be conducted with a variety of species and at levels ranging from the molecular to the whole animal. Research programs are primarily in the area of nutritional biochemistry or experimental animal nutrition.

**Admission Requirement**
To be considered for admission, a student should have a B.S. or M.S degree in a science-related area.

**Master's Degree Requirements**
A minimum of 24 course credit hours is required.

**Doctoral Degree Requirements**
A minimum of 18 course credit hours is required.

**Student Financial Support**
Assistantships and fellowships are available on a competitive basis from the departments in which the advisor resides.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

NTR(ANS,PO) 415 COMPARATIVE NUTRITION.
NTR(AMS) 419 HUMAN NUTRITION IN HEALTH AND DISEASE.

*Associated courses related to nutrition are:*

FS 400 PRINCIPLES OF HUMAN NUTRITION.
FS 402 FOOD CHEMISTRY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**NTR(ANS) 516A,B,C,D ANIMAL NUTRITION RESEARCH METHODS. Preq.: BCH 451 or NTR(ANS) 415 or NTR(ANS) 419 or FS 400. 3(1-6) S.** Theory and practice of modern research techniques in ruminant and monogastric animal nutrition: NTR(ANS) 516A, nutritive evaluation of feedstuffs; NTR(ANS) 516B, biological evaluation of feeds and diets; NTR(ANS) 516C, blood and tissue analysis; NTR(ANS) 561D, forage and pasture evaluation. Students can register for any combination.

**NTR(FS) 530 HUMAN NUTRITION. 3(3-0) S. Alt. yrs.** (See food science.)

**NTR 590 TOPICAL PROBLEMS IN NUTRITION. Preq.: Grad. or sr. standing. 1-6 F,S.** Analysis of current problems in nutrition. Also entails the scientific appraisal and solution of a selected problem designed to provide training and experience in research.

*FOR GRADUATES ONLY*

**NTR 601 PROTEIN AND AMINO ACID METABOLISM. Preqs.: BCH 553, ZO 421, a 400-level nutrition course. 3(3-0) Even yrs.** Study of protein and amino acid metabolism, regulation, dietary requirements and techniques for their investigation in human and other animals.

**NTR(ANS,PO) 605 MINERAL METABOLISM. Preqs.: ANS(NTR,PO) 415 or BCH 553, BCH 451 and ZO 421. 3(3-0) F.** Requirements, function, distribution, absorption, excretion and toxicity of minerals in humans and domestic animals. Interactions between minerals and other factors affecting mineral metabolism or availability. Emphasis on mechanisms associated with mineral functions and the metabolic bases for the development of signs of deficiency.

**NTR(FS) 606 VITAMIN METABOLISM. 2(2-0) F. Even yrs.** (See food science.)

**NTR 608 ENERGY METABOLISM. Preqs.: BCH 553 and an introductory NTR course. 3(3-0) F.** Relationship of biochemical and physiological events within the cell, tissue, organ and system with the nutrient needs as sources of energy for productive animal life. Digestion, absorption and metabolism of energy sources. Presentation of processes of energy transformations within living structures in relation to energetics, biological oxidations, coupled reactions, anabolic and catabolic systems, metabolic control, partitioning and efficiency.

**NTR(ANS,PHY,VMS) 632 COMPARATIVE PHYSIOLOGY OF THE DIGESTIVE SYSTEM. 3(3-0) Every yr.** (See veterinary medical sciences.)

**NTR 690 ADVANCED SPECIAL PROBLEMS IN NUTRITION. 1-6 F,S.** Directed research in a specialized phase of nutrition designed to provide experience in research methodology and philosophy.

**NTR 699 RESEARCH IN NUTRITION. Credits Arranged. F,S.** Original research preparatory to the thesis for the M.S. or Ph.D. degree.

# Occupational Education

**Degrees Offered: Ed.D., M.S., M.Ed., Sixth-Year Certificate**

**GRADUATE FACULTY**

*Professor* D. A. Adams, *Head of the Department and Director of Graduate Programs*

Box 7801, (919) 515-2234, daadams@poe.coe.ncsu.edu
*Associate Professor* J. L. Flowers, ***Program Area Coordinator for Agricultural Education***
*Associate Professor* H. D. Akroyd, ***Program Area Coordinator for Health Occupations Teacher Education***
*Associate Professor* T. P. O'Brien, ***Program Area Coordinator for Marketing Education***
*Associate Professor* R. E. Peterson, ***Program Area Coordinator for Technology Education***

*Professor:* G. E. Moore;
*Professors Emeriti:* J. K. Coster, W. L. Cox Jr., D. M. Hanson, J. T. Nerden, D. W. Olson, C. C. Scarborough;
*Associate Professors:* V. W. DeLuca, W. J. Haynie III, L. R. Jewell, B. M. Kirby, B. Richards, R. E. Wenig;
*Associate Professors Emeriti:* C. D. Bryant, J. R. Clary, T. R. Miller;
*Assistant Professors:* W. J. Vander Wall;
*Assistant Professors Emeriti:* J. L. Crow, T. C. Shore Jr.

Course offerings or research facilities are available in the following areas: agricultural education, health occupations education, marketing education and technology education. In addition, the department offers advanced degrees in occupational education and courses leading to certification in the teaching of middle grades occupational exploration and for local vocational directors.

**Admission Requirements**
Applicants must submit a resume of work experience in addition to the general requirements. Application processes must be completed within six months of the date the application is received.

**Master's Degree Requirements**
The master's programs require a minimum of 36 semester hours of graduate work. Additional hours will be specified by the student's advisory committee for those who do not have a baccalaureate degree in an occupational education field. Students who elect the M.S. substitute the thesis for part of the course load. The Intermediate (Sixth-Year) Program requires a minimum of 60 semester hours of graduate work including the courses included in the master's program.

**Doctoral Degree Requirements**
A minimum of 90 semester hours of graduate work beyond the baccalaureate degree is required. Emphasis is placed on developing competencies, and students may be advised to supplement their course work with internships and/or other experiential activities.

**Student Financial Support**
A limited number of teaching and research assistantships are available. Out-of-state tuition remission may be available for one year to students with assistantships.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**EOE 501 PHILOSOPHY OF OCCUPATIONAL EDUCATION. Preq.: 12 hrs. professional ed. courses. 3(3-0) F.** An historical and philosophical investigation into the social and economic aspects of occupational education; an overview of the broad field of occupational education for youth and adults, with emphasis upon the trends and problems connected with the conduct of occupational education under federal and state guidance. An overview study of federal and state legislation pertaining to occupational education.

**EOE 503 CAREER/VOCATIONAL EDUCATION FOR THE HANDICAPPED. Preqs.: ECI 506 and EOE 501 or CI. 3(3-0) S.** Relevant definitions and current legislation and policies reviewed. Appropriate curriculum, methods and materials studied. Topic areas include program development, vocational evaluation, job placement and support services for the handicapped.

**EOE 505 CURRICULUM MATERIALS DEVELOPMENT. Preqs.: Grad. standing and EOE 501 or equivalent. 3(3-0) S.** Selection and organization of curricula and instructional materials in occupational education.

**EOE 506 COOPERATIVE OCCUPATIONAL EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F.** Individuals preparing to be directors, administrators or supervisors of occupational education programs at local, state and/or national levels. Emphasis on organization and operation of cooperative occupational education programs. Coverage of entire field of cooperative occupational education on secondary, postsecondary and adult levels with references to accepted essentials of cooperative education so details of planning, organization, establishment and operation of cooperative occupational programs practical and meaningful. Student visitations to existing quality programs in cooperative occupational education to study on-site conditions in specialized areas.

**EOE 510 CAREER EXPLORATION. Preq.: 12 hrs. professional ed. courses. 3(3-0) F,S,Sum.** For teachers in the public schools of North Carolina who teach in "Career Exploration" programs. Emphasis on the philosophy of career exploration, theories supporting career exploration, the place of exploration programs in the overall school curriculum, correlation of occupational information in academic subjects, sources of occupational information and its use and approaches to teaching in a career exploration program.

**EOE 512 ANALYSIS OF OCCUPATIONAL INFORMATION, TRENDS AND THE LABOR MARKET. Preq.: Six hrs. of professional ed. courses. 3(3-0) S.** Overview of federal, state and local sources of labor market information. Analysis of labor market concepts and applications for career exploration and decision making. Use of community surveys in vocational program planning.

**EOE 517 PRACTICUM IN OCCUPATIONAL EDUCATION. Preq.: Grad. standing or PBS status. 1-6 F,S.** Under a faculty-supervised practicum in an educational, industrial or governmental setting, the student participates in and analyzes activities associated with the planning, implementation and evaluation of instructional programs or services in vocational education. A unique plan developed by the student and approved by the supervisor.

**EOE 521 PLANNING PROGRAMS IN AGRICULTURAL EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) F.** Consideration of the need for planning programs in education; objectives and evaluation of community programs; use of advisory group; organization and use of facilities.

**EOE 522 OCCUPATIONAL EXPERIENCE IN AGRICULTURE. Preq.: Grad. standing or PBS status. 3(3-0) S.** A major and critical element in all programs of vocational education is the provision for appropriate student learning experiences in a real and simulated employment environment. Due to recent developments in education and agriculture, new and expanded concepts of occupational experience devised. Current research substantiates the need and desire of teachers of agriculture for assistance in implementing the new concepts. Designed not only to provide this aid but to develop a depth of understanding of the theoretical foundations underlying the new developments in occupational experiences to stimulate individual growth and creativity in implementing further developments.

**EOE 523 ADULT EDUCATION IN AGRICULTURE. Preq.: Grad. standing or PBS status. 3(3-0) F.** Designed to meet the needs of leaders in adult education. Opportunity to study some of the basic problems and values in working with adult groups. Attention given to the problem of fitting the educational program for adults into the public school program and other educational programs as well as to the methods of teaching adults.

**EOE 524 AGRICULTURAL OCCUPATIONS. Preq.: 12 hrs. professional ed. courses. 3(3-0) F.** The theory of education and work related to the expanding field of agricultural occupations. Career development in agricultural occupations associated with curriculum development needs. Occupational experience in agriculture in relation to the curriculum and the placement in agricultural occupations.

**EOE 532 HEALTH CARE DELIVERY SYSTEMS AND ENVIRONMENTS. Preqs.: Grad. standing and CI. 3(3-0) Alt. yrs.** Organization of the health care delivery system, services and resources. Focus on the major social, economic, political and professional factors contributing to shaping the system and influencing change. Organizations and environments analyzed in regard to the demand for health manpower and the implications for health occupations education.

**EOE 535 CURRICULUM AND INSTRUCTION IN THE ALLIED HEALTH PROFESSIONS. Preqs.: Advanced undergrad. or grad. standing and CI. 3(3-0) Alt. yrs.** A study of the elements of curriculum design and theoretical considerations for the development of curricula in the health occupations. Identification, analysis and evaluation of instructional strategies appropriate for clinical and classroom teaching.

**EOE 538 ISSUES AND TRENDS IN EDUCATION FOR THE ALLIED HEALTH PROFESSIONS. Preq.: Grad. standing or CI. 3(3-0) Alt. yrs.** An analysis of educational and social factors influencing change in health professions education. Emphasis on educational reform movements and legislation impacting the allied health professions.

**EOE 545 PROFESSIONAL DEVELOPMENT IN MARKETING EDUCATION. Preq.: Grad. standing or CI. 3(3-0) F. Alt. yrs.** The organizational and leadership structure in marketing education; strategies for increasing the effectiveness of local, state and national marketing education programs through organizational development and professional leadership.

**EOE 551 TECHNOLOGY EDUCATION: A DISCIPLINE. Preq.: Grad. standing or PBS status. 3(3-0) F. Alt. yrs.** Essential attributes of technology and the relationship between technology education and related disciplines. Analysis of the theory, models and literature and the constitution of technology education foundation. Synthesis of relevant research and identification of areas of needed research.

**EOE 552 CURRICULA FOR EMERGING TECHNOLOGIES. Preq.: Grad. standing or PBS status. 3(2-2) F. Alt. yrs.** Analysis of advanced technologies and development of instructional programs for technology education curricula in secondary schools. Technologies in production, transportation and communication.

**EOE 555 DEVELOPING AND IMPLEMENTING TECHNOLOGY EDUCATION. Preq.: Grad. standing or PBS status. 3(3-0) S. Alt.yrs.** Technology education curriculum trends, standards, design, implementation and management. Analysis of current curricular trends and development of strategies for implementation and management of technology education programs.

**EOE 558 TEACHING CREATIVE PROBLEM SOLVING. Preq.: Grad. standing or PBS status. 3(2-2) S. Alt. yrs.** Theories and research related to development of higher order thinking skills through design of appropriate technology-based learning activities for development of creative problem-solving abilities.

**EOE 565 ADVANCED TRADE ANALYSIS AND COURSE CONSTRUCTION. Preq.: 12 hrs. professional ed. courses. 3(3-0) F.** Principles and practices in analyzing occupations for the purpose of determining teaching content. Practice in the principles underlying industrial course organization based on occupational analysis. Instructional skills and technology, including course outlines, job sequences and the development of industrial materials and instructional schedules.

**EOE 597 SPECIAL PROBLEMS IN OCCUPATIONAL EDUCATION. Preq.: Grad. standing or PBS status. 1-3 F,S,Sum.** Designed to provide graduate students in education opportunity to study problem areas in professional education under the direction of a member of the graduate faculty.

**EOE 598 SPECIAL PROBLEMS IN OCCUPATIONAL EDUCATION. Preq.: Sr. standing, PBS status or grad. standing in OED. 1-6 F,S,Sum.** Guided independent or group study of current problems or topics in occupational education.

**EOE 599 RESEARCH PROJECTS IN OCCUPATIONAL EDUCATION. Preqs.: CI; ELP 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. The research chosen on the basis of individual students' interests and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**EOE 602 LAWS, REGULATIONS AND POLICIES AFFECTING OCCUPATIONAL EDUCATION. Preq.: EOE 501. 3(3-0) F. Alt. yrs.** A detailed study of legislation (national and state) applying directly to occupational education. Basic social issues and economic conditions which precipitated the legislation. A review of the organizational structure and policies under which national legislation was converted into programs of occupational education.

**EOE 609 SEMINAR IN OCCUPATIONAL EDUCATION. Preq.: EOE 501. 3(3-0) F,S.** A seminar-type course with topics selected each semester. Attention given to the broad concepts of occupational education as manifested in the Vocational Education Act of 1963 and its amendments. Problems and issues underlying the development and implementation of programs of occupational education at elementary, junior high, senior high and postsecondary levels.

**EOE 612 FINANCE, ACCOUNTING AND MANAGEMENT OF OCCUPATIONAL EDUCATION PROGRAMS. 3(3-0) S. Alt. yrs.** A study of the steps in financing a new occupational enterprise, following the determination of curriculum by area study. All financial transactions such as costs of operation, equipment purchase procedures and costs for construction investigated in detail.

**EOE 621 INTERNSHIP IN OCCUPATIONAL EDUCATION. Preqs.: Nine hrs. in grad. level courses and CI. 3-9 F,S,Sum.** Utilizing the participant-observer role, this course requires participation in selected educational situations with emphasis upon development of observational skills, ability to record relevant observations by means of written journals, skills in analyzing critical incidents and projection of events and consequences. The student required to develop possible alternative courses of action in various situations, select one of the alternatives and evaluate the consequences of the course of action selected.

**EOE 624 SUPERVISION IN AGRICULTURAL EDUCATION. Preq.: EOE 521. 3(3-0) S.** Organization, administration, evaluation and possible improvement of supervisory practice; theory, principles and techniques of effective supervision in agricultural education at different levels.

**EOE 637 PRACTICUM IN HEALTH OCCUPATIONS. Preqs.: 21 hrs. grad. work including EOE 535 and CI. 3(3-0) Alt. yrs.** Based upon the participants' professional objectives, a practicum in a teaching or an administrative context designed appropriately for the individual's particular discipline and area of function. Program designed by the student in cooperation with the preceptor and course instructor.

**EOE 645 MARKETING EDUCATION PROGRAM MANAGEMENT. Preq.: EOE 501. 3(3-0) F. Alt. yrs.** The management of secondary, post-secondary and industry-based marketing education programs; usage of a strategic planning model to improve and expand programs. Application of national and state models for marketing, curriculum, development and evaluation.

**EOE 655 TECHNICAL EDUCATION CURRICULUM. Preq.: IA 645. 3(3-0) F,S,Sum.** Technical education curriculum origins, analysis, organization, evaluation and revision. Subject matter deviation and classification applicable to all levels of instruction. Relationships among curriculum, philosophy and methodology.

**EOE 662 PLANNING AND ORGANIZING INDUSTRIAL AND TECHNICAL EDUCATION PROGRAMS. Preq.: EOE 512. 3(3-0) F.** Influences which impinge upon the development of programs of occupational education. Adequate opportunity provided to examine in detail steps that may be taken to analyze needs for

occupational education, to organize for its provision, to study its offerings and to evaluate its results.

**EOE 679 RESEARCH APPLICATION IN OCCUPATIONAL EDUCATION. Preq.: ELP 532. 3(3-0) F.** Methodology, application, analysis and synthesis of research in occupational education. A review of current occupational education studies, clustered by areas, made with attention to statistical techniques, data collecting, data handling, and the audience and impact of particular projects and research organizations. The class activities in research application designed to bridge the gap between the theories of research methodology and the student's independent research projects.

**EOE 698 ADVANCED SPECIAL PROBLEMS IN OCCUPATIONAL EDUCATION. Preq.: Master's degree in vocational field or CI. 1-6 F,S,Sum.** Guided independent or group study of advanced problems, issues or developments in planning, organizing, teaching, administering and/or evaluating occupational education programs.

**EOE 699 THESIS AND DISSERTATION RESEARCH. Preqs.: 15 hrs. of professional ed. courses; CI. Credits Arranged. F,S,Sum.** Individual research on a thesis or dissertation problem.

# Operations Research

**Degrees Offered: Ph.D., M.S., Master of Operations Research**

**GRADUATE FACULTY**

*Professor* S. C. Fang, *Chair and Program Director*
Box 7913, (919) 515-2350, Fax: (919) 515-5281, fang@eos.ncsu.edu

*Professors:* B. B. Bhattacharyya, J. W. Bishir, W. Chou, J. C. Dunn, S. E. Elmaghraby, R. M. Felder, W. S. Galler, H. J. Gold, R. E. Hartwig, T. J. Hodgson, D. M. Holthausen Jr., C. T. Kelley, C. J. Maday, C. D. Meyer, A. A. Nilsson, H. L. Nuttle, H. G. Perros, E. L. Peterson, S. D. Roberts, W. J. Stewart, M. W. Suh, J. R. Wilson;
*Professor Emeriti:* N. J. Rose;
*Associate Professors:* Y. Fathi, T. L. Honeycutt, R. E. King, T. W. Reiland, J. Rodriguez, J. P. Roise, C. D. Savage, C. E. Smith, M. F. M. Stallmann;
*Adjunct Associate Professor:* H. J. Uyttenhove;
*Assistant Professors:* H. Damerdji, H. T. Tran, I. Viniotis

Operations research is a graduate program of an interdisciplinary nature, governed by an administrative board and the program committee, and administered through the office of the program director.

### Admission Requirements

Applications for a master's degree program are accepted majorly from undergraduate majors in mathematical sciences and engineering. Applications for the doctoral degree program are accepted normally from holders of a master's degree from a recognized program (preferably an OR program or one of its allied fields) who show promise of success at the Ph.D. level, as indicated by previous academic performance and independent research.

A score on the Graduate Record Examination (GRE) that is less than two years old is required if financial assistance is sought or if the student is transferring from another doctoral program.

### Master's Degree Requirements

The Master of Operations Research degree is a terminal graduate degree for students who seek careers as OR practitioners in either the private or public sector. The M.S. degree is designed to prepare students for careers as research and development.

### Doctoral Degree Requirements

The Ph.D. degree is intended for students to be a research scientist in industry or an academician. Please consult the OR brochure for more details of degree requirements.

### Student Financial Support

Both teaching and research assistantships are available to qualified applicants. Outstanding students who are U.S. citizens and will been enrolled in the NCSU Graduate School for the first time are eligible for the Engineering Dean's Graduate Fellowship Program.

### *CENTRAL COURSES*
### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**OR 501 INTRODUCTION TO OPERATIONS RESEARCH. Preqs.: MA 421 or ST 421 or ST 371 and ST 372. 3(3-0) F,S.** OR Approach: modeling, constraints, objective and criterion. The problems of multiple criteria, optimization, model validation and systems design. OR Methodology: mathematical programming; optimum seeking; simulation, gaming; heuristic programming. Examples, OR Applications: theory of inventory; economic ordering under deterministic and stochastic

demand. The production smoothing problem; linear and quadratic cost functions. Waiting line problems: single and multiple servers with Poisson input and output. The theory of games for two-person competitive situations. Project management through PERT-CPM.

**OR 502 INTRODUCTION TO SYSTEMS THEORY. Preqs.: CSC (MA) 322, MA 341, ST 371. 3(3-0) F.** Introduction to the modeling of systems and their dynamics in a variety of contexts: systems identification, controllability and observability; operational methods and their use in the modeling; analysis and synthesis of systems; optimization.

**OR(MA) 504 INTRODUCTION TO MATHEMATICAL PROGRAMMING. Preqs.: MA 242, MA 405. 3(3-0) S.** The basic concepts of linear, nonlinear and dynamic programming theory. Not for majors in OR at the Ph.D. level.

**OR(IE,MA) 505 LINEAR PROGRAMMING. 3(3-0) F,S.** (See industrial engineering.

**OR 506 ALGORITHMIC METHODS IN NONLINEAR PROGRAMMING. Preqs.: MA 301, MA 405, knowledge of computer language, such as FORTRAN or PL1. 3(3-0) S.** Introduction to methods for obtaining approximate solutions to unconstrained and constrained minimization problems of moderate size. Emphasis on geometrical interpretation and actual coordinate descent, steepest descent, Newton and quasi-Newton methods, conjugate gradient search, gradient projection and penalty function methods for constrained problems. Specialized problems and algorithms treated as time permits.

**OR(IE) 509 DYNAMIC PROGRAMMING. Preqs.: MA 405, ST 421. 3(3-0) S.** An introduction to the theory and computational aspects of dynamic programming and its application to sequential decision problems.

**OR 520 THEORY OF ACTIVITY NETWORKS. Preqs.: OR 501, OR(IE,MA) 505. 3(3-0) S. Alt. yrs.** Graph theory and network theory. The theory underlying (1) deterministic activity networks (CPM): optimal time-cost trade offs; the problem of scarce resources; (2) probabilistic activity networks (PERT): critical evaluation of the underlying assumptions; (3) generalized activity networks (GERT, GAN): applications of signal flow graphs and semi-Markov process to probabilistic branching; relation to the theory of scheduling.

**OR(CHE) 527 OPTIMIZATION OF ENGINEERING PROCESSES. Preqs.: CHE 451 or OR 501, FORTRAN programming. 3(3-0) F.** The formulation and solution of process optimization problems, with emphasis on nonlinear programming

techniques. Computer implementation of optimization algorithms and structuring of process models to increase computational efficiency.

**OR(E,MA) 531 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL I. Preqs.: MA 301, MA 405. 3(3-0) F.** Modeling, analysis and control of linear discrete-time and continuous-time dynamical systems. State space representations and transfer methods. Controllability and observability. Realization. Applications to biological, chemical, economic, electrical, mechanical and sociological systems.

**OR(IE) 561 QUEUES AND STOCHASTIC SERVICE SYSTEMS. Preq. MA 421. 3(3-0) F.** General concepts of stochastic processes introduced. Poisson processes, Markov processes and renewal theory presented. These then used in the analysis of queues, starting with a completely memoryless queue to one with general parameters. Applications to many engineering problems considered.

**OR(CSC,ECE,IE) 562 COMPUTER SIMULATION TECHNIQUES. 3(3-0) F.** (See computer science.)

**OR(BMA,ST) 575 DECISION ANALYTIC MODELING. 4(3-2) F. Alt. yrs.** (See statistics.)

**OR(CSC,MA) 585 GRAPH THEORY. Preq.: MA 231 or 405. 3(3-0) F.** Basic concepts of graph theory. Trees and forests. Vector spaces associated with a graph. Representation of graphs by binary matrices and list structures. Traversability. Connectivity. Matchings and assignment problems. Planar graphs. Colorability. Directed graphs. Applications of graph theory with emphasis on organizing problems in a form suitable for computer solution.

**OR(IE,MA) 586 NETWORK FLOWS. Preq.: OR(IE,MA) 505 or equivalent. 3(2-2) S. Alt. yrs.** Problems of flows in networks. These problems include the determination of the shortest chain, maximal flow and minimal cost flow in networks. The relationship between network flows and linear programming developed as well as problems with nonlinear cost functions, multi-commodity flows and the problem of network synthesis.

**OR 591 SPECIAL TOPICS IN OPERATIONS RESEARCH. Preq.: CI. 1-3 F,S,Sum.** Individual or small group studies of special areas of OR which fit into the students' programs of study and which may not be covered by other OR courses. Furthermore, the course serves as a vehicle for introducing new or specialized topics at the introductory graduate level.

**OR 592 PRACTICUM IN OPERATIONS RESEARCH. Preqs.: OR 501, OR 505, OR 509 and OR 561. 1-3 F,S.** Practicum in problem solving in industry

applying applicable OR methodologies. Practical experience in diagnosing and solving problems in operational systems at either an industrial site or at NCSU.

*FOR GRADUATES ONLY*

**OR 605 LARGE SCALE LINEAR PROGRAMMING SYSTEMS. Preqs.: OR 505 and FORTRAN programming experience. 3(3-0) Alt. S.** Specialized algorithms for efficient solution of large scale LP problems. Parametric programming, bounded variable algorithms, generalized upper bounding, decomposition matrix factorization and sparse matrix techniques. Emphasis on gaining firsthand practical experience with current computer codes and computational procedures.

**OR(MA,ST) 606 NONLINEAR PROGRAMMING. Preq.: OR (IE, MA) 505. 3(3-0) S.** An advanced mathematical treatment of the analytical and algorithmic aspects of finite dimensional nonlinear programming. A examination of the structure and effectiveness of computational methods for unconstrained and constrained minimization. Special attention directed toward current research and recent developments in the field.

**OR 609 ADVANCED DYNAMIC PROGRAMMING. Preqs.: OR 509, MA 541. 3(3-0) F. Alt. yrs.** Measure theoretic concepts, review of finite state Markov processes, theory of Markovian programming, discrete decision processes, continuous time dynamic programming, relation to calculus of variation and the Maximum Principle. Emphasis throughout on recent theoretical development in the field.

**OR (BMA,MA,ST) 610 STOCHASTIC MODELING. 3(3-0) S. Alt. yrs.** (See biomathematics.)

**OR(BMA) 611 SYSTEM MODELING THEORY. 3(3-0).** (See biomathematics.)

**OR(IE) 612 ADVANCED SCHEDULING AND ROUTING. 3(3-0) F. Alt. yrs.** (See industrial engineering.)

**OR(MA) 614 INTEGER PROGRAMMING. Preqs.: MA 405, OR(MA,IE) 505; Coreq.: Some familiarity with computers (*e.g.*, CSC 111). 3(3-0) S. Alt. yrs.** General integer programming problems and principal methods of solving them. Emphasis on intuitive presentation of ideas underlying various algorithms rather than detailed description of computer codes. The students have some "hands on" computing experience that should enable them to adapt the ideas presented in the course to integer programming problems they may encounter.

**OR(MA) 629 VECTOR SPACE METHODS IN SYSTEM OPTIMIZATION. Preqs.: MA 405, 511 or equivalent. 3(3-0) F.** Algebraic and function-analytic con-

cepts used in system modeling and optimization: vector space, linear mappings, spectral decomposition, adjoints, orthogonal projection, quality, fixed points and differentials. Geometric insight. Least square optimization of linear systems, minimum norm problems in Banach space, linearization in Hilbert space, iterative solution of system equations and optimization problems. Applications in operations research and system engineering including control theory, mathematical programming, econometrics, statistical estimation, circuit theory and numerical analysis.

**OR(E,MA) 631 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL II. Preq.: OR(E,MA) 531. 3(3-0) S. Alt. yrs.** Stability of equilibrium points for nonlinear systems. Liapunov functions. Unconstrained and constrained optimal control problems. Pontryagin's maximum principle and dynamic programming. Computation with gradient methods and Newton methods. Multidisciplinary applications.

**OR(IE) 662 STOCHASTIC SIMULATION DESIGN AND ANALYSIS. 3(3-0) S.** (See industrial engineering.)

**OR 691 SPECIAL TOPICS IN OPERATIONS RESEARCH. Preqs.: OR 501, OR(IE,MA) 505. 3(3-0) F,S,Sum.** The purpose of this course is to allow individual students or small groups of students to take on studies of special areas in OR which fit into their particular program and which may not be covered by other OR courses. The work directed by a qualified faculty member and in some instances by visiting professors. The subject matter in any year dependent on the students and the faculty members.

**OR(IE,MA) 692 SPECIAL TCPICS IN MATHEMATICAL PROGRAMMING. 3(3-0) F,S,Sum.** (See industrial engineering.)

**OR 695 SEMINAR IN OPERATIONS RESEARCH. Preq.: Enrollment in OR as a major or minor. 1(1-0) F,S.** Seminar discussion of operations research problems. Case analyses and reports. Graduate students with minors or majors in operations research expected to attend throughout the period of their residence.

**OR 699 PROJECT IN OPERATIONS RESEARCH. Preq.: Variable. 1-3 F,S,Sum.** Individual research by graduate students minoring and majoring in operations research. Research may be done under the operations research faculty member meeting the interest need of the student.

## *SUGGESTED COGNATE COURSES*

Cognate courses are courses that are often included in OR programs of study, but which carry other departmental designations. They cover subject matter closely related to OR, and provide additional insight into the theory or application of OR

methodology. Students may include cognate courses in their own programs of study with the consent of their faculty advisor.

BMA(MA,ST) 571, 572 BIOMATHEMATICS I & II
CHE 525 CHEMICAL PROCESS CONTROL
CE 575 CIVIL ENGINEERING SYSTEMS
CSC 505 DESIGN AND ANALYSIS OF ALGORITHMS
CSC(MA) 529, 530 NUMERICAL ANALYSIS I & II
CSC(ECE) 671 ADVANCED COMPUTER PERFORMANCE MODELLING
ECG(BUS) 650 ECONOMIC DECISION THEORY
ECG(ST) 651 ECONOMETRICS
ECG(ST) 652 TOPICS IN ECONOMETRICS
ECE 516 FEEDBACK CONTROL SYSTEMS
ECE 521 DIGITAL COMPUTER TECHNOLOGY AND DESIGN
ECE 691 SPECIAL STUDIES IN ELECTRICAL ENGINEERING
IE 523 PRODUCTION PLANNING, SCHEDULING AND INVENTORY CONTROL
IE 547 RELIABILITY ENGINEERING
IE 548 QUALITY ENGINEERING
IE 611 THE DESIGN OF PRODUCTION SYSTEMS
MA(ST) 541 THEORY OF PROBABILITY
MA(ST) 542 INTRODUCTION TO STOCHASTIC PROCESSES
MA(ST) 617, 618 MEASURE THEORY AND ADVANCED PROBABILITY
MA 622 LINEAR TRANSFORMATIONS AND MATRIX THEORY
MA 623 THEORY OF MATRICES AND APPLICATIONS
MA 647 FUNCTIONAL ANALYSIS I
MA 685 SPECIAL TOPICS IN NUMERICAL ANALYSIS
ST 518 APPLIED TIME SERIES ANALYSIS
ST 583 INTRODUCTION TO STATISTICAL DECISION THEORY
ST 613, 614 TIME SERIES ANALYSIS I & II

# Parks, Recreation and Tourism Management

**Degrees Offered: M.S., Master of Parks, Recreation and Tourism Management, Master of Natural Resources Administration**

## GRADUATE FACULTY

*Professor* P. S. Rea, *Head of the Department*
*Associate Professor* B. E. Wilson, *Director of Graduate Programs*
Box 8004, (919) 515-3276, beth_wilson@ncsu.edu

*Professors:* H. A. Devine, A. Lumpkin, C. D. Siderelis, M. R. Warren Jr., J. D. Wellman;
*Professors Emeriti:* T. I. Hines, W. E. Smith, R. E. Sternloff;
*Associate Professors:* L. D. Gustke, S. L. Kirsch, C. S. Love;
*Adjunct Associate Professor:* H. K. Cordell;

*Associate Professors Emeriti:* G. A. Hammon, L. L. Miller;
*Assistant Professors:* G. L. Brothers, R. L. Moore

The master's degree provides students the opportunity to develop and enhance their critical understanding of both the conceptual foundations of parks, recreation and tourism management and the procedures of systematic inquiry and critical problem solving as applied to planning and management issues. The department offers educational opportunities and resources for the preparation of professionals concerned with planning, organizing, managing and directing parks, recreation and tourism programs, areas and facilities. The general emphasis areas at the master's level include: parks and recreation management, tourism development and management, geographic information systems, recreational sport management and natural resource recreation management.

### Admissions Requirements

Scores from the Graduate Record Examination (GRE) or from a comparable substitute examination are required for admission.

### Master's Degree Requirements

The M.S. degree requires 30 hours of course work, of which 4 hours is a master's thesis. The M.PRT. requires a minimum of 36 hours of course work, of which 2 hours is a master's research project. For both degrees, the required core courses are limited to 11 hours for a student with a background in recreation and 17 for a student without such a background. A minor is optional with both degrees. The department offers a co-major with public administration which includes 39 hours of course work.

### Student Financial Support

Graduate assistantships and internships are available to students in this program on a competitive basis.

### *SELECTED ADVANCED UNDERGRADUATE COURSES*

PRT 420 RESORT MANAGEMENT AND OPERATIONS.
PRT 438 RECREATION FOR SPECIAL POPULATIONS.
PRT 442 RECREATION AND PARK INTERPRETIVE SERVICES.
PRT 443 APPLIED RECREATION AND PARK INTERPRETIVE SERVICES.
PRT 451 PRINCIPLES OF RECREATION PLANNING AND FACILITIES DEVELOPMENT.
PRT 453 ADMINISTRATIVE POLICIES AND PROCEDURES.
PRT 454 RECREATION AND PARK FINANCE.
PRT 480 RECREATION ANALYSIS AND EVALUATION.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PRT 500 THEORIES OF LEISURE AND RECREATION. 3(3-0) F.** Analysis of leisure and recreation and a study of their origin and development as revealed by behavioral patterns. Interpretation of the influence and social significance of leisure and recreation concepts on contemporary American culture and their implications on future recreation thought and action.

**PRT 501 RESEARCH METHODS IN RECREATION. Preqs.: Grad.-level statistics. 3(3-0) S.** Examination and understanding of advanced scientific investigative methods in their application toward explaining recreation and leisure behavioral phenomena and for the resolution of recreation management problems.

**PRT (EBG) 503 ECONOMICS OF RECREATION. Preq.: EB 301 or 401. 3(3-0) F.** The principal emphasis on identity and importance of economic information for planning. Examination of the market mechanism and government as they affect and interact to affect allocation of resources to recreation, distribution of recreation services and behavior of recreationists. Other topics include demand analysis, economics of planning, cost/benefit analysis, secondary economic impacts, public decision making, externalities, public finance and supply considerations in urban and rural recreation situations.

**PRT 504 RECREATION AND PARK DATA SYSTEMS. Preqs.: CSC 200, ST 311. 3(3-0) S.** Analysis of such topics as the identification of main-tenance, operation and service delivery work areas in recreation and park agencies for system applications; development of reporting structures; recreation and main-tenance activity scheduling; system monitoring; system implementation evaluation.

**PRT 505 QUANTITATIVE TECHNIQUES FOR RECREATION AND NATURAL RESOURCE MANAGEMENT. Preqs.: CSC 200, ST 311. 3(3-0) S.** Application of specific management science techniques to recreation and natural resource management. Gravity, optimization, simulation and other modeling procedures discussed through a case study approach. The primary emphasis of the course on exposure to techniques and problem formulation rather than development of theoretical bases or computational methodologies.

**PRT 510 THEORIES OF SPORT AND FITNESS PROGRAM MANAGEMENT. Preq.: PRT 358. 3(3-0) Every 3rd semester.** The development of a theoretical basis for sport and physical fitness program management. Study of the sociological, psychological, political and economic considerations of sport and fitness. Stress on values and motivation of sport and fitness.

**PRT 511 FOUNDATIONS FOR SPORT, EXERCISE AND FITNESS PROGRAM MANAGEMENT. Preq.: PRT 358. 3(3-0) Every 3rd sem.** The development of a scientific basis for sport, exercise and fitness program development. Characteristics of human growth, development and aging studied as they relate to participation in physical activity. Emphasis on physical fitness evaluation and program development.

**PRT 512 RECREATIONAL SPORT MANAGEMENT. Preq.: PRT 358. 3(3-0) Every third sem.** An overview and analysis of key managerial concerns of the sports enterprise. Stress on problems and issues unique to the sports-oriented service or business. Emphasis on recreational sports settings.

**PRT 520 CONCEPTS OF TRAVEL AND TOURISM. Preq.: Grad. standing. 3(3-0) S.** Theory and research in travel and tourism, including conceptual foundations, research problems and methods and the application of research results to strategic tourism development and marketing.

**PRT 562 INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS. Preq.: CFR 134 or equivalent. 3(3-0) S.** Application of computers and associated analytic technology to problems in natural resource planing and management. Automated mapping and display procedures in land use decision making and involves the student in first-hand experiences with a number of different procedures and computer hardware configurations. Not a general course in computer graphics and deals exclusively with natural resource management applications.

**PRT 563 TECHNICAL ISSUES IN GEOGRAPHIC INFORMATION SYSTEMS. Preq.: PRT 562. 3(3-0) F.** GIS algorithms, data structures and analysis of error in the context of natural resource management applications. Student development of simple problems to perform overlays, intersections and area measurements and learn to identify sources of error, appropriate methods for spatial data management and advanced GIS application techniques.

**PRT 580 CURRENT ISSUES IN RECREATION RESOURCES. Preqs.: Grad. standing, CI. 1-3 F,S.** Current issues in recreation resources. Course content varies as changing conditions require new approaches to emerging problems

**PRT 591 RECREATION RESOURCES PROBLEMS. Preq.: Advanced undergrad. or grad. status. 1-4 F,S.** Assigned or selected problems in the field of recreation administration, planning, supervision, maintenance, operations, financing or program. Special research problems selected on basis of interest of students and supervised by members of the graduate faculty.

**PRT 595 SPECIAL TOPICS IN RECREATION RESOURCES. Preqs.: Grad. standing, CI. 1-3 F,S.** Special topics in various aspects of recreation resources developed under direction of a graduate faculty member on a tutorial basis. Subjects offered under this course listing also used to test and develop new courses.

*FOR GRADUATES ONLY*

**PRT 663 APPLICATION ISSUES IN GEOGRAPHIC INFORMATION SYSTEMS. Preq.: PRT 563. 3(3-0) S.** Operation and management issues related to GIS use in natural resource organizations. Issues in proposing and implementing GIS through case study analyses and experimental project planning including social and legal impacts, cost and benefit assessments, institutional constraints to implementation, benchmarks, proposal development, education concerns, and planning for technological advances.

**PRT 664 ADVANCED STUDY IN GEOGRAPHIC INFORMATION SYSTEMS. Preq.: PRT 563. 3(3-0) S. Alt. yrs.** Research and application activities in GIS. Individualized study of a major topic related to student's primary field of study of these topics utilizing GIS capabilities with special emphasis on complex spatial analyses. Projects must benefit significantly from the use of GIS methods. Development of sophisticated skills, approaches and strategies directly relevant to their field. Oral presentations and written report required.

**PRT 675 FIELD STUDIES IN RECREATION. Preq.: Minimum of nine hrs. of grad. credit. 1-4 F,S,Sum.** Experience in applying analytical methods to administrative, managerial and planning problems in providing recreation and park opportunities. Completion of an evaluation project or analytical study for the practicum agency required.

**PRT 690 RECREATION MANAGEMENT SEMINAR I. Preqs.: PRT 500, 501. 2(0-4) F.** Research and theories of (1) marketing, (2) case law and liability and (3) personnel practices as they relate to the management of recreation resources.

**PRT 691 RECREATION MANAGEMENT SEMINAR II. Preqs.: PRT 500, PRT 501. 2(0-4) S.** Research and theories of (1) planning and development, (2) financing and (3) maintenance management of recreation resources.

**PRT 692 ADVANCED PROBLEMS IN RECREATION. Preq.: Twelve hrs. of PRT courses. Credits Arranged. F,S.** Directed research in a specialized phase of recreation other than a thesis problem.

**PRT 696 SEMINAR IN RECREATION RESEARCH. Preq. or coreq.: PRT 501. 1(2-0) S.** Research studies, scientific articles and progress reports on research effects presented and critically evaluated. Each student pursuing a graduate degree expected to take this offering twice for one hour of credit each time.

**PRT 699 RESEARCH IN RECREATION. Preq.: Twelve hrs. of PRT courses. Credits Arranged. F,S.** Original research preliminary to writing a master's thesis.

# Physics

**Degrees Offered: Ph.D., M.S.**

## GRADUATE FACULTY

*Professor* R. R. Patty, ***Head of the Department***
*Professor* G. E. Mitchell, ***Director of Graduate Programs***
Box 8202, (919) 515-2521, gary_mitchell@ncsu.edu

***University Professor:*** G. Lucovsky

***Professors:*** D. E. Aspnes, J. Bernholc, K. T. Chung, S. R. Cotanch, W. R. Davis, R. E. Fornes, C. R. Gould, D. G. Haase, C. E. Johnson, K. L. Johnston, G. H. Katzin, F. Lado Jr., J. D. Memory, J. R. Mowat, R. J. Nemanich, M. A. Paesler, J. Y. Park, J. S. Risley, D. E. Sayers, J. F. Schetzina, P. J. Stiles, D. R. Tilley;
***Professors Emeriti:*** W. O. Doggett, G. L. Hall, A. W. Jenkins Jr., E. R. Manring, A. C. Menius Jr., L. W. Seagondollar;
***Associate Professors:*** G. C. Cobb Jr., J. W. Cook Jr., D. C. Ellison, C. Ji, M. A. Klenin, G. W. Parker III, S. P. Reynolds;
***Adjunct Associate Professor:*** J. F. Shriner Jr.;
***Assistant Professors:*** H. Ade, R. Beichner, J. M. Blondin, E. F. Moore, C. M. Roland;
***Adjunct Assistant Professor:*** L. S. Plano

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** J. M. Danby, R. M. Kolbas, J. Narayan, D. L. Ridgeway, E. C. Theil;
***Associate Professor:*** L. K. Norris

Research opportunities are available in the following areas: astrophysics, atomic and molecular physics, condensed matter physics, nuclear physics and physics education.

**Admission Requirements**
Bachelor's degree in Physics (or the equivalent) and the GRE Advanced test in physics.

**Doctoral Degree Requirements**
Six semesters beyond the baccalaurate; core physics courses 521, 581, 582, 583, 585, 586.

**Student Financial Support**
Graduate teaching assistantships are available for new and continuing students; research assistantships are normally available only to continuing students.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

PY 401, 402 QUANTUM PHYSICS I, II.
PY 411, 412 MECHANICS I, II.
PY 413 THERMAL PHYSICS.
PY 414, 415 ELECTROMAGNETISM I, II.
PY 441 SPACETIME PHYSICS.
PY 451 ELECTRONICS FOR PHYSICISTS.
PY 452 ADVANCED PHYSICS LABORATORY.
PY 499 SPECIAL PROBLEMS IN PHYSICS.

*FOR GRADUATE AND ADVANCED UNDERGRADUATES*

**PY 506 NUCLEAR AND SUBATOMIC PHYSICS. Preqs.: PY 203 or 407; PY 412. 3(3-0) F.** Nuclear and subatomic phenomena: properties of nuclear radiations and detectors, accelerators, nuclear forces and nuclear structure, elementary particles, fundamental symmetries and conservation laws.

**PY 507 ELEMENTARY PARTICLE PHYSICS. Preqs.: PY 401 and PY 506. 3(3-0) S.** The fundamental symmetries and dynamics of quarks and leptons. The Standard Model, Dirac equation, Feynman rules in QED and QCD, the Higgs mechanism and electroweak unification.

**PY 508 ION AND ELECTRON PHYSICS. Preq.: PY 414. 3(3-0) F.** Charged particle dynamics, introduction to plasma physics, processes in ionized gases, electron emission and the physics of electron beams.

**PY 509 PLASMA PHYSICS. Preq.: PY 414. 3(3-0) F.** The individual and collective motion of charged particles in electric and magnetic fields and through ionized gases.

**PY(NE) 511 NUCLEAR PHYSICS FOR ENGINEERS. Preq.: PY 410. 3(3-0) F.** The properties of atomic nuclei, of nuclear radiations and of the interaction of nuclear radiation with matter. Emphasis on the principles of modern equipment and techniques of nuclear measurement and their application to practical problems.

**PY 516 PHYSICAL OPTICS. Preq.: PY 415. 3(3-0) F.** Physical optics with the major emphasis on the wave properties of light. Boundary conditions, interference and diffraction, optics of thin films, fiber optics and applications to absorption, scattering and laser operation. A background in Maxwell's equations and vector analysis required.

**PY 517 ATOMIC AND MOLECULAR PHYSICS. Preqs.: PY 401, 412. 3(3-0) S.** The quantum mechanical treatment of structure and spectra for atoms and molecules. The hydrogen atom, helium atom, multielectron atoms, selection rules, diatomic and simple polyatomic molecules and nuclear magnetic resonance spectroscopy.

**PY 521 STATISTICAL PHYSICS I. Preqs.: PY 401, PY 413. 3(3-0) S.** Kinetic theory and equilibrium statistical mechanics, both classical and quantum; applications of the techniques developed to various ideal models of noninteracting particles.

**PY 525 COMPUTATIONAL PHYSICS. Preqs.: MA 341, PY 411, PY 414. 3(3-0) F.** Computational approach to physics problem solving using standard software relevant for physicists. Electrostatic potentials, data analysis, Monte Carlo simulations, Fourier optics, particle orbits, Schrodinger's equation. Examples and assignments for each topic chosen to complement other physics courses.

**PY 531 ADVANCED PLACEMENT PHYSICS FOR SECONDARY SCHOOL TEACHERS. Preq.: Teaching certificate. 6(6-0) Sum.** A preparation for teaching advanced placement physics to high school students. A review of the physics content on the AP curriculum and discussion of teaching techniques, demonstrations and laboratories for use in such a program.

**PY 543 ASTROPHYSICS. Preqs.: PY 203 or 407; PY 411. 3(3-0) S.** The basic physics necessary to investigate, from observational data, the internal conditions and evolution of stars. The formation and structure of spectral lines, methods of energy generation and transport, stellar structure, degeneracy, white dwarfs and neutron stars.

**PY(ECE) 552 INTRODUCTION TO THE STRUCTURE OF SOLIDS. Preq.: PY 401. 3(3-0) S.** Basic considerations of crystalline solids, metals, conductors and semiconductors.

**PY 553 INTRODUCTION TO THE STRUCTURE OF SOLIDS II. Preq.: PY 552 or equivalent. 3(3-0) F.** A study of the properties of semiconductors, superconductors, magnets, ferroelectrics and crystalline defects and dislocations.

**PY(MA) 555 MATHEMATICAL INTRODUCTION TO CELESTIAL MECHANICS. 3(3-0) F.** (See mathematics.)

**PY(MA) 556 ORBITAL MECHANICS. 3(3-0) S.** (See mathematics.)

**PY 561 ELECTRONICS FOR PHYSICISTS. Preq.: Grad. standing. 3(1-4) S.** Analog and digital electronics laboratory course serving as an introduction to the use of modern instrumentation required for experimental research in physics. Bipolar and field effect transistors, operational amplifiers, oscillators, power supplies, analog-digital and digital-analog conversion and digital logic circuits.

**PY 581, 582 QUANTUM MECHANICS I, II. Preqs.: MA 512; PY 411 or 414; grad. standing or permission of the Director of Grad. Programs. 3(3-0) F,S.** Fundamental concepts and formulations, including interpretation and techniques, and the application of theory to simple physical systems, such as the free particle, the harmonic oscillator, the particle in a potential well and central force problems. Approximation methods, identical particles and spin, transformation theory, symmetries and invariance, and an introduction to quantum theory of scattering and angular momentum.

**PY 583 ADVANCED CLASSICAL MECHANICS I. Preqs.: MA 512, PY 412, PY 414; grad. standing or permission of the Director of Grad. Programs. 3(3-0) F.** An introduction to theoretical physics in preparation for advanced study. Emphasis on classical mechanics, special relativity and the motion of charged particles. Variational principles, Hamiltonian dynamics and the canonical transformation theory, structure of the Lorentz group and elementary dynamics of unquantized fields.

**PY 585, 586 ADVANCED ELECTRICITY AND MAGNETISM I, II. Preqs.: PY 415; grad. standing or permission of the Director of Grad. Programs. 3(3-0) F,S.** Techniques for the solution of potential problems, development of Maxwell's equations; wave equations, energy, force and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges.

**PY 590 SPECIAL TOPICS IN PHYSICS. Preq.: Consent of department. Credits arranged. F,S.** Investigations in physics under staff guidance. May consist of literature reviews, experi mental or theoretical projects or special topics lectures.

*FOR GRADUATES ONLY*

**PY 611 ADVANCED QUANTUM MECHANICS I. Preqs.: MA 512, PY 582. 3(3-0) F.** The relativistic quantum theory of Dirac particles and the positron. Second quantization technique and its application to many-body problems, radiation theory and quantization of the electromagnetic field.

**PY 612 ADVANCED QUANTUM MECHANICS II. Preq.: PY 611. 3(3-0) S.** A general propagator treatment of Dirac particles, photons, and scalar and vector mesons. Applications of Feynman graphs and rules illustrating basic tech-niques employed in the treatment of electromagnetic, weak and strong interactions. Renormalization theory, the effects of radiative corrections and aspects of the general Lorentz covariant theory of quantized fields also considered.

**PY 622 STATISTICAL PHYSICS II. Preq.: PY 521. 3(3-0) F.** A continuation of PY 521, with emphasis on the static and dynamic properties of real (interacting) systems. The equilibrium theory of fluids and the linear response theory of time-dependent phenomena.

**PY (ECE) 627 SEMICONDUCTOR THIN FILMS TECHNOLOGY. 3(3-0) S. Alt. yrs.** (See electrical and computer engineering.)

**PY 630 NUCLEAR STRUCTURE PHYSICS I. Preqs.: PY 582; PY 506 or 510. 3(3-0) S.** Advanced description of nuclear models and nuclear reactions. Internucleon forces, compound-nucleus processes, shell model, optical model, R-matrix theory, direct reactions, collective model, electromagnetic transitions, isobaric analog states.

**PY 690 ADVANCED SPECIAL TOPICS IN PHYSICS. Preq.: CI. 1-3 F,S.** Advanced study in astrophysics, atomic and molecular physics, condensed matter physics, nuclear physics or plasma physics. Emphasis on new and rapidly developing research areas.

**PY 695 SEMINAR. 1(1-0) F,S.** Reports on topics of current interest in physics. Several sections offered so that students with common research interests may be grouped together.

**PY 699 RESEARCH. Credits Arranged.** Graduate students sufficiently prepared may undertake research in some selected field of physics.

# Physiology

**Degrees Offered: Ph.D., M.S., Master of Life Sciences**

## GRADUATE FACULTY

*Associate Professor* J. D. Armstrong, *Coordinator*
Box 7621, (919) 515-4011

*Professors:* R. A. Argenzio, G. T. Barthalmus, J. T. Brake, J. H. Britt, E. V. Caruolo, V. L. Christensen, W. J. Croom, F. W. Edens, K. L. Esbenshade, H. F. Heatwole, T. E. LeVere, N. C. Olson, W. D. Oxender, R. M. Petters, J. F. Roberts, M. C. Roberts, T. D. Siopes, D. E. Smith, C. E. Stevens, C. Teng, H. A. Underwood Jr., T. G. Wolcott;
*Professors Emeriti:* L. Goode, C. H. Hill, L. C. Ulberg;
*Associate Professors:* G. W. Almond, B. Alston-Mills, J. D. Armstrong, H. M. Berschneider, B. L. Black, B. A. Breuhaus, W. L. Flowers, J. E. Gadsby, R. M. Grossfeld, S. L. Pardue, M. A. Qureshi, R. M. Roe, S. P. Washburn, M. D. Whitacre;
*Adjunct Associate Professors:* M. S. Hand;
*Assistant Professors:* C. E. Farin, J. N. Petitte, C. Sullivan

The physiology faculty is an interdepartmental group drawn from the departments participating in the program. These departments include animal science, biochemistry, entomology, food animal and equine medicine, poultry science, psychology, veterinary anatomy, physiological sciences and radiology, and zoology. The program emphasizes the comparative approach implicit in this type of organization and is designed to prepare individuals for careers in research and teaching. Experimental animals available cover a wide range, from insects and other invertebrates to large mammals.

### Admission Requirements

Students entering the graduate program in physiology should have a bachelor's degree in a related biological or physical science. Undergraduate courses should include physiology, biochemistry, organic chemistry, calculus and physics. The Aptitude Test of the Graduate Record Examination is required, and the Advanced Tests in biology and chemistry are desirable.

### Master's Degree Requirements

On average, the M.S. degree requires two to three years.

### Doctoral Degree Requirements

On average, completion of the Ph.D. degree requires five years.

**Student Financial Support**
Financial assistance for qualified students in the form of research assistantships, fellowships and traineeships is available through participating departments.

**Other Relevant Information**
The Physiology Program is jointly administered by the Colleges of Agriculture and Life Sciences and Veterinary Medicine. Graduate students enrolled as physiology majors are located in the department of their major professor and may participate in departmental activities.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PHY(ANS) 502 Reproductive Physiology of Mammals. 3(3-0)F.** (See animal science.)

**PHY(ZO) 503 GENERAL PHYSIOLOGY I. Preq.: Sr. or grad. standing; the following courses are recommended: ZO 421 or equivalent, BCH 451 or equivalent, a yr. of physics. 3(3-0) F.** General principles of homeostasis, emphasizing the importance of integrative action. Muscular, cardiovascular and nervous systems.

**PHY(ZO) 504 General Physiology II. Preq.: PHY (ZO) 503. 3(3-0) S.** General principles of homeostasis, emphasizing the importance of integrative action. Alimentary, renal, respiratory and endocrine systems.

**PHY(ZO) 513 COMPARATIVE PHYSIOLOGY. 3(3-0) F. Odd yrs.** (See zoology.)

**PHY(PO,ZO) 524 COMPARATIVE ENDOCRINOLOGY. 4(3-3) S.** (See poultry science.)

**PHY(MB,PO,VMS) 556 IMMUNOGENETICS. 3(2-2) F. Alt. yrs.** (See poultry science.)

**PHY(ANS) 580 MAMMALIAN ENDOCRINOLOGY. 3(3-0) S. Alt. yrs.** (See animal science.)

**PHY 590 SPECIAL PROBLEMS IN PHYSIOLOGY. Preqs.: Grad. standing, CI. Credits Arranged. F,S.**

**PHY(ZO) 595 SEMINAR IN BIOLOGY OF REPRODUCTION. 2(2-0) F. Alt. yrs.** (See zoology.)

*FOR GRADUATES ONLY*

**PHY(ANS,NTR) 632 COMPARATIVE PHYSIOLOGY OF THE DIGESTIVE SYSTEM. 3(3-0) Every yr.** (See veterinary medical sciences.)

**PHY 690 PHYSIOLOGY SEMINAR. 1(1-0) S.**

**PHY 695 SELECTED TOPICS IN PHYSIOLOGY. 1-4.**

**PHY 699 PHYSIOLOGICAL RESEARCH. Preq.: CI. Credits Arranged. F,S.**

*OTHER SUPPORTING COURSES AVAILABLE*

Other supporting course are available in biochemistry, biomathematics, biotechnology, cell biology, entomology, genetics, immunology, microbiology, nutrition, pharmacology, poultry science, psychology, statistics, toxicology, veterinary medical sciences and zoology.

Certain courses on the interface between physiology and engineering may be taken after consultation with advisor and the instructors concerned.

# Plant Pathology

**Degrees Offered: Ph.D., M.S., Master of Agriculture, Master of Life Sciences**

**GRADUATE FACULTY**

*Professor* O. W. Barnett Jr. ***Head of the Department***
(919) 515-2730
*Professor* D. M. Benson, ***Director of Graduate Programs***
(919) 515-3996, Box 7616, Fax: (919) 515-7716, mike_benson@ncsu.edu

***Professors:*** C. W. Averre III, K. R. Barker, D. F. Bateman, M. K. Beute, R. I. Bruck, C. L. Campbell, E. B. Cowling, J. M. Davis, H. E. Duncan, L. F. Grand, W. M. Hagler Jr., J. Huang, R. K. Jones, W. L. Klarman, M. P. Levi, L. T. Lucas, C. E. Main, R. D. Milholland, J. W. Moyer, G. A. Payne, D. F. Ritchie, P. B. Shoemaker, T. B. Sutton, H. H. Triantaphyllou, C. G. Van Dyke;
***Professors (USDA):*** A. S. Heagle, R. A. Reinert, H. W. Spurr Jr.;
***Visiting Professor:*** C. S. Hodges Jr.;
***Professors Emeriti:*** J. L. Apple, R. Aycock, C. N. Clayton, C. B. Davey, E. Echandi, G. V. Gooding Jr., T. T. Hebert, G. B. Lucas, N. T. Powell, J. P. Ross, J. N. Sasser, D. L. Strider, H. H. Triantaphyllou, F. L. Wellman, J. C. Wells, N. N. Winstead;

*Associate Professors:* J. E. Bailey, M. A. Conkling, M. E. Daub, B. C. Haning, S. Lommel, T. A. Melton III, C. H. Opperman, J. B. Ristaino, R. C. Rufty, H. D. Shew;
*Associate Professors (USDA):* M. L. Carson, S. Leath, S. M. Schneider, S. R. Shafer;
*Assistant Professors:* E. L. Davis, P. B. Lindgren;
*Assistant Professor (USDA):* R. G. Upchurch

Plant pathology has a major commitment to solving plant disease problems with research that focuses on plant-pathogen interactions at the genomic, cellular, organismal and ecological levels. Approaches include disease management, epidemiology, molecular biology and host-parasite interactions. Focus areas are bacteriology, mycology, nematology, virology, soil-borne pathogens and mechanisms of pathogenesis.

### Admission Requirements

The general application procedures of the Graduate School noted at the beginning of this section are followed. Normally domestic, but not international, applicants are required to submit GRE results. A detailed statement of applicant interests and goals in plant pathology is most useful to the admissions committee.

### Master's Degree Requirements

Required courses include: PP 501 Phytopathology I and PP 520 Phytopathology II--Nematology, PP 521 Phytopathology II--Virology and PP 522 Phytopathology II--Epidemiology. PP 515 Epidemiology and Plant Disease Control may be substituted for one of the three PP 52X Phytopathology II minicourses. In addition, students take one credit of PP 690 Seminar in Plant Pathology and one advanced course. Students serve as a teaching assistant for one course.

### Doctoral Degree Requirements

A diagnostic examination prior to enrollment is used as a guide to course selection. PP 501 Phytopathology I and PP 520, PP 521 and PP 522 Phytopathology II (minicourses) are required unless competency is demonstrated on the diagnostic examination. In addition, students take two credits of PP 690 Seminar and two advanced courses. Students serve as a teaching assistant for two courses.

### Student Financial Support

A limited number of one-half time assistantships are available on a competitive basis. Stipend levels for each degree are equivalent to those at comparable institutions. Out-of-state tuition waiver is normally granted for the first year. Applicants are considered for assistantship support at time of application. Special supplements to assistantships are available on a competitive basis for outstanding students.

**Other Relevant Information**
Fully equipped and staffed laboratories for research are available in addition to greenhouse facilities and environmental growth chambers in the phytotron. Special facilities for experimental work on diseases under field conditions are available at 16 locations throughout the state. Microcomputers, library, mycological herbarium, photography laboratory and interdepartmental electron microscopy center are additional features available in the department.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PP 501 PHYTOPATHOLOGY I. Preq.: PP 315 or equivalent. 5(3-6) F.** Fungal and bacterial plant diseases. History, classification, etiology, pathogenesis, pathogen biology and genetics of host-parasite interaction. Laboratory emphasis on basic methodology of fungal and bacterial plant pathogens and development of independent research project.

**PP 504 PLANT DISEASE: PRINCIPLES, DIAGNOSIS AND MANAGEMENT. Preq.: B.S. degree in plant sciences. 4(15-15) Sum.** Principles of plant pathology for diagnosis and control of plant diseases, principally for county agents and non-plant pathology graduate students. Taught as a special, three-week summer session course or as needed.

**PP 515 EPIDEMIOLOGY AND PLANT DISEASE CONTROL. Preq.: PP 315 or PP 318. 3(3-0) S.** Fundamental concepts and principles of epidemiology as they apply to modern strategies of plant disease control. Evaluation of current techniques for control of fungal, bacterial, viral and nematode pathogens in an integrated crop protection system. A term paper required to integrate concepts and principles of disease management for a specific crop.

**PP 520 PHYTOPATHOLOGY II–NEMATOLOGY. Preq.: PP 315 or equivalent. 2(3-6) S.** Lectures and laboratory techniques in plant pathology presented as a series of five-week minicourses. Students may enroll for one or all of the series. Each minicourse consists of lectures on principles and laboratories involving experimental techniques fundamental to the study of nematodes and viruses as plant pathogens and analyses of plant disease epidemics. Taught third 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**PP 521 PHYTOPATHOLOGY II–VIROLOGY. Preq.: PP 315 or equivalent. 2(3-6) S.** (See PP 520.) Taught first 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**PP 522 PHYTOPATHOLOGY II--EPIDEMIOLOGY. Preq.: PP 315 or equivalent. 2(3-6) S.** (see PP 520.) Taught second 5 weeks of semester. Drop date is last day of 3rd week of the minicourse.

**PP(MB,BO) 575 THE FUNGI. 3(3-0) F.** (See botany.)

**PP(MB,BO) 576 THE FUNGI--LAB. 1(0-3) F.** (See botany.)

**PP 595 SPECIAL PROBLEMS IN PLANT PATHOLOGY. Preq.: CI. Credits Arranged, Max. 6.** Investigation of special problems in plant pathology not related to a thesis problem. The investigations may consist of original research and/or literature survey.

*FOR GRADUATES ONLY*

**PP 604 MORPHOLOGY AND TAXONOMY OF NEMATODES. Preqs.: PP 502A, CI. 3(1-6) S. Alt. yrs.** A study of the morphology, anatomy and taxonomy of nematodes with emphasis on the identification of important plant-parasitic genera. Exercises include preparation of semipermanent and permanent nematode mounts.

**PP 605 MOLECULAR BIOLOGY OF PLANT VIRUSES. Preqs.: PP 502B, BCH 451 or 551. 4(2-6) S. Alt. yrs.** An in-depth study of plant viruses with emphasis on the relationship between viral structure and function. Areas include infection, replication, genomic expression, encapsidation and transmission. Laboratory introduces students to contemporary molecular techniques.

**PP 608 HISTORY OF PHYTOPATHOLOGY. Preqs.: PP 315, CI. 1(1-0) F. Alt. yrs.** Development of the science of phytopathology from its early beginnings to the early part of the 20th century.

**PP 611 ADVANCED PLANT NEMATOLOGY. Preqs.: PP 604. 4(3-3) F. Alt. yrs.** Nematode biology, genetics, physiology, molecular biology, ecology, embryogenesis, post-embryonic development, gametogenesis, cytology, reproduction, sexuality, evolution, behavior, host-parasite relationships, mechanisms of pathogenesis and resistance, interactions with other pathogens and impacts on crop performance. Laboratory exercises, research projects and techniques.

**PP 612 PLANT PATHOGENESIS. Preqs.: PP 501, BCH 551, BO 551, CI. 3(2-3) F. Alt. yrs.** Infection processes, alterations in photosynthesis, respiration, nitrogen metabolism, vascular function and growth regulator function are considered. The biochemical nature of the weapons utilized by pathogens in patho-

genic attack and the defensive mechanisms employed by the hosts in resisting attack and the resultant dynamic interactions.

**PP 615 BOTANICAL EPIDEMIOLOGY. Preqs.: PP 501, 502 or CI; Coreq.: ST 511. 4(2-6) S. Alt. yrs.** Dynamics of plant disease epidemics in relation to agricultural crop production and forestry systems. Epidemiological concepts and principles, pathogen and host dynamics, disease forecasting, geographic distribution of pathogens, crop-loss assessment and the development of theoretical and practical disease-management strategies.

**PP(CS,GN,HS) 618 BREEDING FOR PEST RESISTANCE. 2(2-0) F. Alt. yrs.** (See crop science.)

**PP (BO) 625 ADVANCED MYCOLOGY. Preq.: PP 575 or CI. 4(2-6) F. Alt. yrs.** Treatment of major groups of fungi. Aspects of taxonomy, nomenclature, developmental morphology, genetics, host-parasite relations, physiology and ecology. Determination of cardinal characteristics of selected fungi representing the major groups. Also required field observations and collecting.

**PP (BO, GN, MB) 627 FUNGAL GENETICS AND PHYSIOLOGY. Preq.: BCH 451, BO 575, GN 411 or PP 501. 3(2-3) S. Alt. yrs.** Genetics and physiology of fungi, with emphasis on saprophytic and plant pathogenic mycelial fungi. Current literature on evolution, cell structure, growth and development, gene expression, metabolism, sexual and asexual reproduction and incompatibility systems. Laboratory exercises on mutant isolation, sexual and parasexual analysis, genetic transformation, and RFLP and isozyme analysis.

**PP 628 SOILBORNE PLANT PATHOGENS. Preq.: PP 501. 3(2-3) S. Alt. yrs.** The ecology of soilborne fungal and bacterial pathogens that induce root and wilt diseases in plants. Concepts and principles including but not limited to the rhizosphere, inoculum potential, soil fungistasis, survival, root disease models and biological control.

**PP 650 COLLOQUIUM IN PLANT PATHOLOGY. Preq.: PP 502 or CI. 1(1-0) S.** Institutional operations in universities, research laboratories, international centers and industry through group discussions and individual presentations. Sources of funding through appropriations, research grants and industry cooperators. Criteria for evaluating the performance of professional employees, the role of scientific journals and professional societies, as well as public responsibilities.

**PP 690 SEMINAR IN PLANT PATHOLOGY. Preq.: Consent of seminar chair. 1(1-0) F,S.** Discussion of assigned phytopathological topics.

**PP 699 RESEARCH IN PLANT PATHOLOGY. Preq.: CI. Credits Arranged.**
Original research in plant pathology.

# Political Science

**Degree Offered: M. A.**

## GRADUATE FACULTY

*Associate Professor* H. G. Kebschull, *Director of Graduate Program*
Box 8102, (919) 515-5072, kebschull@social.chass.ncsu.edu

*Professors:* G. D. Garson, A. Holtzman, E. R. Rubin, M. S. Soroos, D. W. Stewart, J. H. Svara, J. O. Williams;
*Professors Emeriti:* W. J. Block, J. T. Caldwell;
*Associate Professors:* C. K. Coe, D. M. Daley, R. H. Dorff, J. H. Gilbert, S. H. Kessler, J. M. McClain, E. O'Sullivan, T. V. Reid, J. E. Swiss, M. L. Vasu;
*Associate Professor Emeriti:* K. S. Petersen;
*Assistant Professors:* C. E. Griffin, R. LaCourse Korosec, R. S. Moog

The program is designed for students interested in careers in government service, international organizations, education or the private business sector. A typical course of study draws from the fields of political science, history, sociology and anthropology, and economics.

### Admission Requirements
Applicants not meeting the minimum requirements for full admission should consult with the Director of Graduate Programs.

### Master's Degree Requirements
Three credits are allowed for the thesis. Students choose two major fields from American politics, comparative politics, international relations and public administration. Also required: a research methodology course, reading proficiency in a modern foreign language or competence in a research skill, and nine to twelve hours of work outside the department.

### Student Financial Support
A limited number of fellowships are awarded on a competitive basis.

### Other Relevant Information
The methodology requirement should be fulfilled as soon as possible. Students may take courses at Duke or UNC-Chapel Hill on topics not offered by NCSU.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

PS 401 AMERICAN PARTIES AND INTEREST GROUPS.
PS 402 CAMPAIGNS AND ELECTIONS IN THE AMERICAN POLITICAL SYSTEM.
PS 406 POLITICS AND POLICIES OF AMERICAN STATE GOVERNMENTS.
PS 408 URBAN POLITICS.
PS 411 PUBLIC OPINION AND THE MEDIA.
PS 431 INTERNATIONAL LAW AND ORGANIZATION.
PS 437 NATIONAL SECURITY POLICY.
PS 440 POLITICAL SCANDALS AND CORRUPTION.
PS 446 COMPARATIVE COMMUNIST SYSTEMS.
PS 462 SEMINAR IN POLITICAL THEORY.
PS 498 SPECIAL TOPICS IN POLITICAL SCIENCE.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PS 502 THE LEGISLATIVE PROCESS. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. 3(3-0) S.** Formulation of public policy from the institutional and behavioral viewpoints. Important current legislative problems at the congressional and state legislative levels selected and serve as a basis for analyzing the legislative process.

**PS 506 UNITED STATES CONSTITUTIONAL LAW. Preq.: 12 hrs. of PS or grad. standing or PBS status. 3(3-0) F.** Basic constitutional doctrines, including fundamental law, judicial review, individual rights and political privileges and national and state power. Special attention given to the application of these doctrines to the regulation of business, agriculture and labor and to the rights safeguarded by the First, Fifth and Fourteenth Amendments to the Constitution.

**PS 507 CIVIL LIBERTIES IN THE UNITED STATES. Preq.: 12 hrs. of PS or grad. standing or PBS status. 3(3-0) F,S.** Leading constitutional cases in civil liberties and individual rights along with the writings of leading commentators.

**PS 531 INTERNATIONAL LAW. Preq.: Grad. or advanced undergrad. standing. 3(3-0) F,S.** Sources and subjects of international law, domestic and international jurisdictions, judicial settlement, legal and illegal uses of force and the substance of law in selected policy ares.

**PS 533 GLOBAL PROBLEMS AND POLICY. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. Credit for both PS 433 and PS 533 is not allowed. 3(3-0) F.** International policy processes and policy responses to problems of global scope including the role of international law. Consideration given to economic development, human rights and other policy problems selected for specific semesters. Independent research on a global policy problem of student's choice.

**PS 536 GLOBAL ENVIRONMENTAL LAW AND POLICY. Preq.: Grad. standing or PBS status. 3(3-0) S.** International organizations, laws and policies that address global environmental problems including: population growth, atmospheric pollution, climate change, use of oceans, forests and biodiversity. Relationship between environment and Third World economic development.

**PS 539 INTERNATIONAL POLITICAL ECONOMY. Preq.: Advanced undergrad., grad. or PBS status. 3(3-0) F. Alt. yrs.** Politics of the international economic system, with an emphasis on international monetary order, trade, the dynamics of multinational corporations, debt crisis, technology transfer, North-South relations, related current problems and future trends.

**PS 541 MILITARY COUPS AND REGIMES IN THE THIRD WORLD. Preqs.: Advanced undergrad. standing, grad. standing or PBS status. Credit for both PS 441 and PS 541 is not allowed. 3(3-0) F.** The seizure and exercise of political power by military forces in Asia, Africa and Latin America. Causes and techniques of military coups, with emphasis on the social, economic and political policies of military regimes. Case studies within the context of theories about the political role of the military.

**PS 542 WESTERN EUROPEAN POLITICS. Preq.: Nine hrs. of PS, grad. standing or PBS status. Credit for both PS 442 and PS 542 is not allowed. 3(3-0) S.** Analysis of political institutions and processes in selected Western Europen states and the European community and of major social, economic and political issues confronting European societies.

**PS 544 ISSUES IN SOVIET POLITICS. Preqs.: PS 344, grad. standing or PBS status. 3(3-0) F. Alt. yrs.** Issues in the Soviet Union and relationship to the development of ideology, operation of federalism, emergence of group politics and political conflict, and the process of adopting and implementing public policy.

**PS 545 COMPARATIVE SYSTEMS OF LAW AND JUSTICE. Preq.: grad. standing. Credit for both PS 445 and PS 545 is not allowed. 3(3-0) F,S.** Legal culture and administration of justice in various countries and in the U.S. Emphasis on the impact of legal ideology on the nature of crime, political justice, police administration, corrections and judicial processes.

**PS 571 RESEARCH METHODS AND ANALYSIS. Preqs.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. 3(3-0) S.** A survey of methods used in behavioral research as applied to field of political science: elements of empirical theory, research design, measurement of variables, sampling procedures, data courses, techniques of data collection, statistical analysis, qualitative methodologies and the presentation of research findings.

**PS 590 READINGS AND RESEARCH. Preq.: Grad. standing or PBS status. 1-3 F,S,Sum.** Graduate students pursue a subject of particular interest to them by doing extensive readings or research in that subject under direct, individual faculty supervision.

**PS 598 SPECIAL TOPICS IN POLITICAL SCIENCE. Preq.: Six hrs. of PS. 1-6 F,S.** Detailed investigation of a topic. Topic and mode of study determined by the student and a faculty member.

*FOR GRADUATES ONLY*

**PS 631 SEMINAR IN INTERNATIONAL RELATIONS. Preq.: Six hrs. of 500-level course work. 3(3-0) F,S,Sum. May be taken for up to six hours credit.** Examination of a topic within larger field of international politics to be selected by instructor for each semester from subjects pertaining to interstate relations, international law and organization, regional politics, foreign and security policy or global issues. Students undertake substantial independent research project.

**PS 641 SEMINAR IN COMPARATIVE POLITICS. Preqs.: One course in comparative politics and one course in PS methodology or CI. 3(3-0) F,S.** Opens with a survey of the problems and methods of comparative political analysis, after which students assigned a specific, limited subject to be examined within the framework of a systematic, analytical scheme appropriate to the topic. Specific topics drawn from the subjects of political ideologies, political groups, political elites and decision-making institutions and processes.

**PS 691 INTERNSHIP IN POLITICAL SCIENCE. 1-6 F,S,Sum.** This course exposes the student to the environmental and value systems of public organizations through a supervised work experience.

**PS 696 SEMINAR IN POLITICS. Preq.: Advanced grad. standing. 2-4 F,S.** An independent advanced research course in selected problems of government and

politics. The problems chosen in accordance with the needs and desires of the students registered for the course.

**PS 699 RESEARCH IN POLITICS. Preq.: Approval of adviser. Credits Arranged. F,S.** Research for writing the master's thesis.

# Poultry Science

**Degrees Offered: M.S., Master of Life Sciences**

## GRADUATE FACULTY

*Professor* G. B. Havenstein, ***Head of the Department***
(919) 515-5555
*Professor* T. D. Siopes, ***Director of Graduate Programs***
Box 7608, (919) 515-5535, tom@poultry.poulsci.ncsu.edu

***William Neal Reynolds Professor:*** W. E. Donaldson

***Professors:*** J. T. Brake, T. A. Carter, V. L. Christensen, F. W. Edens, J. D. Garlich, W. M. Hagler Jr., F. T. Jones, J. F. Ort, C. R. Parkhurst, J. C. H. Shih;
***Professors Emeriti:*** R. E. Cook, E. W. Glazener, P. B. Hamilton, J. R. Harris, C. H. Hill;
***Associate Professors:*** P. R. Ferket, S. L. Pardue, M. A. Qureshi, D. V. Rives, M. J. Wineland;
***Assistant Professors:*** K. E. Anderson, G. S. Davis, J. L. Grimes, J. N. Petitte;
***Adjunct Assistant Professor:*** R. P. Gildersleeve

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** W. J. Croom Jr., B. W. Sheldon;
***Associate Professors:*** D. P. Wages, R. W. Bottcher;
***Assistant Professor:*** P. A. Curtis

Course offerings and research programs are comprehensive in the areas of physiology, nutrition, microbiology, molecular biology, immunology, genetics, pathology and toxicology. The demand for men and women with advanced training in poultry science is far greater than the supply. Opportunities exist for graduates in research and teaching in universities, government and private industry.

### Admission Requirements

Exceptions to the minimum 3.00/4.00 undergraduate grade point average may be made for students with special backgrounds, abilities and interests.

### Master's Degree Requirements

While there are no specific course requirements for the master's degree in poultry science, most programs exceed the minimum 30 credit hours.

**Doctoral Degree Requirements**
Doctoral degrees are offered only through interdepartmental programs in the disciplines of physiology, nutrition, genetics, toxicology, microbiology and immunology. Associated research is done with domestic birds in the Department of Poultry Science. Requirements are as given in the Graduate Catalogue. Application should be made directly to the specific discipline program.

**Student Financial Support**
Both research and teaching assistantships are available on a competitive basis within the department. General requirements for these assistantships are as described in the Graduate Catalogue. Other financial support may be available in the form of graduate stipend supplementation, out-of-state tuition waivers or research grant support.

**Other Relevant Information**
The Department of Poultry Science occupies new facilities in a three-story building adjacent to the main campus library. The department consists of about 25 faculty, a support staff of approximately 50, 20 to 30 graduate students and postdoctoral associates, and 50-100 undergraduate students.

*SELECTED ADVANCED UNDERGRADUATE COURSES*

PO 405 AVIAN PHYSIOLOGY.
PO 410 PRODUCTION AND MANAGEMENT OF GAME BIRDS IN CONFINEMENT.
PO(ANS,NTR) 415 COMPARATIVE NUTRITION.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PO 505 PHYSIOLOGICAL ASPECTS OF POULTRY MANAGEMENT. Preqs.: PO 201, PO 405 or grad. standing. 3(3-0) S.** Application of physiological principles to modern poultry management. Poultry physiology related to management topics including nutrition, housing, ventilation, disease, heat stress and lighting programs.

**PO(GN) 520 POULTRY BREEDING. Preq.: GN 411. 3(2-2) S.** Application of genetic principles to poultry breeding, considering physical traits and physiological characteristics.

**PO(PHY,ZO) 524 COMPARATIVE ENDOCRINOLOGY. Preq.: ZO 421 or equivalent. 4(3-3) S.** Basic concepts of endocrinology, including functions of major endocrine glands involved in processes of growth, metabolism and reproduction.

**PO(IMM,MB,PHY,VMS) 556 IMMUNOGENETICS. Preq.: MB 501C or MB 551 or CI. 3(2-2) F. Alt. yrs.** Basic concepts of the immune system. Genetic basis of the immune response including immunoglobulin genetics, major histocompatibil-

ity complexes and their role in the immune response, the molecular basis of the immune system and effector mechanisms.

**PO(IMM) 557 AVIAN IMMUNOLOGY. Preqs.: MB 551, PO 556 or CI. 2(1-2) F. Odd yrs.** Specific features of the avian immune system based on its organization, functions and comparison with its mammalian counterparts. Laboratory immunological techniques using the chicken as an animal model.

**PO 590 GRADUATE SEMINAR IN POULTRY SCIENCE. 1(1-0) F.** Preparation for research, research perspectives, rising concerns in poultry production, orientation for graduate studies in poultry science. Required of all graduate students in the Department of Poultry Science.

*FOR GRADUATES ONLY*

**PO(ANS,NTR) 605 MINERAL METABOLISM. 3(3-0) F.** (See animal science.)

**PO 698 SPECIAL PROBLEMS IN POULTRY SCIENCE. Maximum 6 F,S.** Specific problems of study assigned in various phases of poultry science.

**PO 699 POULTRY RESEARCH. Credits Arranged. A max. of six credits is allowed towards a master's degree. F,S.** Appraisal of present research; critical study of some particular problem involving original investigation. Problems in poultry breeding, disease, endocrinology, hematology, microbiology, nutrition or physiology.

# Psychology

**Degrees Offered: Ph.D., M.S.**

GRADUATE FACULTY

*Professor* D. W. Martin, *Head of the Department*
*Associate Professor* S. S. Snyder Jr., *Director of Graduate Programs*
Box 7801, (919) 515-2251, sam_snyder@ncsu.edu

*Professors:* J. W. Cunningham, D. W. Drewes, T. M. Hess, J. W. Kalat, T. E. LeVere, D. H. Mershon, J. J. Michael, S. E. Newman, F. J. Smith, B. W. Westbrook;

*Adjunct Professors:* J. L. Howard, W. W. Tornow;
*Professors Emeriti:* K. L. Barkley, H. M. Corter, J. C. Johnson, H. G. Miller, P. W. Thayer;
*Associate Professors:* L. Baker-Ward, W. P. Erchul, D. O. Gray, A. G. Halberstadt, P. F. Horan, K. W. Klein, J. E. Luginbuhl, R. W. Nacoste, S. B. Pond III;
*Adjunct Associate Professors:* B. A. Burrus-Braddy, B. F. Corder, A. D. Hall;
*Associate Professors Emeriti:* J. L. Cole, M. H. Pitts, R. F. Rawls;
*Assistant Professors:* C. C. Brookins, S. Converse, M. E. Haskett, M. A. Wilson, M. S. Wogalter;
*Visiting Assistant Professor:* M. Y. Bingham;
*Adjunct Assistant Professors:* B. H. Beith, J. W. Fleenor, C. L. Kronberg, C. E. Lorenz, L. G. Tornatzky

## ASSOCIATE MEMBERS OF THE PROGRAM

*Professors:* C. D. Korte, R. G. Pearson, J. L. Wasik

The Department of Psychology offers seven courses of study leading to the Ph.D.: developmental psychology, ergonomics (human factors), experimental psychology, human resource development, industrial/organizational and vocational psychology, school psychology and social psychology.

### Admission Requirements

Applicants should have satisfactory grades in all undergraduate work and at least a "B" average in undergraduate psychology courses, satisfactory scores on the Graduate Record Examination including the Advanced Test in psychology and three satisfactory letters of recommendation. Match of applicants' research interests with current faculty research is also considered.

### Master's Degree Requirements

Specific course requirements can be found in the Department of Psychology Graduate Handbook.

### Doctoral Degree Requirements

The graduate program for each doctoral student is determined in conjunction with the student's graduate advisory committee and tailored to the needs, interests, and accomplishments of the individual. Typically, students can expect to take 30 or more hours of credit beyond the master's degree.

### Student Financial Support

Many graduate students receive financial support in the form of teaching or research assistantships or fellowships. Applicants should request such support when they

apply to the program. Often students supported by assistantships are allowed to pay tuition at the in-state rate, irrespective of residence.

**Other Relevant Information**
The M.S. degree is available as part of work toward the doctorate, but students wishing to obtain a terminal M.S. are advised to consider other programs.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**PSY 476 PSYCHOLOGY OF ADOLESCENT DEVELOPMENT.**
**PSY 491 SPECIAL TOPICS IN PSYCHOLOGY.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PSY 500 VISUAL PERCEPTION. Preq.: Grad. standing or CI. 3(2-2) F.** Detailed consideration of anatomy and physiology of visual system (both peripheral and central components). Modern quantitative approaches to psycho-physical problems of detection, discrimination, scaling. Chief determinants of visual perception, including both stimulus variables and such organismic variables as learning, motivation and attention. Perceptual theory and processes emphasizes several topics in two- and three-dimensional spatial perception.

**PSY 501 INTRODUCTION TO GRADUATE STUDY IN PSYCHOLOGY. Preq.: Grad. standing in PSY. 1(1-0) F.** Orientation to graduate study in psychology. Library and computer systems. Faculty research and teaching interests. Special research facilities and populations. Standards for research with human and infrahuman subjects. Ethical principles of American Psychological Association. Generic and specialty guidelines for providers of psychological services. North Carolina Licensing Law and supporting rules. Psychology as science, discipline and profession.

**PSY 502 PHYSIOLOGICAL PSYCHOLOGY. Preq.: Twelve hrs. of PSY including PSY 200, 300, 310. 3(3-0) F.** First of two-semester sequence concerned with the physiological foundations of behavior. The emphasis in this first course is basic vertebrate neuroanatomy and neurophysiology.

**PSY 504 ADVANCED EDUCATIONAL PSYCHOLOGY. Preq.: Six hrs. of PSY. 3(3-0) F.** A critical appraisal of current psychological findings relevant to educational practice and theory.

**PSY 505 HISTORY AND SYSTEMS OF PSYCHOLOGY. Preqs.: PSY 200, 300, 310, 320 or CI or grad. status. 3(3-0) S.** Aim of this course is to acquaint

students with the history of psychology and psychological systems and to give students some practice in taking different approaches to a particular problem area.

**PSY 508 PSYCHOLOGY AND THE AFRICAN EXPERIENCE. Preq.: Six hrs. PSY. 3(3-0) S. Alt. yrs.** An ethnographic approach to the psychology of peoples of African descent through examination of the influence of historical and cultural phenomena. Specific attention to understanding the Africentric worldview and issues of mental health, personality and identity development, racism, oppression and empowerment.

**PSY 509 PRINCIPLES AND PRACTICE OF ECOLOGICAL/COMMUNITY PSYCHOLOGY. Preq.: Six hrs. PSY. 3(3-0) S. Alt. yrs.** Community psychology and its attempt to redefine social problems according to an ecological frame-of-reference with emphasis on humanitarian values, cultural diversity, the promotion of a psychological sense of community among individuals and groups, and the need for psychologists to engage in systematic community research and action.

**PSY 510 LEARNING AND MOTIVATION. Preq.: Grad. standing or PBS status. 3(3-0) S.** A systematic analysis of some of the major classes of variables determining behavioral change. Learning variables analyzed within their primary experimental setting, and emphasis upon the diversity of the functions governing behavior change rather than upon the development of some comprehensive theory. Examination of both learning and motivational variables as they contribute to changes in performance within the experimental setting.

**PSY 511 ADVANCED SOCIAL PSYCHOLOGY. Preq.: Grad. standing or PBS status. 3(3-0) F.** Theory and research in social psychology through reading and discussion of primary source materials. Issues of methodology, ethical questions in social psychological research and application of research findings to world at large.

**PSY 512 ACTION RESEARCH IN PSYCHOLOGY. Preq.: ST 507 or equivalent; Coreq.: ST 508 or equivalent. 3(3-0) S.** Action research models in psychology and their relationships to research methods. Research in field settings and implications for ethics and social responsibility, internal and external validity, experimenter and volunteer effects and problems of measurement.

**PSY 513 PSYCHOLOGY AND LAW. Preq.: Grad. standing. 3(3-0) S. Alt. yrs.** Interaction between psychology and law, including pretrial surveys, jury selection, eyewitness identification, jury decision making, competence to stand trial, insanity, expert testimony, sexual assault and the death penalty.

**PSY 520 COGNITIVE PROCESSES. Preq.: Grad. standing or PBS status. 3(2-2) F.** Emphasis upon the results from research on a number of complex processes (*e.g.*, remembering, concept learning, problem solving, acquisition and use of language) and the theories that have been proposed to explain these results.

**PSY(PHI) 525 INTRODUCTION TO COGNITIVE SCIENCE. 3(3-0) F.** (See philosophy.)

**PSY 533 BIOLOGICAL FACTORS IN ABNORMAL BEHAVIOR. Preqs.: Six hrs. of PSY and six hrs. of biology. 3(3-0) Sum. Alt. yrs.** Biological influences and predispositions in abnormal human behavior, including brain damage and disconnection syndromes, psychosomatic illnesses, anxiety and neurosis, manic-depressive disorder, schizophrenia and disorders of memory, eating, movement, sexual behavior and others. Assumes only a moderate biology background.

**PSY 535 TESTS AND MEASUREMENTS. Preq.: Six hrs. of PSY. 3(3-0) F,S.** The principles of psychological testing including norms and units of measurement, elementary statistical concepts, reliability and validity. In addition, some attention devoted to the major types of available tests such as general intellectual development, tests of separate abilities, achievement tests, measures of personality and interest inventories.

**PSY(IE) 540 HUMAN FACTORS IN SYSTEMS DESIGN. Preq.: IE 452 or PSY 340; Coreq.: ST 507 or 515. 3(3-0) F.** Problems of the systems development cycle, including human-machine function allocation, military specifications, display-control compatibility, the personnel sub-system concept and maintainability design. Detailed treatment given to people as information processing mechanisms.

**PSY 543 ERGONOMIC PERFORMANCE ASSESSMENT. Preqs.: PSY 200, ST 507 and 508 or equivalent. 3(3-0) F. Alt. yrs.** Fundamentals of ergonomic performance measurement used to assess the effects of environment and system design on human performance. Treatment of topics such as workload measurement, measurement of complex performance, simulator studies, measurement of change, task taxonomies, criterion task sets and statistical methods of task analysis. Problems of laboratory and field research, measurement of change and generalizability of findings.

**PSY(IE) 545 HUMAN PERFORMANCE. Preqs.: Grad. standing; ST 507 or equivalent. S. Alt. yrs.** Fundamentals of human perceptual and motor abilities basic to skilled operator performance. Theoretical models of man as an operator. The human as an information processing mechanism. Motor skills learning, performance decrement and information feedback. Channel capacity, stress, fatigue,

arousal theory. Attention, time-sharing and workload. Sustained performance, vigilance, monitoring, search, inspection and tracking. Circadian rhythms; sleep loss; shiftwork.

**PSY 546 HUMAN INFORMATION PROCESSING. Preqs.: PSY 200, ST 507 and 508 or equivalent. 3(3-0) S. Alt. yrs.** Fundamentals of human information processing basic to skilled operator performance and the design of displays, controls and complex systems. Treatment of topics such as channel capacity, working memory, long-term memory, decision making, attention and process monitoring. Problems of display and control design and evaluation, evaluation of textual material, and human-computer interaction.

**PSY 560 PERSONNEL SELECTION RESEARCH. Preqs.: Six hrs. of grad. ST, PSY 535. 3(3-0) F. Alt. yrs.** A survey of theoretical, methodological and research literature on personnel selection. Topics include organization, task and person analyses, validation strategies, utility and equal opportunity issues and selection strategies. Emphasis on research.

**PSY 561 TRAINING RESEARCH. Preqs.: Six hrs. of grad. PSY and six hrs. of grad. ST. 3(3-0) F. Alt. yrs.** A survey of conceptual and research literature on training. Needs assessments, learning, transfer, maintenance, criterial and evaluation issues, as well as a review of research on specific training techniques. Emphasis on research methods and findings, not skill development in specific training techniques.

**PSY 562 HUMAN RESOURCE PLANNING. Preq.: Grad. standing or PBS status; Coreq.: ST 507 or equivalent. 3(3-0) F. Alt. yrs.** Review of the literature, methods and research issues in the field of human resource planning and evaluation. Goal-setting, needs assessment, information systems, subjective probability, human resource accounting, decision processes, incentive programs, human productivity and related subjects. Focus on planning and evaluation methods for communities and organizations.

**PSY 563 CONSUMER RESEARCH. Preqs.: ST 507 or equivalent, grad. standing or PBS status; Corequisite: ST 508. 3(3-0) S. Alt. yrs.** Review of the literature, methods and research issues pertaining to consumer behavior. Consumer demographics, psychographics, attitudes, persuasion, intentions, decision processes, consumption, saving, innovation and related topics. Research methods including experiments, surveys, focus groups and case studies.

**PSY 565 ORGANIZATIONAL PSYCHOLOGY. Preq.: Nine hrs. of PSY. 3(3-0) F.** The application of behavioral science, particularly psychology and social psychology, to organizational and management problems.

**PSY 566 ORGANIZATION DEVELOPMENT AND CHANGE. Preq.: PSY 565. 3(3-0) S. Alt. yrs.** A survey of theory and research in organization development. Attention directed to: (1) methods of diagnosing need for organizational change, (2) techniques currently used to implement and evaluate organizational change, (3) professional ethics and other issues dealing with client-consultant relationship. Emphasis on developmental approaches originating from psychology and allied fields.

**PSY 571 INDIVIDUAL INTELLIGENCE MEASUREMENT. Preq.: PSY 535 and consent of school psychology coordinator. 3(3-0) F. Alt. yrs.** A practicum in individual intelligence testing with emphasis on the Weschsler-Scales, Stanford-Binet, report writing and case studies.

**PSY 572 PSYCHOLOGICAL SURVEY OPERATIONS. Preq.: ST 507 or equivalent; Coreq.: ST 508 or equivalent. 3(3-0) S.** Application of survey operational methods to problems of interest to psychologists in governmental, institutional and industrial settings. Course designed to provide competency in questionnaire construction, data collection, design and analysis procedures and report writing. The class will design, conduct and analyze a survey on topic of their own selection in the area of psychology.

**PSY 573 THEORIES OF INTELLIGENCE. Preq.: Grad. standing. 3(3-0) S. Alt. yrs.** Critical analysis of the psychological construct of intelligence. Traditional theories, as well as cognitive developmental, information-processing, comparative psychology, artificial intelligence, cross-cultural and epistemological approaches to intelligence explored.

**PSY 576 ADVANCED DEVELOPMENTAL PSYCHOLOGY. Preq.: Nine hrs. of PSY, including PSY 376, PSY 475 or PSY 476. 3(3-0) F.** A survey of the role of growth and development in human behavior, particularly during the child and adolescent periods. This course pays particular attention to basic principles and theories in the area of developmental psychology.

**PSY 577 ADOLESCENT DEVELOPMENT. Preq.: 6 hours in PSY or CI. 3(3-0) S. Alt. yrs.,Sum.** Current theories and research on development during adolescence. Topics include: physical growth, cognitive changes, relationships with peers, parents and teachers, quest for identity and independence, morality and sexuality.

**PSY 580 PSYCHOLOGICAL CONSULTATION. Preq.: Nine hrs. grad. PSY or ED. 3(2-2) S.** Psychological consultation with emphasis on school setting. Presentation of various consultation models and theoretical bases. Development of skills in practice of consultation.

**PSY 585 ADVANCED PROBLEMS IN PSYCHOLOGY. Preq.: Grad. standing. 1-3 F,S.** Offers opportunities to explore various areas of psychology. Sections: Section D, developmental psychology; Section X, experimental psychology; Section I, industrial-organizational and vocational psychology; Section S, social psychology.

**PSY 591 SPECIAL TOPICS IN PSYCHOLOGY. Preq.: 6 hrs. of PSY; Coreq.: 3 hrs. of ST. 1-3 F,S.** Course provides opportunity for exploration in depth of advanced areas and topics of current interest.

**PSY(IE) 593 AREA SEMINAR IN ERGONOMICS. Preq.: Grad. standing or PBS status. 1(0-2), Max. 3. F.** Introduction to ergonomics as an area of study; historical aspects; contemporary issues; ethical questions; overview of campus research, facilities and courses in the area; consideration of information sources, financial support for research proposals and employment opportunities.

**PSY 594 AREA SEMINAR IN HUMAN RESOURCES DEVELOPMENT. Preq.: CI. 1-3, Max. 6. F,S.** The following topics dealt with: (1) human resources development as an area of inquiry, (2) methods of inquiry, (3) contemporary issues, (4) ethical questions, (5) relationship to other areas within psychology.

**PSY 595 AREA SEMINAR IN SCHOOL PSYCHOLOGY. Preq.: Grad. standing or PBS status. 1-3, Max. 6. F. Alt. yrs.** The following topics dealt with: (1) the development of school psychology as a professional area, (2) methods of inquiry, (3) scientific and theoretical bases, (4) contemporary issues, (5) ethical questions, (6) relationship to other areas within psychology.

**PSY 599 RESEARCH PROBLEMS IN PSYCHOLOGY. Preq.: CI. Credits Arranged. F,S.** Research project for graduate students supervised by members of the graduate faculty. Research to be elected on basis of interest of student and not to be part of thesis or dissertation research.

*FOR GRADUATES ONLY*

**PSY 600 ADVANCED PROBLEMS IN PERCEPTION. Preq.: PSY 500. 3(2-2) S. Alt. yrs.** Advanced topics in the field of perception. Specific coverage varies from year to year but may include examination of sensory/perceptual processes in audition and other non-visual systems, attentional and organizational factors in perception, information processing approaches to perception, theories of perception and/or perceptual/motor skills.

**PSY 611 SOCIAL PSYCHOLOGY: SMALL GROUPS RESEARCH. Preq.: PSY 511. 3(3-0) S.** Surveys the literature and research pertaining to social psy-

chological processes in and between groups. Basic principles of group formation, role differentiation, communication, influence, norms, social exchange, equity, co-operation/conflict, decision making and pro-social behavior. Environmental factors affecting group behavior also considered. In conjunction with each substantive topic, suitable methodologies for research considered.

**PSY 612 ATTITUDES. Preq.: Six hrs. grad. PSY or CI. 3(3-0) F. Alt. yrs.** Theory and research in attitude formation and change; analysis of various persuasion paradigms employed in mass communication and group influence processes; study of individual attitudinal structures, resistance to persuasion, behavior as a precursor to attitude change; attitude behavior discrepancy, attitude measurement techniques and methodological considerations.

**PSY 613 ATTRIBUTION. Preq.: PSY 511. 3(3-0) S. Alt. yrs.** The determinants and consequences of assigning causes for the behavior of others and ourselves. Attributional models, emotional states, success and failure, responsibility assignments, self-handicapping, self-fulfilling prophecy, motivational biases and applications to therapy.

**PSY 614 STRESS AND COPING. Preq.: Two grad. PSY courses. 3(3-0) F. Alt. yrs.** Discussion of current research findings and theories in area of psychosocial stress. Biology of the stress response, methodology, physical, behavioral and psychological reactions to stress, and relationships between personal-ity and social support to the development of stress-related disorders.

**PSY 615 CROSS-CULTURAL RESEARCH AND DEVELOPMENT. Preqs.: ST 507 or equivalent, grad. standing; Coreq.: ST 508 or CI. 3(3-0) S. Alt. yrs.** Review of the literature, methods and issues in cross-cultural research and development. Cross-cultural programs evaluation and policy studies in health, education, technology transfer, international cooperation and communications. For graduate students in science and technology with plans to work in international settings.

**PSY 620 ADVANCED PROBLEMS IN COGNITION. Preq.: PSY 520 or CI. 3(3-0) S.** This seminar provides the opportunity for exploring in depth problems and issues in memory, concept learning, problem solving, psycholinguistics and other areas in cognition.

**PSY 635 PSYCHOLOGICAL MEASUREMENT. Preqs.: ST 507, 511 or equivalent, 12 hrs. of PSY. 3(3-0) F.** Theory of psychological measurement. Statistical problems and techniques in test construction.

**PSY(IE) 640 SKILLED OPERATOR PERFORMANCE. Preqs.: PSY 545, ST 507 or ST 515. 3(3-0) F. Alt. yrs.** Theories of human operator considered with regard to classical problems of monitoring, vigilance and tracking. Factors such as biological rhythm, sleep loss, sensory restriction, environmental stress and timesharing considered as they interact with and determine overall systems efficiency.

**PSY 650 VOCATIONAL PSYCHOLOGY. Preqs.: ST 507, PSY 514, 635 or equivalent. 3(3-0) F. Alt. yrs.** The study of the individual's vocational behavior and development through the years of choice and adjustment. An up-to-date review and synthesis of research and theory in the field of vocational psychology. Empirical studies and theoretical statements in the field appraised and evaluated to determine what behavioral laws apply to vocational phenomena.

**PSY 665 WORK MOTIVATION. Preq.: PSY 565. 3(3-0) S. Alt. yrs.** Theory and research in work motivation. An in-depth examination of motivation theory as it pertains to the study of individual behavior in work settings.

**PSY 671 PSYCHOLOGY OF FAMILIES AND PARENTING. Preq.: Nine hrs. grad. PSY or ED. 3(3-0) F. Alt. yrs.** Special topics in the area, including family influences on cognitive development, effects of parental divorce on children, single-parenting, step-families, child abuse and ethnic/cultural differences in family functioning. A critical examination of traditional and contemporary parenting approaches and an introduction to family therapy.

**PSY 672 PERSONALITY MEASUREMENT. Preqs.: PSY 570, 571. 3(2-3) S. Alt. yrs.** Theory and practicum in individual personality testing of children and adults with emphasis on projective techniques, other personality measures, report writing and case studies.

**PSY 674 PSYCHOLOGICAL INTERVENTION I. Preqs.: PSY 672 and CI. 3(2-2) F. Alt. yrs.** Designed to examine theories, research, techniques, ethics and professional responsibilities related to approaches to psychological intervention. Types of psychological intervention include behavior modification, milieu approaches, crisis intervention techniques and group process methods, in addition to more intensive relationship approaches. A close integration of experiences, content and supervision emphasized in a variety of professional settings with a wide range of personal problems and age groups.

**PSY 675 PSYCHOLOGICAL INTERVENTION II. Preq.: PSY 674. 3(2-2) S. Alt. yrs.** The primary purpose of this course is to provide students opportunities to acquire information, conceptual frameworks, interpersonal skills and a sense of ethical responsibility, all basic to their further development as practicing psy-

chologists. A major effort in the course made to help the student increase his/her interpersonal skills as a means of promoting the psychological growth and effectiveness of others.

**PSY 676 COGNITIVE DEVELOPMENT. Preq.: PSY 576. 3(3-0) S. Alt. yrs.** Examination of research and theory in cognitive development. Primary focus on childhood, but implications for the entire life span addressed. Application of cognitive developmental principles in creating interventions and educational programs also discussed.

**PSY 677 SOCIAL DEVELOPMENT. Preq.: PSY 576. 3(3-0) S. Alt. yrs.** Survey of current theory and research on the development of social behavior systems, including attachment, aggression, gender-role behavior, prosocial behavior. Attention to the role of social class, race and culture, and to contemporary phenomena such as day care, single-parent and dual-career families, child abuse.

**PSY 680 SYSTEMS THEORY AND APPLICATIONS IN HUMAN RESOURCE DEVELOPMENT. Preq.: PSY 594 or equivalent. 3(3-0) F.** The systems approach and general systems theory. (1) Concepts and terminology of general systems theory, (2) techniques currently used to access system requirements and (3) methods of analyzing system performance. Emphasis on application of systems techniques to the design and implementation of human resource development programs.

**PSY 681 QUASI-EXPERIMENTAL EVALUATION DESIGN. Preq.: ST 507 or equivalent. 3(3-0) S.** Quasi-experimental design as applied to HRD program evaluation: (1) Methods of assessing informational needs, (2) recognition of internal and external validity threats, (3) design of quasi-experiments to minimize threats and (4) use of results by program decision makers.

**PSY 686 ADULTHOOD AND AGING: COGNITIVE AND INTELLECTUAL CHANGE. Preq.: PSY 576 or equivalent. 3(3-0) F. Alt. yrs.** Critical examination of theory and research associated with the study of cognitive and intellectual change in adulthood and aging. Topics include memory and learning, information processing, language, intelligence, social cognition and expertise.

**PSY 691 SPECIAL TOPICS IN PSYCHOLOGY. Preq.: CI. 1-3 F,S.** Course provides opportunity for exploration in depth of advanced topical areas which, because of their degree of specialization, are not generally involved in other courses; for example, multivariate methodology in psychology, computer simulation, mathematical model building. Some new 600-level courses will first be offered under this title during the developmental phase and as such may involve lectures and/or laboratories.

**PSY 693 PSYCHOLOGICAL CLINIC PRACTICUM. Preqs.: Twelve hrs. in grad. PSY, which must include clinical skill courses PSY 571 and PSY 672 and/or CI. Max. 12 F,S.** Clinical participation in interviewing, counseling, psychotherapy and administration of psychologcal tests. Practicum to be concerned with adults and children.

**PSY 697 ADVANCED SEMINAR IN RESEARCH DESIGN. Preqs.: Nine hrs. of statistical methods and research or CI, advanced grad. status. 3(3-0) F.** A seminar-type course with topics selected each semester in accordance with the interests and needs of the students. Attention given to the research strategies that underlie educational and psychological research, to the development of theoretical constructs, to a critical review of research related to problems in which the students interested, and to a systematic analysis and critique of research problems in which the students engaged.

**PSY 698 INTERNSHIP IN PSYCHOLOGY. Preqs.: Master's degree in PSY and approval of advisory committee. 1-12 F,S.** Supervised work experience in an appropriate setting with professional supervision in the field from a doctoral level psychologist with credentials and/or experience in the appropriate specialty in psychology. Experience consists of full time for one semester or half time for an academic year or equivalent time.

**PSY 699 THESIS AND DISSERTATION RESEARCH. Preq.: CI. Credits Arranged. F,S.** Individual research on a thesis or dissertation problem; a maximum of six credits allowed toward the master's degree, but any number toward the Ph.D. degree.

# Public Administration

**Degree Offered: Master of Public Administration**

**GRADUATE FACULTY**

*Professor* J. H. Svara, *Program Director*
Box 8102, (919) 515-5159, svara@social.chass.ncsu.edu

*Professors:* G. D. Garson, M. S. Soroos, D. W. Stewart;
*Associate Professors:* C. K. Coe, D. M. Daley, E. O'Sullivan, J. E. Swiss, M. L. Vasu;
*Assistant Professor:* R. LaCourse Korosec;
*Visiting Assistant Professor:* S. K. Straus

Administrative specialties are available in the following areas: administration of justice, association/non-profit management, data management, environmental policy and management, financial management, human resource management and urban/ local government management.

**Admission Requirements**
Since a limited number of pre-service students (*i.e.*, those without professional or managerial work positions) are admitted, these applicants are encouraged to submit all materials by May 15 in order to receive full consideration.

**Master's Degree Requirements**
The MPA degree is a 40-semester-hour program consisting of several overlapping tiers: (1) prerequisites to program admission including a course in economics and an intermediate-level course in statistics; (2) a core curriculum of 17 hours; (3) a choice of administrative specialties based on courses in public administration and other departments; and (4) an internship or field experience requirement for pre-service students. It is an option B with a one-person committee and no final oral examination.

**Student Financial Support**
A limited number of fellowships and graduate assistantships are offered by the department. Contact the department for more information. Other forms of student aid are described in the financial aid section of the Graduate Bulletin. Students interested in financial assistance should apply by April 1.

**Other Relevant Information**
The MPA program regularly conducts an Assessment Center to enhance students' skills in oral communication, technical writing and group dynamics. It is required for pre-service students. Activities include technical writing evaluations, evaluations of oral presentation skills and in-basket exercises to measure inter-personal, problem-solving and managerial skills. These exercises enable students to gain valuable training beyond their academic experience.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PA 505 ADMINISTRATIVE LAW. Preq.: Grad. standing or PBS status. 3(3-0) Occasionally.** Case law of the exercise of administrative power, judicial and legislative control of administrative action, legal rights of public employers and legal procedures of administrative tribunals.

**PA 510 ETHICS AND PROFESSIONAL PRACTICE. Preq.: Grad. standing or PBS status. 1(3-0) F,S.** Workshop on ethical responsibilities of public adminis-

trators and codes of ethics used by professional organizations in the field. Knowledge and problem-solving skills to assess ethical challenges encountered in the professional practice of public administration.

**PA 511 PUBLIC ADMINISTRATION. Preq.: Advanced undergrad. standing including 12 hrs. in PS, grad. standing or PBS status. 3(3-0) F,S,Sum.** A general survey of the field of public administration, examining formal and informal organizations, processes of administration, the political environment of administration and administrative responsibility and accountability.

**PA 513 FINANCIAL MANAGEMENT IN THE PUBLIC SECTOR. Preq.: Grad. standing or PBS status. 3(3-0) S,Sum.** Survey of financial practices and con-cepts in the public sector. Topics include: public sector accounting, financial information systems, revenue projections, cash management and debt management. Case-based applications emphasized.

**PA 515 ADMINISTRATION OF CRIMINAL JUSTICE. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status . Credit for both PS 415 and PA 515 is not allowed. 3(3-0) F,S.** Politics and administration in the American criminal justice system. Interrelationships between ideology, organization and policy outputs in the analysis of major problems confronting the system today. Intergovernmental relations, discretionary justice, impact of judicial decisions on criminal justice administration and management trends in criminal justice bureaucracies.

**PA 516 PUBLIC POLICY ANALYSIS. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. 3(3-0) F,S,Sum.** Methods and techniques of analyzing, developing and evaluating public policies and programs. Benefit-cost and cost-effectiveness analysis and concepts of economic efficiency, equity and distribution. Methods include problem solving, decision making and case studies. Examples used in human resource, environmental and regulatory policy.

**PA 518 ORGANIZATION DESIGN. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. 3(3-0) S.** Contemporary approaches to organization design, including organization development, sociotechnical systems analysis and various forms of organizational participation ranging from human relations to self-management models. Emphasis on issues in personnel administration in relation to public management and government structure.

**PA 520 ENVIRONMENTAL POLICY. Preq.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status. 3(3-0) F.** The formation

and impact of environmental policy in the United States. Examination on decision-making processes at all levels of government. Comparisons between political, economic, social and technological policy alternatives. Emphasis upon the application of policy analysis in environmental assessment and consideration on theoretical perspectives on the nature of the environmental crisis.

**PA 536 ASSOCIATION MANAGEMENT. Preq.: Grad. standing or PBS status. 3(3-0) S.** A survey of association management. Application of public management to specific association management concerns. History of associations, legal aspects, public relations, budgeting and financial management, membership development and the politics of associations.

**PA 570 RESEARCH METHODS COMPUTING LAB. Preqs.: Advanced undergrad. standing including 12 hrs. of PS, grad. standing or PBS status and an introductory course in ST. 1(0-2) F,S.** A one-hour computing lab complementing the public administration curriculum. Introduction to computing on both mainframe and microcomputer. Includes TSO/QED statistical packages, SPSS data structures and microcomputing software.

**PA 571 RESEARCH METHODS AND ANALYSIS. Preqs.: Advanced undergrad. standing includ ing 12 hrs. of PS, grad. standing or PBS status and an introductory course in ST. 3(3-0) F,S.** A focus on the behavioral approach to the study of political and administrative behavior. The philosophy of social science; experimental, quasi and non-experimental research design; data collection techniques; basic statistical analysis with computer applications.

**PA 573 COMPUTER APPLICATIONS IN PUBLIC AFFAIRS. Preqs.: ST 507; CSC 462 or PS 371 or PA 571. 3(1-6) F.** The methodology, data analysis techniques and computer-based skills necessary to conduct and manage applied research. Focus on the analysis and processing of data through medium of conventional computer software frequently used in the field, *i.e.*, SPSS, SAS.

**PA 574 DATA MANAGEMENT IN PUBLIC ADMINISTRATION. Preqs.: PS 374 or PA 573 and prior course work involving computing, statistics and public admin. helpful but not required. 3(3-0) S.** Managerial applications of data management in public budgeting, public personnel and public policy analysis. Use of microcomputers to construct data bases and analytic models in these areas.

**PA 580 INDEPENDENT STUDY. Preq.: Grad. standing or PBS. 1-6. F,S,Sum.** Independent research or readings by graduate students under the direct supervision of individual faculty members. Students' work evaluated, based on reports, papers and exams.

**PA 590 READINGS AND RESEARCH. Preq.: Grad. standing. 1-3 F,S,Sum.** To enable graduate students to pursue a subject of particular interest to them by doing extensive readings or research in that subject under direct, individual faculty supervision.

**PA 598 SPECIAL TOPICS IN PUBLIC ADMINISTRATION. Preq.: Advanced undergrad. standing including 12 hrs. in PS, grad. standing or PBS status. 1-6 F,S,Sum.** Detailed investigation of contemporary topics in the fields of public administration. Topic and mode of study determined by program faculty.

*FOR GRADUATES ONLY*

**PA 601 POLITICS AND ETHICS OF PUBLIC ADMINISTRATION. 3(3-0) F.** The linkage of public administration to politics and the policy process in local, state and national government and the relationship of public administrators to the agency, government and public. Accountability in the public sector, the legal and professional responsibilities of public administrators, ethical issues in public administration and codes of ethics.

**PA 608 SEMINAR IN URBAN MANAGEMENT. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work 3(3-0) S.** A seminar focusing on the analytical techniques and managerial principles required for policy formation and implementation in a complex urban governmental environment. Urban planning and community development, housing, intergovernmental relations, organizational roles and decision making, budgeting and selected urban services (for example: police, transportation).

**PA 611 SEMINAR IN PUBLIC PERSONNEL MANAGEMENT. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F,S.** Examination of major issues in public sector personnel management. Staffing, position classification, compensation, affirmative action, performance review and appraisal, patronage, training, career development, employee assistance, unionization and rights of public employees.

**PA 612 THE BUDGETARY PROCESS. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F,S,Sum.** Generalized budgetary process used at all levels of government in the United States. Understanding of the process based upon comprehension of the institutions involved, the roles of politicians and professionals and the objectives of budgetary systems. Focus also upon budgetary reforms and on Planning-Programming-Budgetary and Zero-Based Budgeting as management tools.

**PA 613 GOVERNMENT AND PLANNING. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) S.** The planning function at all levels of government in the United States, with particular attention to the problems posed for planning by the rapid growth of metropolitan areas. Overview of community development, urban spatial structure, housing economics and land use planning.

**PA 614 MANAGEMENT SYSTEMS. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F,S,Sum.** An examination, through case studies and applied methodology, of various management systems and management techniques. Differences between market and non-market organizations, financial management systems, quantitative decision-making approaches, planning techniques such as CPM and PERT, MBO and productivity systems.

**PA 616 SEMINAR IN PROGRAM EVALUATION. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F,S.** Combination of seminar and field research techniques to study the evaluation of public programs. Focus on political and administrative problems associated with program evaluation. The availability and appropriateness of various quantitative methodologies also examined. Seminar concepts applied through evaluative projects conducted for public agencies.

**PA 617 SEMINAR IN ORGANIZATION THEORY. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F,S.** Examination of major conceptual frameworks developed to understand organizational behavior. Stress upon topics including motivation, leadership, group dynamics, communication, socio-technical systems, work design and organizational learning. The emphasis on applying theories and concepts to public sector organizations.

**PA 619 INTERGOVERNMENTAL RELATIONS IN THE UNITED STATES. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) F.** Examination of distinctive features of intergovernmental relations in the United States. Topics stressed include historical adaptations of federalism, the emerging role of the administrator, contemporary trends in intergovernmental relations and assessment of contemporary trends from federal, state and local perspectives.

**PA 620 ENVIRONMENTAL ADMINISTRATION. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course**

**work. 3(3-0) S.** A review and investigation of the major environmental management systems utilized to plan, develop and implement environmental programs.

**PA 621 COLLECTIVE NEGOTIATIONS IN THE PUBLIC SERVICE. Preqs.: Grad. standing or Management Development Certificate Prog. and 6 hrs. of 500-level course work. 3(3-0) Occasionally.** Includes intensive consideration of the background of the collective negotiations movement; analysis of key policy issues, such as bargaining rights and the use of strike weapons; framework for collective negotiations; scope and conduct of negotiations; impasse resolution; grievance procedure.

**PA 691 INTERNSHIP IN PUBLIC AFFAIRS. Preq.: Minimum 9 hrs. graduate work. 1-6 F,S,Sum.** Exposes the student to the environment and value systems of the public organization through a supervised work experience. Involves the application of substantive knowledge and analytical skills to organizational problems. Credit will vary with the nature of the work experience.

# Public History

For a listing of graduate faculty and program information, see history.

# Reading

For a listing of graduate faculty and program information, see curriculum and instruction.

# Rural Sociology

For a listing of graduate faculty and program information, see sociology.

# Science Education

For a listing of graduate faculty and program information, see mathematics and science education.

# Social Studies

For a listing of graduate faculty and program information, see curriculum and instruction.

# Sociology and Anthropology

**Degrees Offered: Ph.D., M.S., Master of Sociology**

## GRADUATE FACULTY

*Professor* W. B. Clifford II, *Head of the Department*
*Professor* M. D. Schulman, *Director of Graduate Programs*
Box 8017, (919) 515-2702, Fax (919) 515-2610, michael_schulman@ncsu.edu

*Professors:* L. R. Della Fave, V. A. Hiday, R. L. Moxley, L. B. Otto, P. N. Reid, M. M. Sawhney, D. Tomaskovic-Devey, R. C. Wimberley;
*Associate Professors:* M. P. Atkinson, R. F. Czaja, A. C. Davis, S. K. Garber, G. D. Hill, T. J. Hoban, J. C. Leiter, S. C. Lilley, B. J. Risman, M. L. Schwalbe, M. S. Thompson, R. J. Thomson, K. M. Troost, M. L. Walek, J. M. Wallace III, E. M. Woodrum, M. T. Zingraff;
*Assistant Professors:* R. S. Ellovich, T. N. Greenstein, P. L. McCall, W. R. Smith, C. R. Zimmer

## ASSOCIATE MEMBER OF THE PROGRAM

*Professor:* R. D. Mustian

The department offers master's and doctoral programs in sociology designed to prepare students for academic, research, and applied careers. The programs are structured to provide an intellectually stimulating and academically rigorous, yet supportive, environment that emphasizes developing research skills through course work and close collaboration with faculty.

### Admissions Requirements

In addition to general Graduate School requirements, applicants are required to provide a writing sample. For fall admission, the completed application should be received no later than February 1 to ensure full consideration for assistantship support; final deadline for fall admission is May 1. Applications for spring admission are considered under special circumstances, but assistantship support is less likely; final deadline for spring admission is November 1.

### Master's Degree Requirements

Applicants should have received/be receiving a bachelor's degree from an accredited institution with a major in sociology. Other majors are considered, but students may have to make up deficiencies without credit. The M.S. requires a thesis, whereas a Master of Sociology (M.SOC.) requires 6 semester credit hours of practicum

(supervised field placement in an organization or agency) and a research paper. A minor for both degrees is optional.

**Doctoral Degree Requirements**
The Ph.D. normally requires a master's in sociology, at least 14 courses (including or after the master's). Doctoral students take core courses in theory and methods/ analysis and select courses in two areas of specialization. Some course work from the master's may be applied. A minor is optional.

**Student Financial Support**
Teaching and research assistantships and a limited number of out-of-state tuition waivers are available on a competitive basis.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

SOC 400 SOCIAL CHANGE.
SOC 401 THEORIES OF SOCIAL INTERACTION.
SOC 402 URBAN SOCIOLOGY.
SOC 410 SOCIOLOGY OF ORGANIZATIONS.
SOC 414 SOCIAL CLASS.
SOC 418 SOCIOLOGY OF EDUCATION.
SOC 420 SOCIOLOGY OF CORRECTIONS.
SOC 425 JUVENILE DELINQUENCY.
SOC 426 THE JUVENILE JUSTICE SYSTEM.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**SOC 501 LEADERSHIP. Preq.: SOC 202 or equivalent. 3(3-0).** Leadership in various fields of American life; analysis of factors associated with it; techniques of leadership. Stress on recreational, scientific and executive leadership procedures.

**SOC 502 SOCIETY, CULTURE AND PERSONALITY. Preq.: SOC 202 or equivalent. 3(3-0).** Human personality from its origins in primary groups through its development in secondary contacts and its ultimate integration with social norms. Exploration of comparative anthropological materials with emphasis on the normal personality and individual adjustment to our society and culture. Dynamics of personality and character structure analyzed in terms of society's general culture patterns and social institutions.

**SOC 505 MEDICAL SOCIOLOGY. Preq.: Six credits in SOC or grad. standing or PBS status. 3(3-0).** Advanced sociological analysis of health care organizations and their systemic linkage to other community institutions. Measurement of health and illness and their social significance. Applications of sociological

and social-psychological theories to practitioner-client relationships and interaction. Implications of alternative models of health care provision.

**SOC 508 SOCIAL ORGANIZATION. Preq.: SOC 400 or SOC 511. 3(3-0).** The study of social structure. Focus on inequality, work, organizations, the economy, the state. Classic writings and their impacts.

**SOC 509 POPULATION PROBLEMS. Preq.: SOC 202 or equivalent. 3(3-0).** Population growth, rates of change and distribution. Emphasis on functional roles of population, *i.e.*, age, sex, race, residence, occupation, marital status and education. Stress on population dynamics fertility, mortality and migration. Analysis on population policy in relation to national and international goals stressing a world view.

**SOC 510 WORK AND INDUSTRY. Preq.: SOC 400 or SOC 508 or SOC 511. 3(3-0).** Control of economy and workplace. Special attention to economic restructuring, the labor process and recent workplace innovations. Theories include managerialism, bank hegemony and deskilling. Historical studies complement analyses of contemporary settings and issues.

**SOC 511 SOCIOLOGICAL THEORY. Preqs.: Six hrs. SOC and grad. standing or PBS status. 3(3-0).** The interdependence of theory and method; the major theoretical and methodological systems. Examination of selected cases of research in which theory and method classically combined.

**SOC 512 SURVEY OF FAMILY SOCIOLOGY. Preq.: SOC 202. 3(3-0).** Examination of structural and demographic continuities and changes for American families in general and within major subgroups (*e.g.*, race, ethnicity, social class). Consideration of historical and cross-cultural comparisons. Assessment of the impact of families upon their members and the dynamics of marital and family relationships.

**SOC 513 COMMUNITY ORGANIZATION AND DEVELOPMENT. Preq.: SOC 202 or equivalent. 3(3-0).** Community organization viewed as a process of bringing about desirable changes in community life. Community needs and resources. Democratic processes in community action and principles of organization, along with techniques and procedures. Analysis of roles of lay and professional workers.

**SOC 514 DEVELOPING SOCIETIES. Preq.: Six hrs. SOC or ANT or grad. standing or PBS status. 3(3-0).** Definition of major problems posed for development sociology and exploration of social barriers and theoretical solutions for

development set forth with regard to the newly developing countries. Review of significant past strategies and presentation of main themes in current development schemes. Proposal and discussion of untested strategies for the future. Examination of these problems in their national and international contexts.

**SOC 515 DEVIANT BEHAVIOR. Preq.: Six hrs. SOC or ANT or grad. standing or PBS status. 3(3-0).** The inevitability of deviance and its social utility; cross-cultural variations in appearance and behavioral cues for labeling the deviant; descriptive and explanatory approaches to kinds and amounts of deviance in contemporary American society; social change, anomie and social disorganization theories; the process of stigmatization; formal and informal societal responses to deviance and the deviant; social action implications.

**SOC 516 SOCIAL CONTROL. Preq.: Six hrs. SOC above 200 level or grad. standing or PBS status. 3(3-0).** Examination of the need, functions, utilization and effects of both informal and formal social control mechanisms. Emphasis and critical evaluation of theoretical perspectives on social control and the empirical support for these positions.

**SOC 520 SOCIOLOGY OF RELIGION. Preq.: SOC 202 or equivalent or grad. standing or PBS status. 3(3-0).** Alternative theoretical analyses for religious beliefs, practices and organizations and the relationships between these and other social phenomena. Assessment of the utility and deficiencies of each conceptual framework through general applications and case studies. Review of major research findings in this classical field of sociology. Address of contemporary trends and issues concerning religion in society.

**SOC 523 SOCIOLOGICAL ANALYSIS OF AGRICULTURAL DEVELOPMENT. Preq.: Six hrs. SOC or grad. standing. 3(3-0).** Systematic sociological analysis of agricultural development and change, emphasizing less-developed countries. Classical and contemporary theoretical perspectives. Land tenure and agricultural development; peasants and peasant societies; peasant revolt and revolution; women and development.

**SOC 534 SOCIOLOGY OF U.S. AGRICULTURE. Preqs.: Six hrs. of SOC or grad. standing. 3(3-0).** Analysis of the structural transformation of U. S. agriculture in the 19th and 20th centuries, particularly in terms of the role of the state in agricultural development. Theoretical perspectives and research in rural sociology and the sociology of agriculture.

**SOC 541 SOCIAL SYSTEMS AND PLANNED CHANGE. Preq.: Three hrs. SOC. 3(3-0).** An examination of social systems within the framework of both func-

tional theory and conflict theory, with particular emphasis upon system change and the planning of social change.

**SOC 555 SOCIAL STRATIFICATION. Preq.: Six hrs. SOC. 3(3-0).** The theoretical background, methodological approaches and analysis of the consequences of systems of stratification. Emphasis on the static and dynamic qualities of stratification systems on relations within and between societies. Attention to the integrative and divisive quality of stratification as expressed in life styles, world views, etc.

**SOC(EB) 574 THE ECONOMICS OF POPULATION. 3(3-0).** (See economics and business.)

**SOC 590 APPLIED RESEARCH. Preq.: SOC 202 or equivalent. 3(3-0).** Studies research process with emphasis upon its application to action problems. Stress upon development of research design to meet action research needs.

**SOC 591 SPECIAL TOPICS IN SOCIOLOGY. Preq.: CI. 1-6.** An examination of current problems organized on a lecture-discussion basis. Course content varies as changing conditions require new approaches to emerging problems.

**SOC 595 PRACTICUM IN SOCIOLOGY. Preqs.: Grad. standing in the Master of Sociology program and 9 hrs. of SOC at the 500-600 level. 3-6.** Opportunity for student under the supervision of graduate advisory committee chairman and organization/agency supervisor to develop and demonstrate competency in the area of graduate specialization through application of sociological knowledge to practical problems facing the organization/agency.

***FOR GRADUATES ONLY***

**SOC 601 URBAN ECOLOGY. Preq.: SOC 509 or equivalent. 3(3-0).** An historical approach to the development of the field as well as an analysis of the present state of the field. Because of the range of subject matter subsumed under the topic of ecology, the linkages between sociology and other disciplines concerning themselves with the subject delineated and examined.

**SOC 610 FORMAL ORGANIZATIONS. Preq.: SOC 511 or equivalent or another course on organizations or CI. 3(3-0).** Sociological study of bureaucracies and other formal organizations, including theoretical roots, current theory and research, especially on organization-environment relations. Sociological assessment of psychological, economic and managerial theories of organizations.

**SOC 611 RESEARCH METHODS IN SOCIOLOGY I. Preqs.: SOC 300, ST 311 or equivalent. 3(3-0).** Issues in philosophy of science, causation, relationship of theory and research. Qualitative, experimental and survey design methodologies.

**SOC 612 SCALING AND INDEXING FOR SOCIAL AND BEHAVIORAL DATA. Preqs.: SOC 611 and ST 507 or equivalent. 3(3-0).** Extensive practical research applications including applied sampling, data collection experience, questionnaire coding design, measurement theory and practice, and introduction to data analysis.

**SOC 615 RESEARCH ON CRIME AND DEVIANCE. Preq.: SOC 515 or equivalent. 3(3-0).** Major topics include: an examination of conceptual problems and research issues and methods in the study of crime and deviance; an assessment of current research on crime causation and deviance processes; an examination of research on social control processes and agencies; and an assessment of social action and evaluative research. A variety of substantive topics dealt with in the context of the above topical areas including: delinquency, drug usage, mental illness, obesity, stuttering, suicide, prostitution, homicide and rape.

**SOC 616 CRIME AND COLLECTIVE ACTION. Preq.: SOC 515 or equivalent. 3(3-0).** Examination of organized and spontaneous community responses to criminality, other normative violations and unpopular governments. Comparison and critique of alternative theoretical explanations for emergence of legal and extra-legal punishment. Application of sociological interpretations to contemporary community and societal policy including economic, political and social consequences of crime.

**SOC 621 SOCIAL PSYCHOLOGY. Preq.: Six hrs. SOC. 3(3-0).** The objective of this course is to present the major ideas of social psychology in the context of the theoretical orientations from which they have emerged. Examination of nature and role of theory in social psychology. The social psychologies of various theorists then examined in terms of their particular approaches including the Gestalt, Field, Role, Psychoanalytic and Reinforcement orientations and combinations of these.

**SOC 625 SOCIAL-PSYCHOLOGICAL PROCESSES IN HEALTH AND ILLNESS. Preq.: SOC 505. 3(3-0) F. Alt. yrs.** Contemporary issues in the sociology of health and illness from a social psychological perspective. The social meaning of illness, social group differences in health, social causes of distress, morbidity and mortality, and measurement of health and illness.

**SOC 628 SOCIOLOGY OF GENDER. Preq.: SOC 512 or CI. 3(3-0).** Micro- and macro-level theories explaining the development and patterns of gendered behavior. Emphasis on understanding gender as a variable in research. Focus on both

how gender roles have developed and how individuals come to exhibit gender-typed behavior.

**SOC 632 CONTEMPORARY FAMILY THEORY AND RESEARCH. Preq.: SOC 512 or CI. 3(3-0).** Emphasis on contemporary research, theory and methodological techniques used by sociologists who study families. Critical examination of where the field is now and where it appears to be heading. Primarily for graduate students designing or doing research about families.

**SOC 633 THE COMMUNITY. Preq.: Six hrs. SOC. 3(3-0).** The community viewed in sociological perspective as a functioning entity. Presentation and application of a method of analysis to eight "dimensions," with emphasis on the unique types of understanding to be derived from measuring each dimension. Finally, analysis of effect of change on community integration and development.

**SOC 641 QUANTITATIVE SOCIOLOGICAL ANALYSIS. Preq.: ST 507. 3(3-0).** Application of common quantitative methodologies in sociology including multiple regression and path analysis. Emphasis on selecting appropriate analytical techniques, model estimation and sociological interpretation of findings.

**SOC 646 ADVANCED SOCIOLOGICAL ANALYSIS. Preqs.: SOC 611, ST 507 or ST 511. 3(3-0).** Examination of advanced analysis techniques adaptable to the needs of sociological research. Special attention given to causal analysis, the analysis of change, and aggregate versus individual level data analyses. Consideration of sociological examples. Attention to emerging issues and techniques.

**SOC 650 CONTEMPORARY SOCIOLOGICAL THEORY. Preq.: SOC 511 or equivalent. 3(3-0).** Works by major figures representing leading schools of sociological theory in the post-World War II period studied as primary sources. Underlying assumptions made explicit, the structure of the theory, including propositions, examined critically, and discussion of relationships with other theoretical perspectives.

**SOC 652 COMPARATIVE SOCIETIES. Preq.: Six hrs. SOC. 3(3-0).** Sociological analysis of societies around the world with particular reference to North and South America. Special emphasis given to cultural and physical setting, population composition, levels of living, relationship of the people to the land, structure and function of the major institutions and forces making for change.

**SOC 655 THEORY CONSTRUCTION. Preq.: SOC 511 or equivalent. 3(3-0).** Provides students with a capability to develop theoretical frames of reference within which to devise and implement research activities. Acquaints students with the

philosophical and disciplinary bases of theory, establishes the relationship between theory and research and enables objective evaluation of theoretical positions encountered in the literature.

**SOC 690 SEMINAR. Credits Arranged.** Appraisal of current literature; presentation of research papers by students; progress reports on departmental research; review of developing research methods and plans; reports from scientific meetings and conferences; other professional matters.

**SOC 699 RESEARCH IN SOCIOLOGY. Preq.: Consent of chair of graduate study committee. Credits Arranged.** Planning and execution of research and preparation of manuscript under supervision of graduate committee.

# Soil Science

**Degrees Offered: Ph.D., M.S., Master of Agriculture, Master of Natural Resources Administration**

**GRADUATE FACULTY**

*William Neal Reynolds Professor* E. J. Kamprath, *Head of the Department*
Box 7619, (919) 515-2643,eugene_kamprath@ncsu.edu

*William Neal Reynolds Professor and Graduate Alumni Distinguished Professor:*
S. W. Buol

*Professors:* H. L. Allen Jr., D. K. Cassel, F. R. Cox, J. W. Gilliam, T. L. Grove, L. D. King, R. Lea, G. S. Miner, G. F. Peedin, C. D. Raper Jr., E. D. Seneca, R. W. Skaggs, M. J. Vepraskas, R. J. Volk, J. B. Weber, A. G. Wollum II, J. P. Zublena;
*Professor (USDA):* D. W. Israel;
*Adjunct Professor:* R. J. McCracken;
*Professors Emeriti:* J. V. Baird, W. V. Bartholomew, M. G. Cook, G. A. Cummings, R. W. Cummings, C. B. Davey, J. W. Fitts, W. A. Jackson, C. B. McCants, P. A. Sanchez, S. B. Weed;
*Associate Professors:* A. Amoozegar, S. W. Broome, S. C. Hodges, M. T. Hoover, G. D. Hoyt, H. J. Kleiss, J. P. Lilly, R. A. McLaughlin, G. C. Naderman Jr., J. E. Shelton, T. J. Smyth, M. G. Wagger;
*Associate Professor (USDA):* S. R. Shafer;
*Associate Professor Emeritus:* R. E. McCollum;

*Assistant Professors:* L. Henry, D. Hesterberg, R. L. Mikkelsen;
*Visiting Assistant Professors:* D. E. Bandy, E. C. Fernandes;
*Assistant Professor Emeritus:* C. K. Martin;
*Senior Researcher:* W. P. Robarge;
*Visiting Scientist:* R. B. Daniels

Graduate students in soil science may specialize in the following subdisciplines: soil physics, soil chemistry; soil microbiology and biochemistry; soil fertility and plant nutrition; soil genesis, morphology and classification; soil and water management and conservation; forest soils, soil mineralogy; tropical soil management.

**Admissions Requirements**
Graduate students accepted in soil science must have a bachelor or master's degree with a major in soil science or a closely related field and with a strong background in the biological and physical sciences.

**Master's Degree Requirements**
A minor is optional, although one-third of the credits should usually be in courses outside of the department.

**Doctoral Degree Requirements**
Normally students take 30 hours credit beyond the Master's degree. A minor is optional, although one-third of the credits should usually be in courses outside of the department.

**Student Financial Support**
The department has a number of assistantships available to students who have demonstrated a high level of academic aptitute or potential. Most of the graduate assistantships are half-time.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

SSC 452 SOIL CLASSIFICATION.
SSC 461 SOIL PHYSICAL PROPERTIES AND PLANT GROWTH.
SSC(CS) 462 SOIL-CROP MANAGEMENT SYSTEMS.
SSC 472 FOREST SOILS.

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**SSC 501 TROPICAL SOILS: CHARACTERISTICS AND MANAGEMENT. Preq.: Six credits in SSC. 3(3-0) S. Alt. yrs.** Characteristics of the tropical environment. Distribution and classification of tropical soils. Soil-plant relationships in the tropics. Soil management systems with emphasis on shifting cultivation,

flooded rice production, subsistence farming and tropical pasture management.

**SSC 511 SOIL PHYSICS. Preqs.: SSC 200, PY 212. 4(3-3) F.** Soil physical properties and theory of selected instrumentation to measure them. Soil solids, soil water, air and heat. Transport processes and the energy concept of soil and water.

**SSC 520 SOIL AND PLANT ANALYSIS. Preqs.: PY 212; CH 315; at least three soils courses including SSC 341 or CI. 3(2-3) S. Alt. yrs.** Theory and advanced principles of the utilization of chemical instruments to aid research on the heterogeneous systems of soils and plants.

**SSC 522 SOIL CHEMISTRY. Preqs.: SSC 200, one yr. of general inorganic chemistry. 3(3-0) S.** A consideration of the chemical and colloidal properties of clay and soil systems, including ion exchange and retention, soil solution reactions, solvation of clays and electrokinetic properties of clay-water systems.

**SSC(MB) 532 SOIL MICROBIOLOGY. Preqs.: MB 401; CH 220 or CI. 4(3-3) S.** Soil as a medium for microbial growth, the relation of microbes to important mineral transformations in soil, the importance of biological equilibrium and significance of soil microbes to environmental quality.

**SSC 541 SOIL FERTILITY. Preq.: SSC 341. 3(3-0) F.** Soil conditions affecting plant growth and the chemistry of soil and fertilizer interrelationships. Factors affecting the availability of nutrients. Methods of measuring nutrient availability.

**SSC 551 SOIL MORPHOLOGY, GENESIS AND CLASSIFICATION. Preqs.: MEA 120, SSC 200, SSC 341. 3(3-0) F.** Morphology: Chemical, physical and mineralogical parameters useful in characterizing soil. Genesis: soil-forming factors and processes. Classification: historical development and present concepts of soil taxonomy with particular reference to worldwide distribution of great soil groups as well as discussions of logical bases of soil classification.

**SSC 553 SOIL MINERALOGY. Preqs.: SSC 200, SSC 341, MEA 330. 3(2-3) F. Alt. yrs.** Composition, structure, classification, identification, origin, occurrence and significance of soil minerals with emphasis on primary weatherable silicates, layer silicate clays and sesquioxides.

**SSC 560 ADVANCED SOIL MANAGEMENT. Preqs.: SSC 200, 341. 3(3-0) Sum. Alt. yrs.** Studies of soil characteristics in the coastal plain, piedmont and mountain areas of North Carolina. Discussion of management practices that should be associated with various soils for different types of enterprises. Two overnight field trips required.

**SSC 562 ENVIRONMENTAL APPLICATIONS OF SOIL SCIENCE. Preq.: SSC 200 or equivalent. 3(2-3) S.** Identification and evaluation of basic factors influencing movement of potential pollutants through soil and their underlying strata. Development of an understanding of the processes of soil and site evaluation for waste disposal and transport of pollutants through soils.

**SSC(FOR) 577 CONSERVATION AND SUSTAINABLE DEVELOPMENT I: CONCEPTS AND METHODS. Preq.: CI. 3(3-0) F.** Agronomic, ecological and economic concepts of sustainability, with emphasis on application in developing countries; forest, soil and wildlife resources; models in conservation biology; historical, cultural and sociological perspectives; policy analysis. Offered as part of the program of the Center for World Environment and Sustainable Development.

**SSC(FOR) 578 CONSERVATION AND SUSTAINABLE DEVELOPMENT II: INTEGRATED PROBLEM SOLVING. Preq.: FOR (SSC) 577. 3(3-0) S.** Approaches to reconciling conservation and development with emphasis on developing countries. Case studies; project formulation, implementation and evaluation; institutional policy formation; conflict resolution. Offered as part of the program of the Center for World Environment and Sustainable Development.

**SSC(FOR) 581 AGROFORESTRY. Preq.: CI. 3(3-0) S.** Global agroforestry systems across diverse agroecological zones and under an array of socioeconomic conditions. Methods for selecting sustainable forest, agricultural and silvipastoral crops that draw upon production agriculture and forestry, community and ecosystem ecology, sociology and economics. Extension of research results to the rural poor in developing countries.

**SSC 590 SPECIAL PROBLEMS. Preq.: SSC 200. Credits Arranged. F,S.** Special problems in various phases of soils. Emphasis placed on review of recent and current research.

*FOR GRADUATES ONLY*

**SSC 621 ADVANCED SOIL CHEMISTRY. Preqs.: SSC 522, CH 530 or equivalent. 3(3-0) F. Alt. yrs.** The application of chemical thermodynamics and kinetics to under standing soil systems, solution equilibria, precipitation and dissolution, complexation, reduction-oxidation, surface-solute interactions and chemical transport. Application of chemical speciation models.

**SSC(CS,HS) 625 HERBICIDE CHEMISTRY. 1(3-0) S. (See crop science.)**

**SSC(CS,HS) 627 HERBICIDE BEHAVIOR IN SOIL AND WATER. 1(3-0) S.** (See crop science.)

**SSC(BAE) 671 THEORY OF DRAINAGE–SATURATED FLOW. 3(3-0) F. Alt. yrs.** (See biological and agricultural engineering.)

**SSC 672 SOIL PROPERTIES AND PLANT DEVELOPMENT. Preqs.: BCH 551, SSC 522 or equivalent. 3(3-0) S. Alt. yrs.** An examination of the interrelationships of soil properties and plant characteristics which regulate inorganic ion accumulation and dry matter production in higher plants.

**SSC(FOR) 673 FOREST PRODUCTIVITY: EDAPHIC RELATIONSHIPS. 3(2-3) F. Alt. yrs.** (See forestry.)

**SSC(BAE) 674 THEORY OF DRAINAGE–UNSATURATED FLOW. 3(3-0) S. Alt. yrs.** (See biological and agricultural engineering.)

**SSC 690 SEMINAR. Preq.: Grad. standing in SSC. 1(1-0) F,S.** A maximum of two semester hours allowed toward the master's degree, but any number toward the doctorate. Scientific articles, progress reports in research and special problems of interest to soil scientists reviewed and discussed.

**SSC 693 COLLOQUIUM IN SOIL SCIENCE. Preq.: Grad. standing in SSC. Credits Arranged. F,S.** Seminar-type discussions and lectures on specialized and advanced topics in soil science.

**SSC 699 RESEARCH. Preq.: Grad. standing in SSC. Credits Arranged. F,S.** A maximum of six semester hours allowed toward the master's degree but any number towards the doctorate.

# Special Education

For a listing of graduate faculty and program information, see curriculum and instruction.

# Statistics

**Degrees Offered: Ph.D., M.S., Master of Statistics;** optional program concentrations in environmental and industrial statistics; master's and Ph.D. co-majors.

## GRADUATE FACULTY

*Professor* J. F. Monahan, ***Interim Head of the Department***
*Professor* T. M. Gerig, ***Director of Graduate Programs***
Box 8203, (919) 515-2528, gerig@stat.ncsu.edu

***Graduate Alumni Distinguished Professor:*** B. B. Bhattacharyya
***William Neal Reynolds Professor:*** B. S. Weir

***Professors:*** R. L. Berger, B. B. Bhattacharyya, P. Bloomfield, D. D. Boos, C. Brownie, D. A. Dickey, E. J. Dietz, F. G. Giesbrecht, H. J. Gold, T. Johnson, K. H. Pollock, C. H. Proctor, C. P. Quesenberry, J. O. Rawlings, D. L. Ridgeway, D. L. Solomon, W. H. Swallow, J. L. Wasik;
***Adjunct Professors:*** M. W. Anderson, J. R. Chromy, A. L. Finkner, J. H. Goodnight, P. D. Haaland, N. L. Kaplan, P. H. Morgan, R. L. Obenchain;
***Professors Emeriti:*** C. C. Cockerham, A. H. Grandage, R. J. Hader, D. W. Hayne, D. D. Mason, R. J. Monroe, L. A. Nelson, J. A. Rigney, R. G. Steel, H. R. van der Vaart, O. Wesler;
***Associate Professors:*** M. Davidian, S. P. Ellner, D. W. Nychka, S. G. Pantula, T. W. Reiland, C. E. Smith, L. A. Stefanski;
***Adjunct Associate Professors:*** B. G. Cox, W. W. Piegorsch, T. K. Pierson, M. V. Smith;
***Associate Professor Emeritus:*** A. C. Linnerud;
***Assistant Professors:*** M. L. Gumpertz, J. M. Hughes-Oliver, T. B. Kepler, J. Lu, J. L. Thorne;
***Research Assistant Professor:*** S. Zeng;
***Adjunct Assistant Professors:*** P. M. Dixon, J. S. Kimbell, M. W. Lutz

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** W. R. Atchley, M. M. Goodman, A. R. Hall, J. F. Selgrade, V. K. Smith, M. W. Suh;
***Associate Professor:*** T. H. Emigh, J. F. Gilliam, G. G. Wilkerson

**Admission Requirements**
The written statement should describe the applicant's academic and career goals as well as special interests in the area of statistics. GRE Subject Test scores in mathematics are not required but may be submitted.

The well-prepared applicant to the department's master's programs has good grades in a three-semester calculus sequence, a two-semester advanced calculus sequence, a semester of linear algebra and a two-semester sequence in probability and statistics. Some of these courses many be taken as part of the program but this may result in lengthening the stay. Admission to the Ph.D. program is granted to those who have been admitted to the master's program and have passed the basic comprehensive (qualifying) examination at the Ph.D. level. Individuals applying for fall enrollment and who wish to be considered for financial aid should have their completed applications in by no later than March 1 for fall enrollment or October 15 for spring. Applications arriving after that will be considered but may be assigned lower priority.

**Master's Degree Requirements**
All master's programs in statistics require a minimum of 34 credit hours, of which 12 are first-year core (ST 512, ST 521,522 and ST 681), one is supervised consulting (ST 595), and at least nine are statistics and/or supporting electives. The remaining 12 hours are program dependent.

**Doctoral Degree Requirements**
The Ph.D. program in statistics requires 22 credit hours beyond the master's, of which 12 are Ph.D. core (ST(MA) 617,618, ST 637 and ST 682), one is supervised consulting (ST 595), six are Ph.D.-level statistics electives, and three are supporting electives. Requirements for co-majors are individually tailored.

**Student Financial Support**
Departmental assistantships and fellowships are awarded each year on a competitive basis. Fellowships and supplements are provided through the department's Gertrude M. Cox Fellowship Fund. Approximately 30 teaching assistantships and 30 research assistantships and traineeships are available along with 10 graduate research internships supported by local industries.

**Other Relevant Information**
With a large graduate faculty representing virtually all major statistical specializations, the department is recognized as a world leader in graduate education and research in statistics. Its applied orientation sets it apart from most other departments in the country, offering education to those wishing to pursue careers as consulting

statisticians in industry and government, as well as to those seeking careers in research and teaching.

Areas of research specialization of the faculty and advanced graduate students include time series, econometrics, statistical genetics and ecology, experiment design and analysis, sampling, environmental applications, statistical process and quality control, biomathematics, statistical computing, nonparametric regression, robust and nonparametric inference, mathematical programming, Bayesian inference, multivariate analysis, decision theory and stochastic processes.

The department also houses the statistical genetics research program, an internationally respected research group of faculty, post-doctoral fellows and graduate students. Long-standing research projects in environmental and industrial statistics provide research and funding opportunities for graduate students.

Departmental computation facilities consist of two computing laboratories. The Statistics Instructional Computing Laboratory (SICL) comprises twenty-three Sun workstations organized in classroom format and is used for instruction and course labs. The Statistics Research Computing and Information System (SRCIS) is a research facility maintained for the use of statistics graduate students. SRCIS consists of 9 high-speed, Unix-based and 2 SUN SPARCserver 10s are available for CPU intensive jobs. Personal computers are also available in the SRCIS facility, as are a variety of high-resolution output peripherals. All departmental systems are connected via an ethernet network to the campus network. Campus resources include an IBM 3090 (Model 180J) running MVS, access to D. H. Hill Library, as well as full access to world-wide networking and information resources through the Internet.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**ST 421, 422 INTRODUCTION TO MATHEMATICAL STATISTICS.**
**ST 430 INTRODUCTION TO REGRESSION ANALYSIS.**
**ST 431 INTRODUCTION TO EXPERIMENTAL DESIGN.**
**ST 432 INTRODUCTION TO SURVEY SAMPLING.**
**ST 435 STATISTICAL METHODS FOR QUALITY AND PRODUCTIVITY IMPROVEMENT.**
**ST 445 INTRODUCTION TO STATISTICAL COMPUTING AND DATA MANAGEMENT.**
**ST 493 SPECIAL TOPICS IN STATISTICS.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ST 505 APPLIED NONPARAMETRIC STATISTICS. Preq.: ST 372 or ST 511. 3(3-0) S.** Statistical methods that require relatively mild assumptions about the form of the population distribution. Hypothesis testing, point and interval estimation and multiple comparison procedures for a variety of statistical problems.

**ST(ZO) 506 SAMPLING ANIMAL POPULATIONS. Preq.: ST 512. 3(3-0) F. Alt. yrs.** Statistical methods applicable to sampling of wildlife populations, including capture-recapture, removal, change in ratio, quadrat and line transect sampling. Emphasis on model assumptions and study design.

**ST 507 STATISTICS FOR THE BEHAVIORAL SCIENCES I. 3(3-0) F.** The use of descriptive and inferential statistics in behavioral science research. Methods for describing and summarizing data presented, followed by procedures for estimating population parameters and testing hypotheses concerning the summarized data.

**ST 508 STATISTICS FOR THE BEHAVIORAL SCIENCES II. Preq.: ST 507 or CI. 3(3-0) S.** Statistical design principles in behavioral science research. Presentation of use of a statistical model to represent the structure of data collected from a designed experiment or survey study. Opportunities provided for use of a computer to perform analyses of data, to evaluate the proposed statistical model and to assist in post-hoc analysis procedures. Least squares principles used to integrate the topics of multiple linear regression analysis, the analysis of variance and analysis of covariance.

**ST 511 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES I. Preq.: ST 311 or grad. standing. 3(3-0) F,S.** Statistical models and use of samples; variation, statistical measures, distributions, tests of significance, analysis of variance and elementary experimental design, regression and correlation, chi-square.

**ST 512 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES II. Preq.: ST 511. 3(3-1) F,S.** Covariance, multiple regression, curvilinear regression, concepts of experimental design, factorial experiments, confounded factorials, individual degrees of freedom and split-plot experiments. Computing laboratory addressing computational issues and use of statistical software.

**ST 514 STATISTICS FOR MANAGEMENT AND SOCIAL SCIENCES II. Preq.: ST 507. 3(3-0) F,S.** Linear regression, multiple regression and concepts of designed experiments in an integrated approach, principles of the design and analysis of sample surveys, use of computer for analysis of data.

**ST 515, 516 EXPERIMENTAL STATISTICS FOR ENGINEERS. Preq.: [515] ST 361 or grad. standing; [516] ST 515. 3(3-0) F,S.** General statistical concepts and techniques useful to research workers in engineering, textiles, wood technology, etc. Probability distributions, measurement of precision, simple and multiple regression, tests of significance, analysis of variance, enumeration data and experimental designs.

**ST 517 APPLIED LEAST SQUARES. Preq.: ST 512. 3(3-0) F.** Least squares estimation and hypothesis testing procedures for linear models. Consideration of regression, analysis of variance and covariance in a unified manner requiring no extensive mathematical background. Emphasis on the use of the computer to apply these techniques to experimental (including unequal cell sizes) and survey situations.

**ST 518 APPLIED TIME SERIES ANALYSIS. Preq.: ST 512. 3(3-0) F.** The use of statistical methods for analyzing and forecasting data observed over time. Trigonometric regression, periodogram/spectral analysis. Smoothing. Autoregressive moving average models. Regression with autocorrelated errors. Linear filters and bivariate spectral analysis. Stress on methods and applications; software implementations described and used in assignments.

**ST 519 APPLIED MULTIVARIATE STATISTICAL ANALYSIS. Preq.: ST 512. 3(3-0) S.** The use of multivariate statistical methods in the analysis of data collected in experiments and surveys. Multivariate analysis of variance, discriminant analysis, canonical correlation analysis and principal components analysis. Emphasis upon use of a computer to perform the multivariate statistical analysis calculations.

**ST 521 STATISTICAL THEORY I. Coreqs.: MA 425 or MA 511 and MA 405. 3(2-2) F.** The probability tools for statistics: description of discrete and absolutely continuous distributions, expected values, moments, moment generating functions, transformation of random variables, marginal and conditional distributions, independence, order statistics, multivariate distributions, concept of random sample, derivation of many sampling distributions.

**ST 522 STATISTICAL THEORY II. Preq.: ST 521; Coreq.: MA 426 or MA 512. 3(2-2) S.** General framework for statistical inference. Point estimators: biased and unbiased, minimum variance unbiased, least mean square error, maximum likelihood and least squares, asymptotic properties. Interval estimators and tests of hypotheses: confidence intervals, power functions, Neyman-Pearson lemma, likelihood ratio tests, unbiasedness, efficiency and sufficiency.

**ST 531 DESIGN OF EXPERIMENTS. Preq.: ST 512. 3(3-0) F.** Completely randomized, randomized complete block and Latin square designs and the basic concepts in the techniques of experimental design. Designs and analysis methods in factorial experiments, confounded factorials, response surface methodology, change-over design, split-plot experiments and incomplete block designs. Examples used to illustrate application and analysis of these designs.

**ST 535 STATISTICAL PROCESS CONTROL. Preqs.: ST 515; students must have access to an MS-DOS PC. 3(3-1) F.** Modern methods of statistical process

control for graduate students with a calculus-level course in engineering statistics. Classical and modern methods of SPC in the framework of the Deming quality management philosophy emphasizing continuous process improvement. Orientation toward the use of PC-class computers for computations.

**ST 536 OFF-LINE QUALITY CONTROL. Preq.: ST 421 or ST 515. 3(3-0) S.** Off-line quality control methods for graduate students with a calculus-level first course in engineering statistics. About one third of lectures presentation of material from the area of sampling inspection with emphasis upon using PCs for computations. Remainder of course presentation of material from design of experiments especially important in industrial applications: factorial experiments, orthogonal arrays, Plackett-Burman plans, Box-Behnken designs, response surfaces, design optimality, variability analysis.

**ST 537 LIFE-TESTING AND RELIABILITY. Preq.: ST 422 or ST 516. 3(3-0) F.** Statistical methods for analyzing life-testing data and accessing system reliability. Grouped and time-censored data, order statistics. Classical and Bayesian inference for univariate and multivariate exponential, Weibull, lognormal and gamma distributions. Experimental designs and sampling plans for accelerated testing and burn-in procedures. Taguchi's reliability improvement philosophy. Field performance and software reliability analysis.

**ST(MA) 541 THEORY OF PROBABILITY I. 3(3-0) F.** (See mathematics.)

**ST(MA) 542 INTRODUCTION TO STOCHASTIC PROCESSES. Preqs.: MA 405 and MA(ST) 541 or ST 521. 3(3-0) S.** Markov chains and Markov processes, Poisson process, birth and death processes, queuing theory, renewal theory, stationary processes, Brownian motion.

**ST 550 CATEGORICAL AND CENSORED DATA ANALYSIS. Preqs.: ST 512 and ST 522. 3(3-0) S.** Statistical models and methods for categorical responses including logistic regression and generalized linear models, probit analysis and log-linear models. Censored data methods include Kaplan-Meier estimation, accelerated life regression and proportional hazards regression. Discussion of software implementation of methods and usage in assignments.

**ST(ECG) 561 INTERMEDIATE ECONOMETRICS. 3(3-0) S.** (See economics.)

**ST(TOX) 563 STATISTICAL PROBLEMS IN TOXICOLOGY. Preq.: ST 511. 3(3-0) S. Alt. yrs.** Statistical issues arising in toxicological research. basic Experimental design and analysis methods, introduction to epidemology, nonpara-

metric methods, dose-response methods, teratology and short-term mutagenicity studies, long-term carcinogenicity studies and risk assessment.

**ST 564 APPLIED SPATIAL STATISTICS. Preq.: ST 512. 3(3-0) S.** Graphical and quantitative description of spatial data. Kriging, block kriging and cokriging. Common variogram models. Analysis of mean-nonstationary data by median polish and universal kriging. Spatial autoregressive models, estimation and testing. Spatial sampling procedures. Use of existing software with emphasis on analysis of real data from the environmental, geological and agricultural sciences.

**ST (GN) 565 GENETIC DATA ANALYSIS. Preqs.: ST 430 and GN 411. 3(3-0) S. Alt. yrs.** Analysis of discrete data, illustrated with genetic data on morphological characters allozymes, restriction fragment length polymorphisms and DNA equences. Maximum likelihood estimation, including iterative procedures. Numerical resampling. Development of statistical techniques for characterizing genetic disequilibrium and diversity. Measures of population structure and genetic distance. Construction of phylogenetic trees. Finding alignments and similarities between DNA sequences. Locating genes with markers.

**ST(BMA,MA) 571 BIOMATHEMATICS I. 3(3-0) F.** (See biomathematics.)

**ST(BMA,MA) 572 BIOMATHEMATICS II. 3(3-0) S.** (See biomathematics.)

**ST(BMA,OR) 575 DECISION ANALYTIC MODELING. Preqs.: MA 421 or ST 421 plus ST 511 or ST 516. 4(3-2) F. Alt. yrs.** Analysis of decision problems involving risk and uncertainty. Modeling decision process; Bayesian probability analysis, use of information, and subjective probability; utility theory and multiattribute utility assessment; dynamics of interacting with decision makers and subject matter specialists; decision trees, influence diagrams and other tools to assist in modeling decision problems. Laboratory develops skill in implementing methodology.

**ST 581 ROBUST AND NONPARAMETRIC STATISTICS. Preq.: ST 522. 3(3-0) S. Alt. yrs.** Theory and methods for standard inference problems where the normal distribution may not correctly describe error distribution. Topics include rank and order statistics, permutation methods, bootstrap, jackknife, Pitman efficiency, influence curve, breakdown point, M-estimation and minimum distance estimation.

**ST 583 INTRODUCTION TO STATISTICAL DECISION THEORY. Preq.: ST 522. 3(3-0) F. Alt. yrs.** Zero sum two-person games and statistical inference. Bayesian methods and orthodox statistical estimation and testing; minimax decision rules; empirical Bayes procedures; Bayes sequential decision procedures.

**ST 591 SPECIAL PROBLEMS. Preq.: CI. 1-3 F,S,Sum.** Development of techniques for specialized cases, particularly in connection with thesis and practical consulting problems.

**ST 595 STATISTICAL CONSULTING. Preqs.: ST 512 and ST 522. 1(1-1) F,S,Sum.** Participation in regularly scheduled supervised statistical consulting sessions with faculty member and client. Consultant's report written for each session. Regularly scheduled meetings with course instructor and other student consultants to present and discuss consulting experiences.

*FOR GRADUATES ONLY*

**ST(MA,OR) 606 NONLINEAR PROGRAMMING. Preqs.: OR(IE,MA) 505 and MA 425 or equivalent. 3(3-0) F.** An advanced mathematical treatment of the analytical and algorithmic aspects of finite dimensional nonlinear programming. It includes an examination of the structure and effectiveness of computational methods for unconstrained and constrained minimization. Special attention directed toward current research and recent developments in the field.

**ST(BMA,MA,OR) 610 STOCHASTIC MODELING. 3(3-0) S. Alt. yrs.** (See biomathematics.)

**ST 613 TIME SERIES ANALYSIS: TIME DOMAIN. Preqs.: ST 512 and ST 522. 3(3-0) S. Alt. yrs.** Estimation inference for coefficients in auto-regressive, moving average and mixed models and large sample. Distribution theory for autocovariances and their use in identification of time series models. Stationarity and seasonality. Extensions of theory and methods to multiple series including vector autoregressions, transfer function models, regression with time series errors, state space modeling.

**ST 614 TIME SERIES ANALYSIS: FREQUENCY DOMAIN. Preqs.: ST 512 and ST 522. 3(3-0) S. Alt. yrs.** Theory and methods of time series analysis from the frequency point of view. Harmonic analysis, complex demodulation and spectrum estimation. Frequency domain structure of stationary time series and space-time processes. Sampling distributions of commonly used statistics.

**ST(MA) 617, 618 MEASURE THEORY AND ADVANCED PROBABILITY. Preqs.: [617] MA 426; ST 521 or MA(ST) 541 or equivalent; [618] ST 617. 3(3-0) F,S.** Modern measure and integration theory in abstract spaces. Probability measures, random variables, expectations. Distributions and characteristic functions. Modes of convergence. Independence, zero-one laws, laws of large num-

bers, three-series theorem. Central limit problem. Conditional expectations, martingales and martingale convergence theorems.

**ST 623 STATISTICS IN PLANT SCIENCE. Preq.: ST 512. 3(3-1) F.** Planning, establishing and executing field and greenhouse experiments. Size, shape and orientation of plots; border effects; estimation of size of experiments for specified accuracy; subsampling plots and yields for laboratory analysis; combining data from a series of years and/or loca-tions; rotation experiments; repeated measures data; multiple comparisons in variety trial results; selection of predictors in multiple regression; introduction to interspecies and intraspecies plant competition experiments and models.

**ST(GN) 626 STATISTICAL CONCEPTS IN GENETICS. Preq.: GN 506; Coreq.: ST 512. 3(3-0) S. Alt. yrs.** Migration, mutation, selection, drift, linkage, mating system and other processes that bear on rates of change in population frequencies, means and variances; magnitude and nature of genotypic and nongenotypic variability and their role in alternative procedures of plant and animal breeding; experimental and statistical approaches to the analysis of quantitative inheritance.

**ST 631 THEORY OF SAMPLING APPLIED TO SURVEY DESIGN. Preqs.: MA 214; ST 512. 3(3-0) F.** Principles for interpretation and design of sample surveys. Estimator biases, variances and comparative costs. Simple random sample, cluster sample, ratio estimation, stratification, varying probabilities of selection. Multi-stage, systematic and double sampling. Response errors.

**ST 637 ADVANCED STATISTICAL INFERENCE. Preqs.: ST 522, ST 617. 3(3-0) S.** Treatment of the classical areas of statistical inference, estimation and hypothesis testing, at the measure-theoretical level. Emphasis upon treatment of these areas in depth.

**ST 639 LARGE SAMPLE THEORY. Preq.: ST 522. 3(3-0) F. Alt. yrs.** Use of classical probability theorems to prove consistency and asymptotic distribution results for a wide variety of sample statistics. Examples of such statistics include maximum likelihood estimators, quadratic form test statistics and regression coefficients.

**ST 645 STATISTICAL COMPUTING. Preq.: ST 681. 3(3-0) F. Alt. yrs.** The intent of the course is to provide the statistician with the computational tools for statistical research and applications using digital computing machinery. Topics to include random number generation and Monte Carlo methods, regression computations and application to statistical methods of optimization, sorting and Fast Fourier transform.

**ST(ECG) 651 ECONOMETRICS. 3(3-0) F.** (See economics.)

**ST(ECG) 652 TOPICS IN ECONOMETRICS. 3(3-0) S.** (See economics.)

**ST 671 ADVANCED ANALYSIS OF VARIANCE AND VARIANCE COMPONENTS. Preqs.: ST 512, ST 681. 3(3-0) S. Alt. yrs.** Expected mean squares, exact and approximate tests of hypotheses for balanced and unbalanced data sets. Fixed, mixed and random models. Randomization theory. Estimation of variance components using regression, MINQUE and general quadratic unbiased estimation theory.

**ST 674 ADVANCED TOPICS IN CONSTRUCTION AND ANALYSIS OF EXPERIMENTAL DESIGNS. Preqs.: ST 512, ST 681. 3(3-0). S. Alt. yrs.** Construction and analysis of multifactor designs, factorials, fractional factorials, balanced incomplete block designs, Latin squares, orthogonal arrays of strength d and response surface designs. Fractionating mixed level factorials, confounding and blocking techniques, study of robustness of designs to loss of design point.

**ST 681 LINEAR MODELS AND VARIANCE COMPONENTS. Preqs.: MA 405, ST 521; Coreq.: ST 522. 3(2-2) S.** Theory of estimation and testing in full and non-full rank linear models. Normal theory distributional properties. Least squares principle and the Gauss-Markoff theorem. Estimability and properties of best linear unbiased estimators. General linear hypothesis. Application of dummy variable methods to elementary classification models for balanced and unbalanced data. Analysis of covariance. Variance components estimation for balanced data.

**ST 682 MULTIVARIATE LINEAR MODELS AND NONLINEAR MODELS. Preqs.: ST 512, ST 681. 3(3-0) F.** Inference for the multivariate general linear model. Normal theory distributional properties. Wishart matrices, Wilks' lambda criterion and Roy's maximum root test. Univariate and multivariate nonlinear models. Modified Gauss-Newton method for obtaining estimates. Asymptotic properties of estimators. Inference through the likelihood ratio test, the Lagrange multiplier test and the Wald test. Applications using computer implementation.

**ST 683 MULTIVARIATE ANALYSIS. Preqs.: ST 522 and ST 682. 3(3-0) S. Alt. yrs.** Survey of multivariate statistical theory. Multivariate distributions including the multinormal, Wishart, Hotelling's T, Fisher-Roy-Hsu, Wilks' $\Lambda$ and multivariate Beta distributions. Applications of maximum likelihood estimation, likelihood ratio testing and the union-intersection principle. Development of the theory of Hotelling's T tests and confidence sets, discriminant analysis, canonical correlation, multivariate analysis of variance and principal components.

**ST 691 ADVANCED SPECIAL PROBLEMS. Preqs.: ST 512, ST 681. 1-3 F,S,Sum.** Any new advance in the field of statistics which can be presented in lecture series as unique opportunities arise.

**ST 694 SEMINAR. 1(1-0) F,S.**

**ST 699 RESEARCH. Credits Arranged. F,S,Sum.**

# Technical Communications

For a listing of graduate faculty and program information, see English.

# Technology Education

For a listing of graduate faculty and program information, see occupational education.

# Textile and Apparel Management

**Degrees Offered: M.S., Master of Textiles**

**GRADUATE FACULTY**

*Professor* T. J. Little, ***Head of the Department***
***Associate Professor*** P. Banks-Lee, ***Director of Graduate Programs***
Box 8301, (919) 515-6633, pbanks_lee@ncsu.edu

***Klopman Distinguished Professor:*** S. C. Winchester Jr.

***Professors:*** R. A. Barnhardt, S. K. Batra, G. A. Berkstresser III, R. A. Donaldson, A. H. El-Shiekh, M. W. Suh;
***Visiting Professors:*** E. M. McPherson;
***Adjunct Professor:*** D. S. Brookstein;
***Professors Emeriti:*** A. B. Moss, W. C. Stuckey Jr.;
***Associate Professors:*** T. K. Ghosh, T. F. Gilmore, P. B. Hudson, W. Oxenham, M. L. Robinson Jr., G. W. Smith;
***Visiting Research Associate Professor:*** H. A. Davis;
***Adjunct Associate Professors:*** R. W. Dent, N. A. Hunter, D. M. Powell, P. E. Sasser;
***Assistant Professors:*** H. H. A. Hergeth, G. L. Hodge, A. M. Seyam;

The Department of Textile and Apparel Management offers the degree of Master of Science in Textiles with specialization in textile management and technology and the professional degree of Master of Textiles. The department specializes in the disciplines of textile management, apparel management, textile technology, textile design, integrated manufacturing systems, textile marketing, quality control and modeling of the textile and apparel pipeline. Fundamental research in yarn and fabric mechanics, machine monitoring and material properties is also conducted in the department.

**Admission Requirements**
Students applying to this department should have or be able to develop strong quantitative skills. Students interested in management areas should have background in market analysis, quantitative management and quality management. Students should have a minimum of 24 course hours in advanced mathematics and sciences in their undergraduate degree.

**Master's Degree Requirements**
Completion of the professional degree, Master of Textiles, requires a minimum of 33 course hours.

**Student Financial Support**
Financial aid in the form of assistantships is normally available for all full-time Master of Science students.

**Other Relevant Information**
The Department of Textile and Apparel Management currently houses the National Science Foundation's Center for Nonwoven Technology. This Centers allows students to conduct research in new technologies for nonwoven fabric manufacture. Participation in the National Textile Center allows students to conduct research in a variety of management, manufacturing, technology and engineering applications.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**TAM(TES) 520 YARN PROCESSING DYNAMICS. Preqs.: MA 301 and CI or grad. standing. 3(2-2) F.** Theoretical analysis of the dynamics and machine-fiber interactions of such functions as opening, cleaning, carding actions, fiber attenuation, ring spinning, open-end spinning, texturing and winding. The role of fiber placement, cohesion and lubrication on yarn processing and properties. Laboratory experiments designed to verify the analysis discussed in the lectures.

**TAM 530 TEXTILE QUALITY CONTROL. Preq.: TAM 330 OR CI. 3(3-0) S.** Quality control systems for textile operations with emphasis on sampling plans

for attributes and variables and on interpretation of data as related to identifying sources of product variability.

**TAM 541 THEORY AND PRACTICE OF KNITTED FABRIC PRODUCTION AND CONTROL. Preqs.: TT 370 and CI. 3(3-0) F.** The technology and control systems for manufacturing simple and complex knitted fabrics; control and monitoring of yarn feeding systems; influence of yarn, machine, finishing and fabric structure on the fabric aesthetics, physical and mechanical properties; optimization of fabric properties and machine productivity, including costing; problems of jacquard fabric processing and control.

**TAM 549 WARP KNIT ENGINEERING AND STRUCTURAL DESIGN. Preq.: TT 443. 3(3-0) S.** Engineering analysis of tricot and raschel machinery. Design of yarn let-off and fabric take-up mechanisms. Studies of fabric production techniques and quality control systems. Theory of production optimization and the properties of fabrics. Complex geometrical loop models and their application.

**TAM(TES) 555 PRODUCTION MECHANICS AND PROPERTIES OF WOVEN FABRICS. Preqs.: MA 301 and CI or grad. standing. 3(2-2) S.** The interrelations between the mechanics of production and mechanical properties of woven fabrics; unit operations required to prepare yarns for weaving and the mechanisms employed in weaving; fabric structure, geometry and mechanical properties; designing for specific fabric properties.

**TAM(BUS) 585 MARKET RESEARCH IN TEXTILES. Preq.: TAM (EB) 482. 3(3-0) S.** A study and analysis of the quantitative methods employed in market research in the textile industry. The function of market research and its proper orientation to management and decision making.

**TAM 589 SPECIAL STUDIES IN TEXTILE MANAGEMENT AND TECHNOLOGY. Preq.: Sr. or grad. standing. 1-4 F,S.** New or special course on developments in textile management and technology. Specific topics and prerequisites vary.

**TAM 590 SPECIAL PROJECTS IN TEXTILE MANAGEMENT AND TECHNOLOGY. Preqs.: Sr. standing or grad. standing, CI. 2-3 F,S,Sum.** Advanced studies on current problems of the industry, independent investigations, seminars and technical presentations, both oral and written.

*FOR GRADUATES ONLY*

**TAM 610 YARN PRODUCTION/PROPERTIES: ADVANCED TOPICS. Preq.: TAM(TES) 520. 3(2-3) F. Alt yrs.** Lectures and seminar discussions on recent developments in yarn manufacturing. Group research into topical areas of yarn production and properties.

**TAM 621 ADVANCED TEXTILE TESTING. Preqs.: TAM 530; ST 421 or CI. 3(2-2) S.** Design of textile laboratories required for specific needs; experimental design and performance of tests; analysis of data relating to industrial problems; specialized physical tests; interlaboratory correlations; development of standardized test methods.

**TAM(TES) 640 PHYSICAL AND MECHANICAL PROPERTIES OF KNITTED FABRIC. Preq.: TES 541. 3(3-0) Alt. S.** Seminar discussions of research literature on studies of the physical and mechanical properties of knitted fabrics.

**TAM(TES) 651, 652 FABRIC DEVELOPMENT AND CONSTRUCTION. 3(1-4) F,S.** Application of advanced technology to the development and construction of woven fabrics.

**TAM(TES) 663 MECHANICS OF TWISTED STRUCTURES. Preq.: TES 561 or equivalent. 3(3-0) S. Odd yrs.** The basic mechanics of fibrous assemblies. Geometry and mechanics of twisted structures (yarns, cords, braids, etc.) and the translation of fiber properties into structural behavior.

**TAM(TES) 664 MECHANICS OF FABRIC STRUCTURES. Preq.: TES 561 of equivalent. 3(3-0) S. Even yrs.** Analysis of the geometry and behavior of woven, knitted and nonwoven fabrics under various stress conditions and end use applications.

**TAM 680 SPECIAL PROJECTS IN TEXTILE MANAGEMENT. Preq.: TAM (ECG) 585. 1-3 F,S,Sum.** Special studies in textile management covering current problems of the industry, independent investigations, seminars and technical presentations, both oral and written.

**TAM 686 ADVANCED TEXTILE LABOR MANAGEMENT SEMINAR. Preq.: TAM 487 or CI. 3(3-0) F,S.** Advanced labor management problems in the textile industry, with particular emphasis directed toward the application of the Occupational Safety and Health Act.

**TAM 687 COMPETITIVE STRATEGY AND PLANNING FOR THE TEXTILE FIRM. Preq.: Completion of 18 hrs. in a graduate degree program, of which at least 6 hrs. must be in economics and related courses at the 500 level or higher. 3(3-0). F.** Elements of competitive strategy and planning methods within the textile complex with emphasis on concepts of strategy in a mature industry, defining business in a global industry, resource allocation through strategic planning methods and implementing strategy in single business and multi-business firms.

**TAM 697 INDEPENDENT STUDY IN TEXTILES. 3(3-0) F,S,Sum.** Problems of specific interest in textiles will be assigned for study and investigation. The preparation of a report for publication will be required. Three hours maximum credit will be allowed toward Master of Textiles degree. No credit is allowed toward Master of Science in Textiles degree.

**TAM 698 SEMINAR. 1(1-0) F,S.** Discussion of scientific articles of interest to the textile industry; review and discussion of student papers and research problems.

**TAM 699 TEXTILE THESIS OR DISSERTATION RESEARCH. Credits Arranged. F,S,Sum.** Problems of specific interest to the textile industry assigned for study and investigation. The use of experimental methods emphasized. Attention given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.

# Textile Chemistry

For a listing of graduate faculty and program information, see textile engineering, chemistry and science.

# Textile Engineering and Science

For a listing of graduate faculty and program information, see textile engineering, chemistry and science.

# Textile Engineering, Chemistry and Science

**Degrees Offered: M.S. in Textile Chemistry, M. S. in Textile Engineering and Science, Master of Textiles**

**GRADUATE FACULTY**

*Burlington Professor* M. H. M. Mohamed, *Head of the Department*

*Professor* K. R. Beck, *Assistant Head and Director of Graduate Programs*
Box 8301, (919) 515-6636, keith_beck@ncsu.edu

***Celanese Corporation Professor:*** J. A. Cuculo
***Charles A. Cannon Professor:*** S. P. Hersh
***Ciba-Geigy Professor:*** H. S. Freeman
***Cone Mills Professor:*** R. McGregor

***Professors:*** R. L. Barker, D. R. Buchanan, P. L. Grady, B. S. Gupta, C. D. Livengood, G. N. Mock, C. B. Smith, M. H. Theil, C. Tomasino, P. A. Tucker Jr.;
***Adjunct Professors:*** R. F. Goldman, T. Iijima, R. K. Koger, J. Preston, T. Y. Tam;
***Professors Emeriti:*** K. S. Campbell, D. M. Cates, P. D. Emerson, R. D. Gilbert, D. S. Hamby, P. R. Lord, H. A. Rutherford, W. K. Walsh, W. M. Whaley, R. W. Work;
***Associate Professors:*** T. G. Clapp, H. Hamouda, S. M. Hudson, C. M. Pastore, J. W. Rucker, A. E. Tonelli;
***Research Associate Professor:*** M. B. Gunner;
***Visiting Associate Professor:*** I. Shalev;
***Adjunct Associate Professors:*** W. P. Behnke, L. D. Claxton, W. D. Hunter;
***Associate Professors Emeriti:*** T. H. Guion, A. C. Hayes, T. G. Rochow;
***Assistant Professors:*** W. J. Jasper, J. P. Rust;
***Adjunct Assistant Professor:*** A. C. Bullerwell

## ASSOCIATE MEMBERS OF THE PROGRAM

***Professors:*** S. K. Batra, R. E. Fornes

***Master of Science in Textile Chemistry (MS/TC):*** The M.S. in textile chemistry program offers unique educational and research opportunities in textile and polymer chemistry. Fundamentals of chemistry, physics, and mathematical sciences are applied to solve polymer and textile wet processing problems. ***M.S. in Textiles with Specialization in Textile Engineering and Science (MS/T):*** The M.S. in textiles with a specialization in textile engineering and science program offers unique educational and research opportunities in fiber science and textile engineering. Fundamentals of physics, engineering, and mathematical sciences are applied to textile-related problems.

### Admission Requirements

*(MS/TC):* Applicants must have a physical science or engineering background, including physical chemistry and differential equations. Formal education in textile or polymer chemistry is desired but not required. *(MS/T):* Applicants must have a physical science or engineering background and differential equations. Some background in textiles is desired but not required.

### Degree Requirements

*(MS/TC):* This degree requires 15 credit hours in textile chemistry, nine credit hours in a minor, six credit hours of research, and two semester audits of the College Seminar (TC 698). *(MS/T):* This degree requires nine credit hours from a core of fiber science and mechanics courses, nine credit hours in a minor, six credit hours of research, six hours of electives, and two semester audits of the College Seminar (TES 698).

### Student Financial Support

Financial aid in the form of assistantships and fellowships is normally available for all full-time students.

### Other Relevant Information

The department either houses or has access to all major analytical tools necessary to effect a quality research program covering a wide range of topics. It also houses state-of-the-art facilities for conducting research in fiber science and textile engineering. Close cooperation between College faculty and the fiber/textile and allied industries provides students with opportunities for learning and employment.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

TC 407 WET PROCESSING OPERATION AND QUALITY CONTROL.
TC 412 TEXTILE CHEMICAL ANALYSIS.
TC 441 THEORY OF PHYSICO-CHEMICAL PROCESSES IN TEXTILES I.
TC 442 THEORY OF PHYSICO-CHEMICAL PROCESSES IN TEXTILES II.
TC(CH) 461 INTRODUCTION TO FIBER-FORMING POLYMERS.
T 497 INDEPENDENT RESEARCH IN TEXTILE ENGINEERING, CHEMISTRY AND MATERIALS SCIENCE I.
T 498 INDEPENDENT RESEARCH IN TEXTILE ENGINEERING, CHEMISTRY AND MATERIALS SCIENCE II.
TC 490 SPECIAL TOPICS IN TEXTILE CHEMISTRY.
TC 491 SEMINAR IN TEXTILE CHEMISTRY.
TT 405 CONTEMPORARY NONWOVEN TEXTILES.
TT 420 MODERN DEVELOPMENTS IN YARN MANUFACTURING.
TT 425 TEXTURED YARN PRODUCTION AND PROPERTIES.
TT 443 ADVANCED KNITTING SYSTEMS AND FABRICS.
TT 450 ADVANCED WEAVING.
TT 451 ADVANCED WOVEN FABRIC DESIGN.

TMS 460 PHYSICAL PROPERTIES OF TEXTILE FIBERS.
TMS 465 TEXTILE STRUCTURAL COMPOSITES.
TMS 492 SPECIAL TOPICS IN TEXTILE MATERIALS SCIENCE.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**TC 504 FIBER FORMATION--THEORY AND PRACTICE. Preqs.: MA 301, PY 208 or CI. 3(3-0) F.** Practical and theoretical analysis of the chemical and physical principles underlying the conventional methods of converting bulk polymer to fiber; rheology; melt, dry and wet polymer extrusion; fiber drawing; heat setting; general theory applied to unit processes.

**TC 505 THEORY OF DYEING. Preq.: CH 433 or CI. 3(3-0) S.** Mechanisms of dyeing. Application of thermodynamics to dyeing systems. Kinetics of diffusion in dyeing processes.

**TC 506 COLOR SCIENCE. Preq.: Sr. or grad. standing in TC; Coreq.: TC 507. 3(3-0) F.** Basis of modern techniques for color specification, measurement, control and communication. Applications of color science to textiles, plastics, color reproduction, computer-based imaging and display systems. Basic concepts taught by computer color graphics.

**TC 507 COLOR LABORATORY. Preq.: Sr. or grad. student in textile chemistry; Coreq.: TC 506. 1(0-2) F.** Exercises with modern methods and equipment to aid in understanding color perception, color science and color measurement. Computer color graphics exercises for comprehension of basic concepts. Independent projects in color science. Limited enrollment.

**TC 520 CHEMISTRY OF DYES AND COLOR. Preqs.: CH 221 and CH 223. 3(3-0) S.** Correlation of color and chemical constitution, synthetic routes for popular dyes of all important types; electronic mechanisms for reactive dyes; chemistry of dye interactions with light, washing and other in-use influences; economic and environmental considerations.

**TC 521 DYE SYNTHESIS LABORATORY. Preq.: TC 520. 3(0-9) F.** Laboratory work in the preparation and analysis of synthetic dyes of a large number of types. Personal instruction in techniques and processes for preparation and purification of intermediates and dyes.

**TC 525 DYEING CELLULOSE. Preqs.: TC 305, TC 320, TC 442. 3(3-0) F.** Organic and physiocochemical principles in the application of dyes to cellulose. Stress on practical aspects of applications. Types and sources of cellulose. Quality

control practices and issues in raw materials and dyeing. Specific application information for each dye class.

**TC 530 THE CHEMISTRY OF TEXTILE AUXILIARIES. Preq.: One yr. of organic chemistry. 3(3-0) F.** Industrially important textile chemicals used for enhancing fiber and fabric properties such as durable press, water repellency, antisoiling, flame retardancy, softness, stiffness, lubricity and other uses will be studied. Correlation of effect with structure, end-use influences, interaction with fabric and fibers, sources and synthetic routes, economic and environmental considerations covered.

**TC(MAT) 561 ORGANIC CHEMISTRY OF POLYMERS. Preqs.: TC 461 and CH 231 or CH 431. 3(3-0) S.** Principles of step reaction and addition polymerizations; copolymerization; emulsion polymerization; ionic polymerization; characterization of polymers; molecular structure and properties.

**TC(CH,MAT) 562 PHYSICAL CHEMISTRY OF HIGH POLYMERS–BULK PROPERTIES. Preqs.: CH 220 or TC 203, CH 431. 3(3-0) F. Alt. yrs.** Molecular weight description; states of aggregation and their interconversion; rubbery, glassy and crystalline states; rubber elasticity; diffusion properties.

**TC 565 POLYMER APPLICATIONS AND TECHNOLOGY. Preqs.: One yr. of organic chemistry; TC 461. 3(3-0) S.** Poly(olefins), poly(vinyl chloride), poly(vinyl acetate), poly(urethanes), epoxies, silicones, styrene copolymers used as textile finishes, nonwoven binders, fabric coatings, composites, adhesives, foams, carpet backing adhesives. Emphasis upon synthesis, industrial processes, properties and products.

**TC(CHE) 569 POLYMERS, SURFACTANTS AND COLLOIDAL MATERIALS. 3(3-0) F.** (See chemical engineering.)

**TC 591 SPECIAL TOPICS IN TEXTILE SCIENCE. Preqs.: Sr. or grad. standing and CI. 1-4 F,S.** Intensive treatments of selected topics in textile, polymer and fiber science.

**TES 500 FIBER AND POLYMER MICROSCOPY. Preqs.: MA 212, PY 212, TC 203. 3(1-4) F.** The art and science of light and electron microscopy; theoretical and practical aspects of visibility, resolution and contrast. Laboratory practice in assembling, testing and using various microscopes and accessories in analyzing, describing and identifying unoriented and oriented crystalline or amorphous materials. Laboratory emphasis on the study of fibers and polymers through transmission microscopy with polarized light.

**TES 505 TEXTILE INSTRUMENTATION AND CONTROL SYSTEMS. Preqs.: MA 301, PY 212 and one course in computer science. 3(3-0) F.** The theory and application of instruments and control systems used in modern textile plants. Description of basic instruments and computer systems along with their use in process control, production control, research and development.

**TES(TAM) 520 YARN PROCESSING DYNAMICS. Preqs.: MA 301 and CI or grad. standing. 3(2-2) F.** Theoretical analysis of the dynamics and machine-fiber interactions of such functions as opening, cleaning, carding actions, fiber attenuation, ring spinning, open-end spinning, texturing and winding. The role of fiber placement, cohesion and lubrication on yarn processing and properties. Laboratory experiments designed to verify the analysis discussed in the lectures.

**TES(TAM) 555 PRODUCTION MECHANICS AND PROPERTIES OF WOVEN FABRICS. Preqs.: MA 301 and CI or grad. standing. 3(2-2). S.** The interrelations between the mechanics of production and mechanical properties of woven fabrics; unit operations required to prepare yarns for weaving and the mechanisms employed in weaving; fabric structure, geometry and mechanical properties; designing for specific fabric properties.

**TES 561 MECHANICAL AND RHEOLOGICAL PROPERTIES OF FIBROUS MATERIAL. Preq.: MA 301. 3(2-2) S.** In-depth study of the stress-strain, bending, torsional, dynamic and rheological behavior of natural and man-made fibers. Presentation and discussion of theoretical relations and advanced techniques.

**TES 562 PHYSICAL PROPERTIES OF FIBER FORMING POLYMERS, FIBERS AND FIBROUS STRUCTURES. Preqs.: MA 301, PY 208. 3(3-0) F.** Experimental results and theoretical considerations of the physical properties of fibers and fiber forming polymers discussed. Includes electrical, thermal, optical, frictional and moisture properties of these materials. Discussion of the influence of chemical and molecular fine structure on these properties.

**TES(MAT) 563 CHARACTERIZATION OF STRUCTURE OF FIBER FORMING POLYMERS. Preqs.: MA 301, PY 208. 3(3-0) F.** Theories, experimental evidence and characterization methods of the molecular fine structure of fiber forming polymers in the solid state discussed. Characterization methods include X-ray diffraction, microscopy, infrared, thermal and magnetic resonance. An introduction to nucleation theory of polymer systems.

**TES 565 TEXTILE COMPOSITES. Preqs.: MA 341, MAE 206. 3(3-0) S.** Fiber architecture of textiles used for composites. Manufacturing processes and geo-

metric quanitification. Basic analysis for predicting elastic properties. Interrelationship of elastic properties and geometric quantities. Failure criteria for these materials.

**TES 589 SPECIAL STUDIES IN TEXTILE ENGINEERING AND SCIENCE. Preq.: Sr. or grad. standing. 1-4 F,S.** New or special course on developments in textile engineering and science. Specific topics and prerequisites identified vary. Generally used for first offering of a new course.

**TES 590 SPECIAL PROJECTS IN TEXTILE ENGINEERING AND SCIENCE. Preqs.: Sr. standing or grad. standing, CI. 2-3 F,S,Sum.** Advanced studies include current problems of the industry, independent investigations, seminars and technical presentations, both oral and written.

*FOR GRADUATES ONLY*

**TC(CH,MAT) 662 PHYSICAL CHEMISTRY OF HIGH POLYMERS--SOLUTION PROPERTIES. Preqs.: CH 433, TC (CH, MAT) 562. 3(3-0) S. Alt. yrs.** Thermodynamics of polymer solutions; phase equilibria; determination of molecular weight.

**TC(CHE) 669 DIFFUSION IN POLYMERS. 2(2-0) S.** (See chemical engineering.)

**TC(CHE) 671 SPECIAL TOPICS IN POLYMER SCIENCE. 1-3 F.** (See chemical engineering.)

**TC(TES) 691 SPECIAL TOPICS IN FIBER SCIENCE. 1-3 S.** (See textile engineering and science/textile management and technology.)

**TC 698 SEMINAR FOR TEXTILE CHEMISTRY. 1(1-0) F,S.** Discussion of scientific articles and presentations; review and discussion of student papers and research problems.

**TC 699 TEXTILE RESEARCH FOR TEXTILE CHEMISTRY. Credits Arranged.** Individual research in the field of textile chemistry.

**TES(TAM) 640 PHYSICAL AND MECHANICAL PROPERTIES OF KNITTED FABRIC. Preq.: TES 541. 3(3-0) Alt. S.** Seminar discussions of research literature on studies of the physical and mechanical properties of knitted fabrics.

**TES(TAM) 651, 652 FABRIC DEVELOPMENT AND CONSTRUCTION. 3(1-4) F,S.** Application of advanced technology to the development and construction of woven fabrics.

**TES(TAM) 663 MECHANICS OF TWISTED STRUCTURES. Preq.: TES 561 or equivalent. 3(3-0) S. Odd yrs.** Study of the basic mechanics of fibrous assemblies. Geometry and mechanics of twisted structures (yarns, cords, braids, etc.) and the translation of fiber properties into structural behavior.

**TES(TAM) 664 MECHANICS OF FABRIC STRUCTURES. Preq.: TES 561 or equivalent. 3(3-0) S. Even yrs.** Analysis of the geometry and behavior of woven, knitted and nonwoven fabrics under various stress conditions and end-use applications.

**TES(TC) 691 SPECIAL TOPICS IN FIBER SCIENCE. Preq.: CI. 1-3 S.** Study of selected topics of particular interest in various advanced phases of fiber science.

**TES 697 INDEPENDENT STUDY IN TEXTILES. 3(3-0) F,S,Sum.** Problems of specific interest in textiles assigned for study and investigation. The preparation of a report for publication required. Three hours maximum credit allowed toward Master of Textiles degree. No credit allowed toward Master of Science in Textiles degree.

**TES 698 SEMINAR. 1(1-0) F,S.** Discussion of scientific articles of interest to the textile industry; review and discussion of student papers and research problems.

**TES 699 TEXTILE THESIS OR DISSERTATION RESEARCH. Credits Arranged. F,S,Sum.** Problems of specific interest to the textile industry assigned for study and investigation. The use of experimental methods emphasized. Attention given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.

# Textile Management and Technology

For a listing of graduate faculty and program information, see textile and apparel management.

# Textile Technology Management

**Degree Offered: Ph.D.**

## GRADUATE FACULTY

*Charles A. Cannon Professor* S. P. Hersh, *Program Director*
Box 8301, (919) 515-3057, sol_hersh@ncsu.edu

*Professors:* R. A. Barnhardt, S. K. Batra, K. R. Beck, G. A. Berkstresser III, R. A. Donaldson, S. E. Elmaghraby, A. H. El-Shiekh, S.-C. Fang, P. L. Grady, B. S. Gupta, D. M. Holthausen Jr., T. J. Little, C. D. Livengood, S. E. Margolis, M. H. M. Mohamed, C. B. Smith, C. Tomasino, S. C. Winchester;
*Professors Emeriti:* J. R. Canada, A. B. Moss;
*Associate Professors:* P. Banks-Lee, J. C. Beghin, T. F. Gilmore, P. B. Hudson, S. M. Hudson, M. W. Suh, W. Oxenham;
*Assistant Professors:* T. K. Ghosh, H. H. A. Hergeth, G. L. Hodge, J. W. Rucker, J. P. Rust, A. M. Seyam

Textile technology management is a multidisciplinary program designed to educate students for research careers in the management of technology in the fiber, textile, apparel and related industries complex. The program is designed to give the students a breadth of knowledge of the materials and technologies employed in the industries as well as the quantitative and analytical tools of management.

### Admission Requirements

Students majoring in textiles; industrial, systems and manufacturing engineering; statistics; operations research; computer science; economics; consumer economics; marketing; and business administration, and having at least a 3.0/4.0 average in their undergraduate studies and a master's degree will normally qualify for admission. Exceptionally qualified students may be admitted directly without a master's degree.

### Doctoral Degree Requirements

There are no fixed credit-hour requirements for the Doctor of Philosophy degree. Students are admitted to candidacy for the Ph.D. degree after passing two preliminary written and oral examinations (the first covering manufacturing technology and the second the management of technology), and orally defending a research proposal. They must also have passed an English technical writing course during their college career and, depending on the nature of their research interests, may also be required to demonstrate a reading knowledge of one foreign language.

**Student Financial Support**
Financial aid in the form of assistantships and fellowships is normally available for all full-time students.

**Other Relevant Information**
In 1991, the College of Textiles moved to its new 298,000 square-foot complex, now valued at over $50 million, which houses exceptional teaching, research, computer and library facilities. With a graduate faculty of 45 and research expenditures exceeding $6,000,000 in fiscal year 1992/93, opportunities abound. Facilities available to textile technology management students include: the Model Manufacturing Facility which contains over $10,000,000 of textile processing equipment from fiber formation to end products; the IBM Computer Integrated Manufacturing (CIM) Facility which contains PS/2's, AS/400 and RS/6000 computers running plant floor, supervisory monitoring and control, and manufacturing resource planning software packages; and the Textile Design Laboratory which contains several design packages which can communicate with plant floor devices providing CAD/CAM integration.

COURSE OFFERINGS (Extensive use may be made of graduate course offerings in other colleges on campus when developing the minor field. See departmental listing for descriptions) )

## GENERAL COURSES

TT 420 MODERN DEVELOPMENTS IN YARN MANUFACTURING.
TT 425 TEXTURED YARN PRODUCTION AND PROPERTIES.
TT 443 ADVANCED KNITTING SYSTEMS AND FABRICS.
TT 450 ADVANCED WEAVING.
TT 451 ADVANCED WOVEN FABRIC DESIGN.
TMS 460 PHYSICAL PROPERTIES OF TEXTILE FIBERS.
TAM 480 TEXTILE PRODUCTION COST CONTROL.
TAM 482 TEXTILE MARKETING MANAGEMENT.
TAM 484 MANAGEMENT DECISION MAKING FOR THE TEXTILE FIRM.
TAM 487 TEXTILE AND APPAREL LABOR MANAGEMENT.

## COURSES IN AREAS OF SPECIALIZATION

TAM(TES) 520 YARN PROCESSING DYNAMICS
TAM 530 TEXTILE QUALITY CONTROL
TAM(TES) 541 THEORY AND PRACTICE OF KNITTED FABRIC PRODUCTION AND CONTROL
TAM 549 WARP KNIT ENGINEERING AND STRUCTURAL DESIGN
TAM(TES) 555 PRODUCTION MECHANICS AND PROPERTIES OF WOVEN FABRICS
TES 565 TEXTILE COMPOSITES
TAM(BUS) 585 MARKET RESEARCH IN TEXTILES
TAM 589 SPECIAL STUDIES IN TEXTILE MANAGEMENT AND TECHNOLOGY
TAM 590 SPECIAL PROJECTS IN TEXTILE MANAGEMENT AND TECHNOLOGY
TAM 610 YARN PRODUCTION PROPERTIES

TAM 621 ADVANCED TEXTILE TESTING
TES 631 SYNTHETIC FIBERS
TAM(TES) 640 PHYSICAL AND MECHANICAL PROPERTIES OF KNITTED FABRIC
TAM(TES) 651, 652 FABRIC DEVELOPMENT AND CONSTRUCTION
TAM(TES) 663 MECHANICS OF TWISTED STRUCTURES
TAM(TES) 664 MECHANICS OF FABRIC STRUCTURES
TAM 680 SPECIAL PROJECTS IN TEXTILE MANAGEMENT
TAM 686 ADVANCED TEXTILE LABOR MANAGEMENT SEMINAR
TAM 687 COMPETITIVE STRATEGY AND PLANNING FOR THE TEXTILE FIRM
TAM 697 INDEPENDENT STUDY IN TEXTILES

# Toxicology

**Degrees Offered: Ph.D., M.S., Master of Toxicology**

## GRADUATE FACULTY

*William Neal Reynolds and Graduate Alumni Distinguished Professor* E. Hodgson, *Head of the Department*
(919) 515-2595
*Associate Professor* R. B. Leidy, *Director of Graduate Programs*
Box 7633, (919) 515-3391

*Professors:* C. Brownie, W. C. Dauterman;
*Adjunct Professors:* A. L. Chasson, J. R. Fouts, J. A. Goldstein, R. J. Langenbach, R. M. Philpot;
*Professor Emeritus:* T. J. Sheets;
*Associate Professors:* R. M. Roe, R. C. Smart;
*Research Associate Professor:* P. E. Levi;
*Adjunct Associate Professor:* H. B. Matthews Jr.;
*Assistant Professors:* M. B. Genter, G. A. LeBlanc, S. A. Meyer, D. Shea;

### Admission Requirements

Prospective students should have a strong background in the biological and physical sciences with a minimum undergraduate grade point average of 3.0 (on a 4.0 scale) in the biological and physical sciences.

### Master of Science Degree Requirements

Students not electing a minor must take at least 9 hours of additional courses as approved by their committee.

### Master of Toxicology Degree Requirements

A total of 36 credit hours is required. A minimum of four credit hours and a maximum of six credit hours in TOX 590 or TOX 600-level courses is required. This

is a non-thesis degree, but in all other respects the requirements of the M.Tox degree are the same as for the M.S. degree.

### Doctoral Degree Requirements

A minimum of 37 credit hours is required for the Ph.D. degree. At least 20 hours must come from 500- and 600-level courses.

### Student Financial Support

Financial assistance is available for qualified applicants through traineeships, fellowships, teaching assistantships and research assistantships with participating faculty members. Approximately 90 percent of the students pursuing master's and doctoral degrees on campus currently receive financial assistance.

### Environmental Toxicology Option

Students pursuing either the M.S. or Ph.D. degree may elect to specialize in environmental toxicology. Students who choose this option are required to enroll in TOX 515, Environmental Toxicology (3 credits), and students who choose to minor must do so in an environmentally related discipline (*i.e.*, ecology, forestry, zoology). Students not electing a minor must take at least 6 additional credit hours of relevant course work.

### *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**TOX 501 GENERAL TOXICOLOGY. Preqs.: BCH 451, sr. or grad. standing. 3(3-0) F.** The basis of toxic action at cellular and molecular levels covering the absorption, distribution, elimination and metabolism of toxicants; toxic action (acute toxicity, carcinogenesis, mutagenesis, organ toxicity, etc.); chemical classes of toxicants; and toxicity testing.

**TOX 510 BIOCHEMICAL TOXICOLOGY. Preqs.: Biochemistry, sr. standing. 3(3-0) S.** Emphasis on the occurrence of molecular events during the toxic action of xenobiotics, including penetration phenomena, mechanisms involved in detoxication and the mechanisms of action at the target site.

**TOX 515 ENVIRONMENTAL TOXICOLOGY. Preq.: Two years of biology. 3(3-0) F.** Evaluation of the nature, distribution and significance of microchemical contamination. Emphasis on current, relevant problems.

**TOX(ST) 563 STATISTICAL PROBLEMS IN TOXICOLOGY. 3(3-0) S. Alt. yrs.** (See statistics.)

**TOX 590 SPECIAL PROBLEMS IN TOXICOLOGY. Preq.: Grad. standing. 1-3.** Topics include environmental contaminants, developmental toxicology, regulatory toxicology and analytical toxicology.

*FOR GRADUATES ONLY*

**TOX 601 CHEMICAL CARCINOGENESIS. Preqs.: BCH 553, TOX 501, TOX 510. 1(1-0) F. Alt. yrs.** Emphasis on mechanisms including somatic mutation hypothesis, pathology of neoplasia, multistage carcinogenesis, tumor promotion, oncognes, tumor suppressor genes and rodent bioassays. Fundamentals of cancer biology and their relationships to chemical-induced carcinogenesis.

**TOX 604 CHEMICAL RISK ASSESSMENT. Preqs.: TOX 501, a ST course. 1(1-0) S.** Concepts and vocabulary of risk assessment. Risk assessment models and techniques used in cancer and non-cancer risk assessment and strategies for successful risk communications. Case studies of risk assessment and issues of current interest. Utilization of background in toxicology and statistics to examine a critical end-point in toxicological science, the quantitative risk assessment.

**TOX(IMM) 605 IMMUNOTOXICOLOGY. Preqs.: TOX 501 and IMM. 2(2-0) F. Alt. yrs.** Concepts in the study of adverse effects of chemicals on the immune system, including allergic responses, autoimmunity and immunosuppression. Significance of immunotoxic effects resulting from environmental or workplace exposure. Role of immunotoxicity in risk assessment.

**TOX(BCH) 606 FREE RADICALS IN TOXICOLOGY. Preqs.: BCH 451 and TOX 510. 1(1-0) F. Alt. yrs.** Introduction to the field of free radicals and their role in toxicology and health; chemical and physical properties of partially reduced oxygen intermediates and the natural biological defense mechanisms.

**TOX 690 TOXICOLOGY SEMINAR. 1(1-0) S.**

**TOX 699 RESEARCH. Credits Arranged. F,S.** Original research in connection with thesis problem in toxicology.

*COURSES FROM ASSOCIATED DEPARTMENTS*

BCH 540 PROTEINS
BCH 542 METABOLISM
BCH 553 METABOLISM AND MOLECULAR BIOLOGY
BCH 652 STRUCTURES AND INTERACTIONS OF BIOLOGICAL MACROMOLECULES
CH 428 QUALITATIVE ORGANIC CHEMISTRY
ENT 622 INSECT TOXICOLOGY
VMS 531 MAMMALIAN NEUROANATOMY

VMS 540 RESEARCH ANIMAL CARE AND USE
VMS 553 VETERINARY IMMUNOLOGY
VMS 560 INTRODUCTORY PHARMACOLOGY
VMS 562 SYSTEMIC PHARMACOLOGY AND TOXICOLOGY
VMS 563 SYSTEMIC PHARMACOLOGY AND TOXICOLOGY LABORATORY
VMS 690B SPECIAL TOPICS IN PATHOLOGY
VMS 696A SEMINAR IN PHARMACOLOGY
ZO 614 ADVANCED CELL BIOLOGY

*SELECTED COURSES AT UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL*

PHARM 216 INTRODUCTORY PHARMACOLOGY
EPID 162 EPIDEMIOLOGY

*SELECTED COURSE AT DUKE UNIVERSITY*

PATH 382 TOXICOLOGICAL PATHOLOGY

# Training and Development

For a listing of graduate faculty and program information, see adult and community college education.

# Veterinary Medical Sciences

**Degrees Offered: Ph.D., M.S.**

**GRADUATE FACULTY**

*Professor* J. H. Britt, *Coordinator*
Box 8401, (919) 829-4262, jack_britt@ncsu.edu

***Burroughs Wellcome Distinguished Professor:*** J. E. Riviere

*Professors:* C. F. Abrams Jr., K. B. Adler, K. L. Anderson, J. J. Arends, R. A. Argenzio, A. L. Aronson, H. J. Barnes, H. A. Berkhoff, E. B. Breitschwerdt, T. T. Brown Jr., P. B. Carter, L. Coggins, W. J. Croom Jr., T. M. Curtin, E. V. DeBuysscher, D. J. DeYoung, O. J. Fletcher Jr., F. J. Fuller, T. E. Hamm Jr., B. Hammerberg, B. D. Harrington, D. R. Howard, M. G. Levy, D. J. Meuten, D. J. Moncol, N. C. Olson, W. D. Oxender, M. C. Roberts, J. E. Smallwood, C. E. Stevens, J. B. Stevens, E. A. Stone, M. K. Stoskopf, C. Teng, D. E. Thrall, W. A. F. Tompkins;

*Adjunct Professors:* S. W. Crane, J. P. Fetrow, R. R. Maronpot, J. A. Popp, F. Welsch;
*Professors Emeriti:* W. M. Adams, E. G. Batte, P. J. Bentley, R. C. Dillman, D. M. Hanson, J. K. Magor;
*Associate Professors:* G. W. Almond, C. E. Atkins, S. A. Bai, H. M. Berschneider, K. F. Bowman, B. A. Breuhaus, D. G. Bristol, C. F. Brownie, S. E. Bunch, P. Cowen, J. M. Cullen, M. G. Davidson, M. D. Ficken, K. Flammer, L. N. Fleisher, R. B. Ford, J. E. Gadsby, C. B. Grindem, J. S. Guy, E. M. Hardie, E. C. Hawkins, J. M. Hinshaw, L. C. Hudson, E. Hunt, B. W. Keene, J. F. Levine, D. H. Ley, R. E. Meyer, M. P. Nasisse, E. J. Noga, P. E. Orndorff, R. L. Page, M. G. Papich, M. A. Qureshi, D. V. Rives, C. L. Robinette, P. L. Sannes, K. A. Spaulding, C. R. Swanson, L. P. Tate Jr., M. B. Tompkins, S. L. Tonkonogy, S. D. Van Camp, D. P. Wages, M. D. Whitacre;
*Research Associate Professors:* M. C. McGahan, N. A. Monteiro-Riviere;
*Visiting Associate Professor:* S. Kennedy-Stoskopf;
*Adjunct Associate Professors:* G. A. Boorman, K. L. Dreher, T. E. Eling, J. J. Heindel, M. R. Loomis, E. E. McConnell, K. T. Morgan, R. L. Peiffer Jr., J. A. Raleigh, D. C. Richardson, C. T. Teng;
*Assistant Professors:*C. R. Berry, D. E. Bevier, J. Deen, L. A. Degernes, W. M. Duckett, P. W. Hellyer, G. A. Lewbart, N. E. Love, M. B. McCaw, W. E. Morgan Morrow, B. P. Peters, G. S. Price, S. C. Roe, D. C. Sellon, N. J. H. Sharp, B. Sherry, B. D. Slenning, I. W. Smoak, G. J. Spodnick, S. L. Vaden, B. J. Weigler, D. Weinstock;
*Research Assistant Professor:* P. L. Williams;
*Visiting Assistant Professors:* B. R. Grubb, B. D. Hansen, C. S. Hughes;
*Adjunct Assistant Professors:* R. C. Cattley, M. W. Dewhirst, D. C. Dorman, J. Everitt, D. C. Wolf;
*Electron Microscopy Director:* M. J. Dykstra

Course offerings and research topics currently include, but are not limited to: immunology, cardiology, pharmacokinetics, oncology, toxicology, gastroenterology, neurophysiology, reproductive physiololgy, biotechnology, microbiology, aquatic/-wildlife biology, biomedical engineering, endocrinology, molecular biology, pulmonary biology, epidemiology, health systems monitoring, transplantation and radiology.

### Admission Requirements

All applications are reviewed by the Graduate Student Admissions Committee of the College, composed of faculty members representing each area of the graduate program. Scores from the Graduate Record Examination (GRE) are required for admission by applicants who do not have a DVM degree. Candidates who do not have a DVM degree must have a baccalaureate degree or advanced degree from a college

or university recognized as standard by a regional or general accrediting agency. Student with a 3.0 (on a 4.0 scale) undergraduate or DVM curriculum with appropriate course background will be considered for admission.

**Doctoral Degree Requirements**
Credit hour requirements for the Ph.D. degree are determined by the graduate student's committee with approval of the Director of Graduate Program and the Graduate School.

**Student Financial Support**
Research assistantships are awarded to qualified candidates on the competitive basis by the College. These are for 12-month periods, and stipends are competitive with those of other programs. These positions are funded by the grants of individual faculty members and the state appropriations to the College and departments.

**Other Relevant Information**
The program is organized across traditional departmental lines as areas of concentration which include: cell biology/morphology, epidemiology/population medicine, microbiology, pathology and pharmacology. These provide extensive interdisciplinary training and maintain a highly effective liaison with graduate programs in other schools of the university, as well as those of nearby Duke University and the University of North Carolina at Chapel Hill.

*SELECTED ADVANCED UNDERGRADUATE COURSE*

**VMS 490 SPECIAL TOPICS IN VETERINARY MEDICINE.**

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**VMS(BAE) 522 MECHANICS OF BIOLOGICAL MATERIALS. 3(2-2) F. Alt. yrs.** (See biological and agricultural engineering.)

**VMS 530 VETERINARY HISTOLOGY. Preqs.: BCH 451 and CI. 3(2-4) F. Alt. yrs.** The study of the structure of cells, tissues and organs of domestic animals using light microscopy.

**VMS 532 ELECTRON MICROSCOPY IN VETERINARY MEDICINE. Preq.: CI. 4(2-4) S.** An introduction to ultramicrotomy, tissue processing for electron microscopy, theory and utilization of the transmission electron microscope and scanning electron microscope, darkroom techniques and an introduction to various specialized techniques for the preparation of samples for veterinary diagnostic and research electron microscopy.

**VMS 540 RESEARCH ANIMAL CARE AND USE. Preq.: ZO 201 or equivalent. 3(2-3) S. Alt. yrs.** The principles of the selection, care and use of animals in laboratory teaching and investigation presented. Topics include the ethics of animal experimentation, selection of animal models, biology and care of laboratory animals, techniques of administration of substances and obtaining of specimens, producing surgical alterations and common laboratory animal health problems.

**VMS 550 VETERINARY MEDICAL VIROLOGY I. Preqs.: BCH 451, MB 401 and grad. standing. 2(2-0) S.** Basic principles of animal virology and the relationship of viruses to diseases in domestic animals discussed.

**VMS 551 PATHOGENIC BACTERIOLOGY AND MYCOLOGY. Preqs.: MB 411, grad. standing and CI. 3(2-2) F.** The pathogenic bacteria and fungi important in medicine. Lectures supplemented by laboratory exercises providing students the opportunity to learn basic characteristics of these microorganisms and how they are isolated, cultivated and identified.

**VMS 552 DIAGNOSTIC BACTERIOLOGY AND MYCOLOGY. Preqs.: Grad. standing, VMM 814 or VMS 551 and CI. 3(1-8) F,S.** Principles of specimen collection, selection and use of media, culture processing and identification of bacteria and fungi important in animal disease.

**VMS 553 VETERINARY IMMUNOLOGY. Preq.: Grad. standing. 2(2-0) S.** Basic and clinical immunology Discussion of the role of the immune system in disease prevention, inflammation and autoimmune diseases.

**VMS 554 PRINCIPLES OF EPIDEMIOLOGY. Preq.: Grad. standing or CI. 3(2-4) F. Alt. yrs.** Principles of epidemiology related to the investigation of disease involving the agent-host-environment concepts. Stress on epidemiological techniques and experimental design. Main focus on descriptive, analytical and experimental epidemiology pertinent to disease etiology and prevention.

**VMS(IMM) 555 IMMUNOPARASITOLOGY. Preq.: MB 551. 2(2-0) S. Alt. yrs.** Helminth and protozoal parasite immune evasion and immunomodulation; consequences of parasite-induced immunopathogenesis; learning from failed attempts to develop protective vaccines against protozoa and helminths.

**VMS(IMM,MB,PHY,PO) 556 IMMUNOGENETICS. 3(2-2) F. Alt. yrs.** (See poultry science.)

**VMS 560 INTRODUCTORY PHARMACOLOGY. Preqs.: BCH 451, grad. standing or CI. 5(4-1) F.** The action of drugs in animals and man including basic

principles of drug disposition and pharmacokinetics. Description of modification of physiological processes by drugs influencing coordination by the nervous, endocrine and circulatory system.

**VMS 561 INSTRUMENTATION IN PHARMACOLOGICAL RESEARCH. Preqs.: BCH 452B or CH 315 and grad. standing or CI. 2(1-4) F.** The theory and applications of modern scientific instrumentation to the analysis of tissues, body fluids and drugs in pharmacological research. Discussion of appropriate aspects of the pharmacological use of spectroscopy, microscopy, chromatography, electrophoresis, radioisotope usage and centrifugation.

**VMS 562 SYSTEMIC PHARMACOLOGY AND TOXICOLOGY. Preq.: VMS 560 or equivalent. 3(3-0) S. Alt. yrs.** Discussion of drug and toxicant action at the rgan systems level in terms of underlying physiological mechanisms and responses. Emphasis on the kidney and liver with additional consideration given to the respiratory, reproductive, gastrointestinal, hematologic and immune systems. Methods for assessing function of these systems.

**VMS 570 CELL BIOLOGY. Preqs.: BCH 451, BS 100, CH 223 or equivalent or CI. 3(3-0) F.** Advanced cell and organelle structure and function, and recent advances in molecular biology. Emphasis on current literature and application of research procedures.

**VMS 580 VETERINARY PRODUCTION EPIDEMIOLOGY. Preqs.: VMM 844 or equivalent, basic statistics or CI. 2(2-0) S.** Examination of the tools, limits, advantages and disadvantages specific to veterinary epidemiology and its execution. Assessment of means of disease prevention and outbreak investigation; mathematical simulation and economics; plus monitoring and evaluation of disease control programs; use of a multiple-species orientation. Application of the above epidemiologic techniques and their roles in assisting producers, practitioners and regulators.

**VMS 590 SPECIAL TOPICS IN VETERINARY MEDICAL SCIENCES. Preq.: Sr. or grad. standing. 1-3 F,S,Sum.** A course designed to present new or special subject matter within the scope of pathology, veterinary microbiology, morphology or pharmacology. The studies may include independent investigations, seminars and/or formal lectures.

*FOR GRADUATES ONLY*

**VMS 631 APPLIED VETERINARY ANATOMY I. Preqs.: DVM or equivalent and CI. 4(2-8) F. Alt. yrs.** The graduate veterinarian provided with detailed

anatomic information relevant to surgical and medical problems in domestic carnivores. Designed for graduate veterinarians in pursuit of advanced training in the areas of anatomy, physiology, surgery, radiology and pathology.

**VMS(ANS,NTR,PHY) 632 COMPARATIVE PHYSIOLOGY OF THE DIGESTIVE SYSTEM. Preq.: Course in general or comparative physiology; Coreq.: CI. 3(3-0) F.** The major functions of vertebrate digestive systems and structural and functional adaptations to diet, environment and other characteristics of the animals.

**VMS 642 ADVANCED SYSTEMIC HISTOPATHOLOGY. Preq.: Grad. students holding DVM or equivalent degree and CI. 2(1-3) S. Alt. yrs.** Histopathologic changes associated with diseases of various organ systems. Emphasis on the pathogenesis and morphologic changes associated with selected diseases.

**VMS 643 TOXICOLOGIC PATHOLOGY I. Preqs.: Those holding DVM or equivalent degree or CI. 3(2-2) F. Alt. yrs.** The principles and practices of toxicologic pathology and a survey of common spontaneous and chemically induced lesions by organ systems with emphasis on recognition and interpretation.

**VMS 650 BACTERIAL PATHOGENIC MECHANISMS. Preqs.: VMS 552 or VMM 814. 2(2-0) S. Alt. yrs.** Principles of pathogenesis and host-response in bacterial infections of animals discussed.

**VMS 651 VETERINARY MEDICAL VIROLOGY II. Preq.: VMM 824 or VMS 550 or CI. 3(3-0) F. Alt. yrs.** Principles of animal viral pathogenesis and host-response to viral infection. The biology of selected viral groups including oncogenic viruses and persistent viral infection.

**VMS(MB) 653 ADVANCED IMMUNOLOGY. Preq.: VMS 553 or VMM 815 or MB 551 or equivalent or CI. 3(3-0) F. Alt. yrs.** The ontogeny and phylogeny of self and non-self recognition. Emphasis on basic mechanisms that evolved during the evolution of the species. Speciality areas such as immunology of reproduction and genetic regulation of the immune response.

**VMS 654 EPIDEMIOLOGY OF INFECTIOUS DISEASES OF INTERNATIONAL IMPORTANCE. Preq.: CI. 3(2-4) F. Alt. yrs.** Discussion of infectious diseases and epidemiological principles. Stress on selected enteric, zoonotic, nosocomial diseases of worldwide importance. Consideration of population dynamic techniques related to host-vector-agent.

**VMS 660 ADVANCED PHARMACOLOGY. Preqs.: VMS 560 or equivalent and CI. 2(2-0) S. Alt. yrs.** Current topics in pharmacology. Subjects include but not limited to: the actions of drugs on ion permeability, prostaglandins, receptors, pharmacologically active peptides, toxicity of heavy metals and anti-fertility drugs.

**VMS 661 PHARMACOKINETICS. Preqs.: VMS 560 or equivalent, working knowledge of calculus and CI. 3(3-0) F. Alt. yrs.** Mathematical models to describe the disposition of drugs and toxic chemicals in the animal body. Areas covered include classic compartmental and nonlinear models as well as physiological approaches. Discussion of the application of these techniques to toxicologic studies.

**VMS 690A SPECIAL TOPICS IN VETERINARY MICROBIOLOGY. 1-3 F, S.** Specific topics of study assigned in various laboratories involved in veterinary microbiology investigation. Students conduct in-depth studies of assigned problem areas.

**VMS 690B SPECIAL TOPICS IN PATHOLOGY. Preqs.: Those holding DVM degree and CI. 1-4 F,S,Sum.** Students perform necropsies, microscopically evaluate tissue changes and prepare written reports of findings. Students conduct in-depth studies of each assigned case.

**VMS 690C SPECIAL TOPICS IN LABORATORY PHARMACOLOGY. Preq.: CI. 1-3 F,S,Sum.** Involvement in practical participation in the normal research activities of different laboratories working in pharmacological research. Students pursue a semi-independent project.

**VMS 690D SPECIAL TOPICS IN CLINICAL PATHOLOGY. Preqs.: DMV or equivalent degree and CI. 1(0-4) F,S,Sum.** New, fundamental and in-depth understanding of selected topics in clinical pathology (blood coagulation, acid-base balance, hematology, cytology, and clinical chemistry). A new topic selected each semester. Students read pertinent current journal articles and references and lead weekly discussion sessions. Stress upon clinical application of this information.

**VMS(IMM) 691 ADVANCED TOPICS IN IMMUNOLOGY AND BIOTECHNOLOGY. Preqs.: VMS 553, MB 551 or CI. 1(1-0) F,S,Sum.** Selected topics of current interest in immunology/biotechnology. A new topic selected each semester to keep the advanced graduate students up to date on the most recent developments in these fields.

**VMS 694A SEMINAR IN NECROPSY PATHOLOGY. Preqs.: Those holding the DVM or equivalent degree and CI. 1(1-0) F,S,Sum.** Description and interpretation of gross changes in tissues from diseased domestic animals. Students attend

daily (M-F) 15- to 30-minute review of necropsy lesions presented by a member of the graduate staff.

**VMS 694B SEMINAR IN SURGICAL PATHOLOGY. Preqs.: Those holding the DVM or equivalent degree and CI. 1(1-0) F,S,Sum.** Description and interpretation of microscopic changes in tissues from diseased domestic and laboratory animals. Students attend and participate in a one-hour weekly seminar where microscopic lesions described, interpreted and discussed.

**VMS(IMM) 695A SEMINAR IN VETERINARY MICROBIOLOGY/ IMMUNOLOGY. 1(1-0) F,S.** Presentation of ongoing research and current topics in microbiology.

**VMS 696A SEMINAR IN PHARMACOLOGY. Preq.: CI. 1(1-0) S.** Presentations and discussions of pharmacological topics of current interest and importance.

**VMS 697 SEMINAR IN CELL BIOLOGY. Preq.: CI. 1(1-0) F,S.** Presentation and discussions of ongoing research and current topics in cell biology.

**VMS 699 RESEARCH IN VETERINARY MEDICAL SCIENCES. 1-3 F,S, Sum.** Original research in connection with thesis or dissertation problems in veterinary medical sciences.

# Wildlife Biology

**Degrees Offered: M.S., Master of Wildlife Biology**

**GRADUATE FACULTY**

*Professor* R. L. Noble, ***Coordinator***
*Professor* D. L. Holley Jr., ***Director of Graduate Programs, Forestry***
Box 8002, (919) 515-2892
*Professor* J. R. Walters, ***Interim Director of Graduate Programs, Zoology***
Box 7617, (919) 515-2587

***Professors:*** G. T. Barthalmus, P. T. Bromley, B. J. Copeland, L. B. Crowder, P. D. Doerr, J. E. Easley Jr., E. C. Franklin, R. A. Lancia, J. M. Miller, K. H. Pollock;
***Professors Emeriti:*** D. A. Adams, D. W. Hayne;
***Associate Professors:*** J. F. Gilliam, J. M. Hinshaw, R. G. Hodson, E. J. Jones, S. C. Mozley, R. A. Powell, J. A. Rice;
***Associate Professor (USDI):*** W. J. Fleming;

*Assistant Professors:* T. M. Losordo, C. Sullivan;
*Assistant Professors (USDI):* J. A. Collazo, J. E. Hightower

The wildlife biology degrees are offered through the fisheries and wildlife science program, an inter-college program administered by the Departments of Forestry and Zoology. The degrees emphasize assessment, biology, ecology and management of fish and wildlife species and their habitats.

### Admissions Requirements

Application for admission is made through the Departments of Forestry or Zoology. Miminum requirements include a graduate record examination score of 1000 on the verbal and quantitative sections. Admission is contingent upon acceptance by an advisor. Exceptions to minimum requirements may be made for students with special backgrounds.

### Master's Degree Requirements

The Master of Wildlife Biology degree consists of a minimum of 36 credits, which may include up to eight hours of special problems and seminars. A professional paper is required. Further requirements may be imposed by the advisory committee and/or department. The M.S. degree program may include up to eight hours of research and seminars. A research-based thesis is required.

### Student Financial Support

Graduate research and teaching assistantships are offered for qualified students through participating departments. Commitments for assistantships are normally made at the time of admission to graduate study.

### Other Relevant Information

Research facilities near campus include the Aquatic Research Laboratory, Wildlife Research Laboratory, Biology Field Laboratory, Schenck Forest, Harris Lands natural area and several university farm units. Off-campus research is conducted at the Pamlico Aquaculture Center, research and extension centers in the east and west, and at facilities of state and federal agencies and private organizations.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**FW(FOR) 404 FOREST WILDLIFE MANAGEMENT.**
**FW(ZO) 420 FISHERY SCIENCE.**
**FW(ZO) 430 FISHERIES AND WILDLIFE ADMINISTRATION.**
**FW 485 NATURAL RESOURCES ADVOCACY.**

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**FW(ZO) 515 FISH PHYSIOLOGY. 3(2-3) F. Alt. yrs.** (See zoology.)

**FW(ZO) 553 PRINCIPLES OF WILDLIFE SCIENCE. 3(2-3) F.** (See zoology.)

**FW(ZO) 554 WILDLIFE FIELD STUDIES. 3(2-3) S. Odd yrs.** (See zoology.)

**FW(FOR) 585 ADVANCED WILDLIFE HABITAT MANAGEMENT. 3(2-3) S. Alt. yrs.** (See forestry.)

**FW(ZO) 586 AQUACULTURE I. 3(3-0) F. Alt. yrs.** (See zoology.)

**FW(ZO) 587 AQUACULTURE I LABORATORY. 1 (0-3) F. Alt. yrs.** (See zoology.)

**FW(FOR) 594 SEMINAR IN WILDLIFE MANAGEMENT. 1(1-0) S. Alt. yrs.** (See forestry.)

COURSES FROM ASSOCIATED DEPARTMENTS

FOR 572A,B FOREST MANAGEMENT POLICIES ON THE PUBLIC LANDS. 2(2-0) S.
FOR(MDS) 584 THE PRACTICE OF ENVIRONMENTAL IMPACT ASSESSMENT. 4(0-8) F. Alt. yrs.
ZO 501 ORNITHOLOGY. 3(2-3) S.
ZO(ST) 506 SAMPLING ANIMAL POPULATIONS. 3(3-0) F. Alt. yrs.
ZO(ENT) 509 ECOLOGY OF STREAM INVERTEBRATES 4(2-6) S. Alt. yrs.
ZO 519 LIMNOLOGY. 4(3-3) F.
ZO(MEA) 520 PRINCIPLES OF BIOLOGICAL OCEANOGRAPHY. 3(3-0) S.
ZO 542 HERPETOLOGY. 3(2-3) S. Even yrs.
ZO 544 MAMMALOGY. 4(3-3) F.
ZO 593 AQUATIC ECOLOGY SEMINAR. 1-3. F,S.
ZO 619 ADVANCED LIMNOLOGY. 3(3-0) S. Alt. yrs.
ZO 621 FISHERY SCIENCE. 3(2-3) F. Alt. yrs.
ZO(MEA) 624 ECOLOGY OF FISHES. 3(3-0) F.
ZO 644 ADVANCED TOPICS IN THE STUDY OF MAMMALS. 3(2-3) S.

# Wood and Paper Science

**Degrees Conferred: Ph.D., M.S., Master of Wood and Paper Science**

THE GRADUATE FACULTY

*Professor* R. J. Thomas, ***Head of the Department***

*Professor Emeritus* R. D. Gilbert, ***Director of Graduate Programs***
Box 8005, (919) 515-5321

***Elis and Signe Olsson Professor and Graduate Alumni Distinguished Professor:*** J. S. Gratzl
***Reuben B. Robertson Professor:*** H.-m. Chang

***Professors:*** E. L. Deal Jr., C. A. Hart, H. Jameel, T. W. Joyce, M. W. Kelly, H. G. Olf, E. A. Wheeler;
***Adjunct Professors:*** L. L. Edwards, T. K. Kirk;
***Professors Emeriti:*** A. C. Barefoot Jr., E. L. Ellwood, I. S. Goldstein, R. G. Pearson;
***Associate Professors:*** J. Denig, J. A. Heitmann Jr., J. P. Roise;
***Research Associate Professor:*** J. S. Stewart;
***Adjunct Associate Professor:*** R. B. Phillips;
***Assistant Professor:*** B. Kasal;
***Research Associate:*** C. L. Chen

Course offerings and research facilities are available in the following areas: Wood chemistry, lignin and carbohydrate chemistry, pulping chemistry, pollution abatement processes, polymer chemistry, fiber and paper properties, secondary fiber studies, wood physics (especially wood liquid relations), wood anatomy, wood biology, wood mechanics and engineering, wood machining, manufacturing processes, wood-based industry economics and marketing.

### Admission Requirements

Requirements listed here are in addition to graduate school requirements stated elsewhere. To be admitted, a student should have earned a B.S. degree with a major in wood and paper science or the equivalent. Graduates with other physical science or engineering baccalaureate degrees can be admitted but may be required to make up certain undergraduate deficiencies. Students with a 3.00 GPA and with appropriate course backgrounds will be considered for admission.

### Master of Science Degree Requirements

In addition to Graduate School requirements, a minor is required.

### Master of Wood and Paper Science Degree Requirements

The Master of Wood and Paper Science is a non-thesis, professional degree for students not interested in research. A minimum of 36 course credits is required. The regulations regarding credits are the same as for the M.S. degree except that up to 6 credits of 400 level courses in the major field may be included. A technical

report which demonstrates the student's ability to gather, analyze and report information is required.

### Doctoral Degree Requirements

In addition to Graduate School requirements, Ph.D. candidates must present two seminars before their final oral examination will be arranged.

### Student Financial Support

A limited number of research assistantships are available.

### Other Relevant Information

Graduate students should select a chairman and other advisory committee members and submit a graduate plan of work by the end of their first semester of residence. They are also urged to take the qualifying examinations within one year of residence. The department believes M.S. and Ph.D. students should select a research topic and begin their thesis research as early as possible.

As the field of wood and paper science is a derived science, considerable emphasis is placed upon developing a strong minor in the graduate program in any one or more of the supporting disciplines such as organic chemistry, polymer chemistry, chemical engineering, mathematics, statistics, biology, engineering mechanics, mechanical engineering, physics, and economics or business administration.

Students in wood chemistry and pulp and paper programs must pass certain qualifying examinations.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**WPS 410 PULP AND PAPER SYSTEMS ANALYSIS AND CONTROL.**
**WPS 416 PROJECT MANAGEMENT AND ANALYSIS II.**
**WPS(FOR) 434 MANAGEMENT DECISION MAKING IN FORESTRY AND WOOD PRODUCTS.**
**WPS 441 WOOD MECHANICS.**
**WPS 444 WOOD COMPOSITES.**
**WPS 471 PULPING PROCESS ANALYSIS.**
**WPS 472 PAPER PROCESS ANALYSIS.**
**WPS 475 PROCESS CONTROL IN PULP AND PAPER.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**WPS 513 TROPICAL WOODS. Preq.: WPS 202. 2(1-3) F. Alt. yrs.** Structure, identification, properties, characteristics and use of tropical woods, especially those used in plywood and furniture.

**WPS 515 SURFACE AND COLLOID CHEMISTRY OF PAPERMAKING. Preq.: CH 331 or CH 431. 3(3-0) S.** The fundamental principles of surface and colloid chemistry important in paper making and their application to optimizing wet-end processes. The electrokinetic basis of flocculation, retention and other wet-end phenomena and the science of wet-end additives.

**WPS 521 CHEMISTRY OF WOOD POLYSACCHARIDES. Preqs.: CH 223 and WPS 332 or BCH 451. 3(3-0) F. Alt. yrs.** Fundamental chemistry and physical chemistry of monosaccharides and polysaccharides with emphasis on hemicellulose and cellulose. Topics include construction and configuration, stereochemistry, solution properties, molecular weight determination and reactivity.

**WPS 522 CHEMISTRY OF LIGNIN AND EXTRACTIVES. Preqs.: CH 223 and WPS 332 or BCH 451. 3(3-0) S. Alt. yrs.** The biosynthetic pathways, structure and reactivity of lignin and wood extractives with emphasis on topics important to pulping and conversion to useful by-products.

**WPS 525 POLLUTION ABATEMENT IN FOREST PRODUCTS INDUSTRIES. Preq.: Grad. or advanced undergrad. standing in science or engineering curricula. 3(3-0) S.** Pollution sources, in-plant control and treatment of water and air pollution in forest products with concentration on the pulp and paper industry.

**WPS 533 ADVANCED WOOD ANATOMY. Preq.: WPS 202 or CI. 3(1-6) S. Alt. yrs.** Fundamental wood anatomy and cell wall ultrastructure. Laboratory techniques for light and electron microscopic studies of wood.

**WPS 540 WOOD COMPOSITES. Preqs.: WPS 441; grad. or advanced undergrad. standing. 3(3-0) S. Alt. yrs.** Designed to acquaint advanced undergraduate and graduate students with the rapidly expanding field of wood composites. Presentation of production processes for particle board, plywood, hardboard, fiberboard, and other wood composites. Developmenmt of elastic theory for the stiffness, strength and buckling resistance of composites. Test procedures for determining mechanical properties and design procedures for glued laminated members, panel products, and built-up members, including I- and box-beams, stressed-skin panels and sandwich panels, outlined.

**WPS 560 ADVANCED PULP AND PAPER PROCESS ANALYSIS. Preqs.: WPS 321 and 322. 3(3-0) S.** Design and analysis of pulp and paper mill processes; process control applications in pulping, chemical recovery, bleaching and papermaking; principles of pulp mill chemical and energy recovery; and new alkaline pulping recovery technology.

**WPS 591 WOOD AND PAPER SCIENCE PROBLEMS. Preq.: Sr. or grad. standing. Credits Arranged.** Assigned or selected problems in the field of wood, paper and pulp science and technology.

**WPS 599 METHODS OF RESEARCH IN WOOD AND PAPER SCIENCE. Preq.: Advanced undergrad. or grad. standing. Credits Arranged.** Research procedures, problem outlines, presentation of results; consideration of selected studies by forest research organizations; sample plot techniques.

*FOR GRADUATES ONLY*

**WPS 604 TIMBER PHYSICS. Preqs.: MA 212, PY 221, WPS 202. 3(3-0) F. Alt. yrs.** Density, specific gravity and moisture content variation affecting physical properties; physics of drying at high and low temperatures; thermal, sound, light and electrical properties of wood.

**WPS 691 GRADUATE SEMINAR. 1(1-0) F,S.** Presentation and discussion of progress reports on research, special problems and outstanding publications.

**WPS 693 ADVANCED WOOD AND PAPER SCIENCE PROBLEMS. Credits Arranged. F,S.** Selected problems in the field of wood and paper science.

**WPS 699 PROBLEMS AND RESEARCH. Credits Arranged.** Specific problems that will furnish material for a thesis.

# Zoology

**Degrees Offered: Ph.D., M.S., Master of Life Sciences, Master of Wildlife Biology**

**GRADUATE FACULTY**

*Professor* H. F. Heatwole, ***Head of the Department,***
*Professor* J. R. Walters, ***Interim Director of Graduate Programs***
Box 7617, (919) 515-2587

*Professors:* G. T. Barthalmus, P. C. Bradbury, P. T. Bromley, B. J. Copeland, L. B. Crowder, P. D. Doerr, W. C. Grant, R. A. Lancia, C. F. Lytle, J. M. Miller, R. L. Noble, K. H. Pollock, J. F. Roberts, D. E. Smith, H. A. Underwood Jr., J. G. Vandenbergh, T. G. Wolcott;

*Adjunct Professors:* F. A. Cross, J. D. Hair, D. E. Hoss, G. R. Huntsman;
*Professors Emeriti:* D. E. Davis, W. W. Hassler, D. W. Hayne, M. T. Huish, G. C. Miller, T. L. Quay;
*Associate Professors:* B. L. Black, M. N. Feaver, J. F. Gilliam, R. M. Grossfeld, J. M. Hinshaw, R. G. Hodson, E. J. Jones, S. C. Mozley, R. A. Powell, J. A. Rice;
*Associate Professor (USDI):* W. J. Fleming;
*Adjunct Associate Professor:* C. S. Manooch III;
*Assistant Professors:* B. H. Grimes, T. M. Losordo, C. Sullivan;
*Assistant Professors (USDI):* J. A. Collazo, J. E. Hightower

Areas of study include: cell biology and physiology, ecology and behavior, and fisheries and wildlife biology. Specializations within these areas include developmental biology, invertebrate biology, animal reproduction, biorhythms, behavioral ecology, population ecology, conservation biology, wildlife field studies, aquaculture and many others.

**Admission Requirements**
GRE scores (general and biology) are required for admission. Regular admission requires an undergraduate grade point average of 3.0 in an appropriate biological discipline. Some research experience is highly recommended.

**Master's Degree Requirements**
No more than 6 hours of temporary courses (ZO 592, ZO 692) or 2 hours of departmental seminar can be included in the 30-hour requirement for the M.S. Six hours of research credits (ZO699) are requird. A minor (usually 9-10 hours) is required.

**Doctoral Degree Requirements**
A student's advisory committee recommends appropriate courses which will provide a strong foundation in the student's area of interest. This typically includes 21-27 credit hours plus a minimum requirement of 10 hours of research (ZO 699). A minor (usually 9-10 hours) is required.

**Student Financial Support**
Graduate teaching and research assistantships are available to well-qualified students.

**Other Relevant Information**
Students may also pursue degrees in interdepartmental programs in physiology and ecology. Excellent research facilities, equipment and computers are available. Field

work can be conducted at nearby natural areas and laboratory work at various state and federal laboratories associated with the department.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**ZO 410 INTRODUCTION TO ANIMAL BEHAVIOR.**
**ZO(BO) 414 CELL BIOLOGY.**
**ZO(FW) 420 FISHERY SCIENCE.**
**ZO 421 VERTEBRATE PHYSIOLOGY.**
**ZO(ENT) 425 GENERAL ENTOMOLOGY.**
**ZO 441 BIOLOGY OF FISHES.**
**ZO 442 BIOLOGY OF FISHES LABORATORY.**
**ZO 450 EVOLUTIONARY BIOLOGY.**

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ZO 501 ORNITHOLOGY. Preqs.: ZO 201 or 303; BO(ZO) 360. 3(2-3) S.** The biology of birds, including evolution, functional morphology, physiology, ecology and behavior. Field and museum laboratories emphasize particular aspects of morphology, ecology and behavior, as well as taxonomy and identification. One coastal weekend field trip required.

**ZO(PHY) 503 GENERAL PHYSIOLOGY I. 3(3-0) F.** (See physiology.)

**ZO(PHY) 504 GENERAL PHYSIOLOGY II. 3(3-0) S.** (See physiology.)

**ZO(ST) 506 SAMPLING ANIMAL POPULATIONS. 3(3-0) F. Alt. yrs.** (See statistics.)

**ZO(ENT) 509 ECOLOGY OF STREAM INVERTEBRATES. Preqs.: ZO 201 or 302, BO (ZO) 360 or equivalent. 4(2-6) S. Odd yrs.** Introduction to stream ecology and analysis of animal communities. Lectures cover community structure and function, life histories of dominant animals, sampling design and techniques and responses to pollution. Laboratory exercises include field collections, identification of animals and quantitative research techniques. A personal collection of animals and a weekend field trip to mountain streams required.

**ZO 512 ANIMAL SYMBIOSIS. Preq.: 12 hrs. of biology and ZO. 3(3-0) S. Odd yrs.** Symbiotic associations of animals including mutualism, commensalism and parasitism. The morphological, physiological, behavioral and ecological adaptations of symbionts and the complex interactions between partner species.

**ZO(PHY) 513 COMPARATIVE PHYSIOLOGY. Preq.: ZO 421 or CI. 3(3-0) F. Odd yrs.** A comparative study of the organ systems of vertebrates and the phys-

iological processes involved in maintaining the homeostatic state. The various compensatory mechanisms employed during environmental stress included.

**ZO(FW) 515 FISH PHYSIOLOGY. Preqs. or coreqs.: GN 411, ZO 420, 421, 441. 3(2-3) F. Odd yrs.** The biology of fishes: physiology, anatomy, endocrinology, behavior and genetics. Designed especially for graduate students in fisheries. Several trips to research laboratories taken.

**ZO 517 POPULATION ECOLOGY. Preqs.: ZO(BO) 360 and ST 511 or equivalent. 3(3-0) F.** The dynamics of natural populations. Current work, theories and problems dealing with population growth, fluctuation, limitation and patterns of dispersion, species interactions, community structure and ecological genetics.

**ZO 519 LIMNOLOGY. Preqs.: Grad. standing and CI. Credit in both ZO 419 and ZO 519 is not allowed. 4(3-3) F.** Structure and function of lakes and ponds, including physical, chemical and biological controls of productivity and species composition of aquatic plants and animals and effects of pollution on water quality. One local weekend field trip required.

**ZO(MEA) 520 PRINCIPLES OF BIOLOGICAL OCEANOGRAPHY. 3(3-0) S.** (See marine, earth and atmospheric sciences.)

**ZO 522 BIOLOGICAL CLOCKS. Preq.: Grad. standing or CI. 3(3-0) S.** The anatomy, physiology and development of biological clocks in a variety of organisms, including humans. Required readings in primary literature.

**ZO(PHY,PO) 524 COMPARATIVE ENDOCRINOLOGY. 4(3-3) S.** (See poultry science.)

**ZO(MEA) 534 MARINE BENTHIC ECOLOGY. 3(3-0) S. Alt. yrs.** (See marine, earth and atmospheric sciences.)

**ZO(GN) 540 EVOLUTION. 3(3-0) F.** (See genetics.)

**ZO 542 HERPETOLOGY. Preqs.: ZO 323 or 303, ZO 421. 3(2-3) S. Even yrs.** The biology of the amphibians and reptiles: systematics, life history, anatomy, behavior, physiology and ecology.

**ZO 544 MAMMALOGY. Preq.: ZO 323 or ZO 303. 4(3-3) F.** The biology of mammals: evolution, functional morphology, reproduction, behavior, ecology, population biology, classification and identification. One weekend field trip planned.

**ZO(FW) 553 PRINCIPLES OF WILDLIFE SCIENCE. Preq.: ZO (BO) 360. 3(2-3) F.** The principles of wildlife management and their application studied in the laboratory and in the field.

**ZO(FW) 554 WILDLIFE FIELD STUDIES. Preqs.: ZO 553, ST 311; CI. 3(2-3) S. Odd yrs.** Field application of methods for studying vertebrate wildlife populations; sampling methods, data gathering, analysis and interpretation of results practiced. Participation in field laboratories and one or two weekend field trips required.

**ZO(MB) 555 PROTOZOOLOGY. Preq.: CI. 4(2-6) S. Odd yrs.** The biology of the Protozoa: morphology, physiology, ecology, genetics, reproduction, evolution, systematics and life-cycles of both free-living and parasitic taxa; laboratory stress recognition of selected forms and demonstrate techniques used to prepare specimens for microscopic examination.

**ZO(BO) 560 PRINCIPLES OF ECOLOGY. Preq.: Three semesters of college-level biology courses. 4(3-3) F.** A consideration of principles of ecology at graduate level. Each of the major subject areas of ecology developed in sufficient depth to provide a factual and philosophical framework for the understanding of ecology.

**ZO 581 HELMINTHOLOGY. Preqs.: ZO 323 or 303, ZO 315 or equivalent. 4(2-4) F. Odd yrs.** The morphology, biology and control of parasitic helminths.

**ZO(ENT) 582 MEDICAL AND VETERINARY ENTOMOLOGY. 3(2-3) S.** (See entomology.)

**ZO(FW) 586 AQUACULTURE I. Preqs.: ZO (BO) 360, sr. or grad. standing. 3(3-0) F. Even yrs.** The biological and general principles of aquaculture. Emphasis on the present status of aquaculture, species involved, techniques employed, and problems encountered. Discussion of recent advances in research and development and identification of areas of future research and development.

**ZO(FW) 587 AQUACULTURE I LABORATORY. Preqs.: ZO (BO) 360, sr. or grad. standing; Coreq.: ZO 586. 1(0-3) F. Even yrs.** Methods and techniques of cultivating aquatic organisms. Field trips and reports on local hatcheries and facilities required. (Three to four overnight field trips taken on week days to coastal areas, state hatcheries, and private hatcheries; students are responsible for shared room costs and their meals. Four field trips also taken on laboratory day within driving range of Raleigh.)

**ZO 590 SPECIAL STUDIES. Preqs.: Twelve hours ZO, CI. 1-3. Max. 6. F,S,Sum.** A directed individual investigation of a particular problem in zoology, accompanied by a review of the pertinent literature. A maximum of three hours allowed toward the master's degree.

**ZO 592 TOPICAL PROBLEMS. Preq.: CI. 1-3 F,S.** Organized, formal lectures and discussion of a special topic.

**ZO 593 AQUATIC ECOLOGY SEMINAR. Preqs.: Grad., PBS or sr. standing; one course in aquatic, marine or fisheries areas. 1-3 F.S.** Presentations and discussions of recent research and topical issues in aquatic and marine sciences. Each student enrolled for credit must make at least one presentation.

**ZO(PHY) 595 SEMINAR IN BIOLOGY OF REPRODUCTION. Preq.: ZO 421. 2(2-0) F. Even yrs.** Current topics in animal reproduction presented by reproductive physiologists from various Research Triangle institutions. Student presentations of research projects or library projects in the area of animal reproduction.

*FOR GRADUATES ONLY*

**ZO 614 ADVANCED CELL BIOLOGY. Preq.: ZO (BO) 414 or equivalent. 3(3-0) S. Even yrs.** The current problems of cell biology including the problems of the molecular organization and functions of membrane systems, subcellular organelles and specialized cells.

**ZO 618 COMMUNITY ECOLOGY. Preqs.: BO(ZO) 360, BO(ZO) 560 or equivalent; BO(ZO) 365 or equivalent. 3(3-0) S. Odd yrs.** Animal community structure and function. Effects of competition, predation, coevolution and disturbance on community composition. Emphasis on ecological and evolutionary controversies from empirical and theoretical approaches.

**ZO 619 ADVANCED LIMNOLOGY. Preq.: ZO 419. 3(3-0) S. Even yrs.** Recent topics in limnological research. Lectures and discussion draw from journal articles on physical, chemical and biological aspects, including nutrient control of productivity, predator control of community structure and determinants of water quality. A research paper or project required.

**ZO 621 FISHERY SCIENCE. Preqs.: ST 511, ZO 420, a course in calculus. 3(2-3) F. Even yrs.** An analysis of fishery research methods. Population enumeration and dynamics. The relationship between fluctuations in natural populations and environmental factors.

**ZO(MEA) 623 ADVANCES IN MARINE COMMUNITY ECOLOGY. 3(3-0) S. Alt. yrs.** (See marine, earth and atmospheric sciences.)

**ZO(MEA) 624 ECOLOGY OF FISHES. 3(3-0) F. Odd yrs.** (See marine, earth and atmospheric sciences.)

**ZO 626 QUANTITATIVE FISHERIES MANAGEMENT. Preqs.: ST 511 and ZO 420 or equivalent. 3(2-3) F. Even yrs.** Current methods for assessment and management of exploited fish populations, including sampling methods, data analysis and modeling. A required research paper or project.

**ZO 644 ADVANCED TOPICS IN THE STUDY OF MAMMALS. Preq.: ZO 544. 3(2-3) S. Even yrs.** Current topics in the study of mammals with concentration each year on a different topic, such as community ecology, population biology, evolution or functional morphology. Student research projects required.

**ZO(BO) 660 ADVANCED TOPICS IN ECOLOGY I. 3(3-0) S.** (See botany.)

**ZO 690 SEMINAR. 1(1-0) F,S.** The presentation and defense of original research and current literature.

**ZO 691 TOPICS IN ANIMAL BEHAVIOR. 3(3-0) F. Even yrs.** Intensive examination of selected aspects of animal behavior and their relationship to physiology, ecology and other biological fields. May be repeated for credit when topic changes.

**ZO 692 SEMINAR IN EVOLUTIONARY BIOLOGY. 1-3 F.** Seminar exploring current concepts and issues in evolutionary aspects of animal behavior, ecology and population biology. Topic varies, may be repeated for credit when topic changes. Format may be reading and discussing important new books, current journal articles or classic papers. Intended primarily as forum for interaction of students in this area of zoology but open to others.

**ZO 699 RESEARCH IN ZOOLOGY. Preqs.: Twelve semester credits in ZO and CI. Credits Arranged. F,S.**

# MINOR AND OTHER ORGANIZED PROGRAMS OF STUDY

## Agricultural Communications

*FOR GRADUATES AND ADVANCED UNDERGRADUATES ONLY*

**AC 590 SPECIAL TOPICS IN AGRICULTURAL COMMUNICATIONS. Preq.: Sr. or grad. standing. 1-6.** Selected special topics for study in the theoretical approaches to communications problems or experimental investigation with instructor guidance.

## Anthropology

*SELECTED ADVANCED UNDERGRADUATE COURSES*

ANT 416 RESEARCH METHODS IN CULTURAL ANTHROPOLOGY.
ANT 420 BIOLOGICAL BASES FOR HUMAN SOCIAL BEHAVIOR.
ANT 498 SPECIAL TOPICS IN ANTHROPOLOGY.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ANT 508 CULTURE AND PERSONALITY. Preq.: ANT 252 or 6 hrs. in cultural anthropology. 3(3-0).** The interplay between cultural norms and the enculturation process. From a cross-cultural perspective, an examination of the process of transmission and learning of cultural norms, as well as the effect of culture change on the individual. The historical development of the field as well as contemporary trends in both theoretical and applied contexts.

**ANT 511 ANTHROPOLOGICAL THEORY. Preqs.: ANT 252 or 6 hrs. in cultural anthropology. 3(3-0).** Approach to theory from both an historical and contemporary point of view. Emphasis upon the key anthropological concept of culture and its significance for understanding man and his works.

**ANT 512 APPLIED ANTHROPOLOGY. Preq.: ANT 252 or CI. 3(3-0).** A review of the historical development of applied anthropology and a study of anthropology as applied in government, industry, community development, education and medicine. Analysis of the processes of cultural change in terms of the application of anthropological techniques to programs of developmental change.

**ANT 591 SPECIAL TOPICS IN ANTHROPOLOGY. Preq.: ANT 501 or equivalent. 1-6.** Provision for in-depth investigation of some particular topic in anthropology. Reflection of current student needs and interests through variations in course content and mode of study. Deterimination of topics by the faculty member(s) and student.

# Artificial Intelligence (Minor Program)

## GRADUATE FACULTY

*Professors:* R. C. Luo, H. E. Schaffer, A. L. Tharp; *Associate Professors:* D. R. Bahler, H. D. Levin, W. J. Rasdorf, R. D. Rodman, E. T. Sanii; *Lecturer:* J. C. Sutton III

Artificial intelligence is the branch of computer science concerned with designing computer systems which exhibit the characteristics normally associated with intelligence in human behavior, such as understanding language, learning, reasoning, solving problems, and so on. At NCSU, artificial intelligence is an interdisciplinary field, with faculty from several departments engaged in fundamental research and applications.

The university offers courses of study leading to a minor in artificial intelligence as part of the Master of Science and Doctor of Philosophy degrees. This option is available to all graduate students except those in computer science, who can choose artificial intelligence as an interest area.

To fulfill the academic requirements for a minor in artificial intelligence, each master's student must successfully complete at least three, and each doctoral student at least six, of the courses in the artificial intelligence curriculum. Two of the courses must be CSC 511, Artificial Intelligence I and CSC 611, Artificial Intelligence II. Other courses offered as part of the artificial intelligence curriculum include: CSC 502 Computational Linguistics; CSC 602 Computational Semantics; ECE 659 Computer Vision; CSC (ECE,IE) 575 Voice Communication Systems; CSC(ECE,IE) 675 Advances in Voice Input/Output Communication Systems. Also, from time to time special topics courses are offered covering subjects such as knowledge engineering, fuzzy reasoning, knowledge representation, artificial intelligence applications to CAD, and artificial intelligence in manufacturing.

Graduate students in computer science who select artificial intelligence as an interest area are subject to the same academic requirements that define other interest areas within computer science.

# Biological Sciences

There is no separate graduate major in the biological sciences, but both M.S. and Ph.D. degrees are offered in several life science departments and programs of the College of Agriculture and Life Sciences. Also, non-thesis Master of Life Sciences degrees are offered by several departments and programs for students who wish to emphasize course work in a graduate program. Master of Life Sciences degrees may be appropriate for students who are already working or plan to work in a professional capacity in business, industry or government agencies rather than to continue to the doctorate. These degrees are not necessarily terminal, however, and successful students may be able to proceed to other advanced degrees. Interdisciplinary courses applicable to several graduate programs are offered by the Biological Sciences Interdepartmental Program.

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**BS 510 ADVANCED BIOLOGY FOR SECONDARY TEACHERS. Preq.: Two yrs. of college biology. 6(4-6) Sum.** A comprehensive review of important principles and concepts of biology for secondary teachers preparing to teach advanced placement biology. Contemporary topics in biology emphasized; extensive laboratory and field work are included.

**BS 590 SPECIAL PROBLEMS IN BIOLOGICAL INSTRUMENTATION. Preq.: CI. 1-3 F,S.** Basic components of spectrophotometers including light sources, dispersing devices, detectors and read-out methods; theoretical and practical aspects of electron microscopy; basics of analog and digital computing methods and applications of computers to biological research; methods of separation and identification of bio-polymers; principles of measurement; the application of electronics in biological measuring and sensing devices; and human cytological techniques. Course consists of five-week modules (sections) devoted to specific types of instrumentation.

# Biomedical Engineering (Minor Program)

## GRADUATE FACULTY

*Professors:* C. F. Abrams, M. A. Ayoub, R. G. Carbonell, B. S. Gupta, J. J. Hren, C. Kleinstreuer, H. T. Nagle Jr., A. A. Nilsson, D. F. Ollis, H. G. Perros, S. A. Rajala, J. E. Smallwood, W. E. Snyder, L. Stikeleather, E. A. Stone, M. K. Stoskopf, D. E. Thrall, H. J. Trussell, T. G. Wolcott;
*Professors Emeriti:* F. M. Richardson, C. W. Suggs;

*Associate Professors:* S. M. Blanchard, D. G. Bristol, R. D. Gould, L. C. Hudson, S. M. Hudson, J. M. Mackenzie, R. E. Meyer, T. K. Miller III, R. A. Powell, C. E. Smith, K. A. Spaulding;
*Visiting Associate Professor:* J. C. Russ;
*Adjunct Associate Professor:* J. P. Archie;
*Assistant Professors:* P. W. Hellyer, S. C. Roe;
*Adjunct Assistant Professor:* P. Santago II

The biomedical engineering program provides graduate minors under the direction of faculty from fourteen departments in the Colleges of Agriculture and Life Sciences, Engineering, Forest Resources, Physical and Mathematical Sciences, Textiles and Veterinary Medicine at NCSU. Faculty from the Biomedical Engineering Departments at Duke University and the University of North Carolina at Chapel Hill are also actively involved. Graduate students from all departments may elect a biomedical engineering minor. To fulfill the minor requirements, a student must take three courses in one of four specialty tracks: biomechanics, biofluids and biomaterials; biomedical modeling and signal processing; instrumentation, sensors and telemetry; medical imaging and communications systems.

The graduate faculty maintain lists of courses from which the students may make their selections. The particular choice of courses is left to the student and the student's advisory committee. A student may choose a minor outside one of the four tracks with the approval of the Biomedical Engineering Academic Affairs Committee. The courses for all biomedical engineering graduate minors must be distinctly different from the student's major field of study.

Students who elect the biomedical engineering graduate minor are encouraged to engage in research activities that involve interactions with faculty and students in other departments and/or colleges.

## Biotechnology (Minor Program)

### GRADUATE FACULTY

*Associate Professor* M. A. Conkling, ***Director***
Box 7512, (919) 515-4230, Fax (919) 151-4231, Email: biotech@ncsu.edu

*Professors:* K. B. Adler, P. F. Agris, W. F. Boss, R. G. Carbonell, P. B. Carter, H.-m. Chang, E. V. L. DeBuysscher, W. J. Dobrogosz, E. J. Eisen, F. J. Fuller, C. K. Hall, B. B. Hammerberg, H. M. Hassan, T. W. Joyce, R. M. Kelly, T. R. Klaenhammer, C. S. Levings III, W. L. Miller, D. F. Ollis, R. M. Petters, J. F. Roberts, J. G. Scandalios, R. R. Sederoff, J. C. H. Shih, S. L. Spiker, H. T.

Stalker, H. E. Swaisgood, C. S. Teng, E. C. Theil, W. F. Thompson, W. A. F. Tompkins, B. S. Weir;
*Professor (USDA):* P. E. Bishop;
*Associate Professors:* B. Alston-Mills, H. V. Amerson, M. T. Andrews, R. S. Boston, E. F. Bowden, S. E. Curtis, M. E. Daub, T. J. Hoban IV, P. K. Kilpatrick, R. J. Linderman, S. A. Lommel, E. S. Maxwell, T. Melton, E. S. Miller, C. H. Opperman, P. E. Orndorff, S. M. Peretti, M. A. Qureshi, R. M. Roe, P. L. Sannes, R. C. Smart, A.-M. Stomp, K. G. Tatchell, M. B. Tompkins, S. L. Tonkonogy;
*Assistant Professors:* R. E. Dewey, C. E. Farin, L. K. Hanley-Bowdoin, C. L. Hemenway, P. B. Lindgren, J. N. Petitte, I. T. D. Petty, D. Robertson, B. Sherry, D. Weinstock, A. K. Weissinger;
*Assistant Professor (USDA):* P. H. Sisco

The Biotechnology Program includes faculty from twenty departments in the Colleges of Agriculture and Life Sciences, Engineering, Forest Resources, Physical and Mathematical Sciences, and Veterinary Medicine. Graduate study leading to a Ph.D. minor in biotechnology may be taken by students who reside and conduct their research in one of the participating departments. To obtain a minor in biotechnology, the student must successfully complete at least six credit hours in the laboratory core courses selected from the list below and must conduct graduate thesis research in an area of biotechnology.

Research in biotechnology is focused in three main areas: recombinant DNA technology, bioprocessing/bioanalytical techniques, and *in vitro* culture techniques. The multidisciplinary nature of biotechnology means that a wide range of research topics and techniques are applicable, such as molecular level genetics and associated research in molecular biology, enzyme technology and protein engineering, bioprocessing using cells or enzymes, development of biosensors, hybridoma technology, cell culture techniques and embryo manipulation.

*FOR GRADUATES ONLY*

**BIT 660 CORE TECHNOLOGIES IN MOLECULAR AND CELLULAR BIOLOGY. Preq.: CI. 4(3-37) Sum.** Intensive four-week course in basic technologies of recombinant DNA procedures, isolation and identification of nucleic acids and proteins.

**BIT 697 ADVANCED TOPICS IN BIOTECHNOLOGY. Preq.: BIT 660. 3-6 Sum.** Intensive three-week or six-week courses in advanced technologies such as DNA sequencing, downstream processing, immunological techniques, construction of c-DNA libraries, mammalian embryo manipulation, plant transformation, bio-

reactor design, cloning in gram positive bacteria, electron microscopy or techniques in yeast molecular biology.

*COURSES FROM ASSOCIATE DEPARTMENTS*

**ANS 606 ANIMAL BIOTECHNOLOGY: EMBRYO MANIPULATION.**
**BCH 552 EXPERIMENTAL BIOCHEMISTRY.**
**CS(BO,GN,HS) 547 CELL AND TISSUE TECHNIQUES IN PLANT BREEDING.**
**FS 504 FOOD PROTEINS AND ENZYMES.**
**GN 666 LABORATORY IN MOLECULAR GENETICS.**
**MB 660 EXPERIMENTAL MICROBIAL GENETICS.**

# Business Management (Minor Program)

## GRADUATE FACULTY

*Professor* J. W. Wilson, ***Interim Head***
*Professor* S. G. Allen, ***Director of Graduate Programs***

*Professors:* R. L. Clark, J. D. Hess, D. M. Holthausen Jr., C. P. Jones, D. K. Pearce;
*Associate Professors:* A. Agrawal, D. L. Baumer, J. C. Dutton, E. A. McDermed, K. Mitchell, A. Padilla, J. C. Poindexter Jr.;
*Assistant Professors:* C. C. Bozarth, S. N. Chapman, K. S. Davis, S. K. Markham, V. L. Mitchell, Y. E. Yang, G. S. Young

The department offers a graduate minor in business management. Students enrolled in master's programs other than the Master of Science in Management may earn a minor by successfully completing nine hours of courses in the department at the 500 or 600 level. For a listing of courses in business management, see management.

# Communication

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**COM 552 HUMAN COMMUNICATION THEORY. Preq.: Grad. standing or PBS status. 3(3-0) F.** The role of theory in the study of human communication. General social scientific theories as well as context-based theories including interpersonal, public, group, organizational and mass communication contexts.

**COM 556 SEMINAR IN ORGANIZATIONAL COMMUNICATION. Preq.: Advanced undergrad. or grad. standing. 3(3-0) S.** Theoretic and applied approaches for studying communication perspectives of organizational behavior.

Topics relate communication with organizational theories, research methods, leadership, power, attraction, conflict and theory development.

**COM 566 SEMINAR IN CRISIS COMMUNICATION. 3(3-0) S. Alt. yrs.** Working within the theoretical perspectives of communication, conflict management and organizational designs, a theoretical understanding for crisis communication, including thorough guidelines for strategic communication planning for, managing and evaluating crises.

**COM 598 INDEPENDENT STUDY IN COMMUNICATION. Preq.: Grad. standing, 1-3 F,S,Sum.** A special projects course to be utilized for guided research at the graduate level. Topic determined by the instructor. No more than 6 hrs. may be used as credit toward graduation with a master's degree.

*FOR GRADUATES ONLY*

**COM(ENG) 622 THE RHETORIC OF WRITTEN DISCOURSE. 3(3-0) S.** (See English.)

**COM(ENG) 623 RHETORICAL CRITICISM: THEORY AND PRACTICE. 3(3-0) F.** (See English.)

**COM 698 SPECIAL TOPICS IN COMMUNICATION. 1-3 F,S,Sum.** A detailed investigation of a special topic in communication. No more than 6 hrs. may be used as credit toward graduation with a master's degree.

# Computational Engineering and Sciences (Minor Program)

## GRADUATE FACULTY

*Professor* P. J. Turinsky, ***Program Coordinator***

*Professors:* W. E. Alexander, J. Bernholc, S. R. Cotanch, R. E. Funderlic, C. K. Hall, C. Kleinstreuer, D. F. McAllister, D. S. McRae, G. E. Mitchell, J. F. Monahan, H. G. Perros, R. O. Scattergood, W. J. Stewart, M. H. Whangbo, R. E. White, J. L. Whitten;
*Associate Professors:* J. M. Doster, J. E. Franke, E. F. Gehringer, Y.-L, Lin, T. K. Miller III, M. A. Vouk;
*Assistant Professor:* J. W. Baugh

The Computational Engineering and Sciences Program includes faculty from twelve departments in the College of Engineering and College of Physical and Mathemati-

cal Sciences. Graduate students pursuing graduate study toward a master's or Ph.D. degree in one of the participating science or engineering departments may elect this program in place of the traditional minor. [Note that students wishing to earn a graduate degree in mathematics or computer science should reference these departments' sections of the Graduate Catalog for details on options available in computational mathematics and scientific computing.] To complete the program requirements, a student must successfully complete a sequence of graduate-level applied mathematics and computer science courses and, if a research dissertation is required, utilize advanced computational techniques in the course of conducting the research.

The Computational Engineering and Sciences Program is designed to efficiently prepare graduate students to undertake research utilizing scientific computing by combining course work in applied mathematics and computer science in addition to course work in the traditional major. The program recognizes that a new area of scientific pursuit, numerical simulation, is emerging as a new paradigm for scientific inquiry complementing theory and laboratory experiment. Typical areas of research include, but are not limited to, computational fluid dynamics, quantum chemistry and atmospheric modelling. Admission to the program is gained after enrollment in the Graduate School and the graduate program is underway. Program course requirements are selected from applied mathematics and computer science courses listed elsewhere in this Graduate Catalog. To facilitate the satisfaction of prerequisite requirements for graduate-level computer science courses, a migration course offered for graduate credit is available which combines the key contents of several undergraduate courses. Typical courses that may be selected to satisfy this program's requirements include advanced calculus, numerical analysis, numerical linear algebra for parallel architectures, stochastic simulation, computer operating systems, digital systems architecture, computer graphics, compiler construction, software engineering, and design and analysis of algorithms.

# Design

For a listing of graduate faculty and program information, see architecture, graphic design, industrial design and landscape architecture.

## *SELECTED ADVANCED UNDERGRADUATE COURSES*

**DN 400 DESIGN STUDIO.**
**DN 412 ADVANCED PHOTOGRAPHY.**
**DN 413 SYNTHETIC DRAWING.**
**DN 414 COLOR AND LIGHT.**
**DN 454 GEOMETRY FOR DESIGNERS.**
**DN 455 BUILDING WORKSHOP.**

DN 472 ADVANCED SURFACE DESIGN.
DN 480 INTERMEDIATE STUDIO.
DN 481 INTERMEDIATE DRAWING.
DN 484 INTERMEDIATE PAINTING.
DN 486 INTERMEDIATE SCULPTURE.
DN 487 SCULPTURE: LIFE MODELING.
DN 491 SPECIAL SEMINAR IN DESIGN.
DN 492 SPECIAL TOPICS IN DESIGN.
DN 494 INTERNSHIP IN DESIGN.
DN 495 INDEPENDENT STUDY IN DESIGN.

*FOR GRADUATES ONLY*

**DN 611 ADVANCED VISUAL LABORATORY. Preq.: May be taken for a max. of 12 credit hours. 2-4 F,S.** Advanced experimental studies in visual phenomena related to design.

# Education [General Courses]

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**ED 597 SPECIAL PROBLEMS IN EDUCATION. Preq.: Grad. standing or PBS status. 1-3 F,S,Sum.** Opportunity for graduate students in education to study problem areas in professional education under the direction of a member of the graduate faculty.

**ED 599 RESEARCH PROJECTS IN EDUCATION. Preqs.: CI; ELP 532 or equivalent. 1-3 F,S,Sum.** A project or problem in research in education for graduate students, supervised by members of the graduate faculty. Research choice on basis of individual students' interests and not to be part of thesis or dissertation research.

# Engineering [General Courses] (Designed for use by graduate students in any department in the College of Engineering.)

*FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**E(MA,OR) 531 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL I. 3(3-0) F.** (See operations research.)

*FOR GRADUATES ONLY*

**E(MA,OR) 631 DYNAMIC SYSTEMS AND MULTIVARIABLE CONTROL II. 3(3-0) S. Alt. yrs.** (See operations research.)

# Foreign Languages and Literatures

## GRADUATE FACULTY

*Professor* J. H. Stewart, ***Head of the Department***

***Professors:*** G. F. Gonzalez, J. R. Kelly, G. G. Smith, M. A. F. Witt;
***Professors Emeriti:*** A. A. Gonzalez, M. Paschal, G. W. Poland, E. M. Stack;
***Associate Professors:*** R. M. A. Alder, S. G.-Q. Alonso, W. M. Holler, M. M. Magill, A. C. Malinowski, L. Mykyta, M. L. Salstad, S .E. Simonsen, M. L. Sosower;
***Associate Professor Emeritus:*** H. Tucker Jr.;
***Assistant Professors:*** V. Bilenkin, H. G. Braunbeck, G. A. Dawes, D. M. Marchi, D. J. Mennell, J. P. Mertz, G. Williams

The Department of Foreign Languages and Literatures offers courses to assist graduate students in preparing to use modern foreign languages in research and advanced study. These courses are not open to undergraduates. With special permission of the Graduate School, certification may be obtained in languages not normally taught by the department.

The following courses are designed to be audited, and credits do not apply toward advanced degrees.

**FLF 401 FRENCH FOR GRADUATE STUDENTS. 3(3-0) F.** Basic French grammar, with special attention to characteristics of formal expository style, and illustrative readings. Study of extracts from scholarly publications in the students' areas of research. Graduate language certification granted on satisfactory completion of the course.

**FLG 401 GERMAN FOR GRADUATE STUDENTS. 3(3-0) F.** Basic German grammar, with special attention to characteristics of formal expository style, and illustrative readings. Study of extracts from scholarly publications in the students' areas of research. Graduate language certification granted on satisfactory completion of the course.

**FLS 401 SPANISH FOR GRADUATE STUDENTS. 3(3-0) F.** Basic Spanish grammar, with special attention to characteristics of formal expository style, and illustrative readings. Study of extracts from scholarly publications in the students' areas of research. Graduate language certification granted on satisfactory completion of the course.

The following registration categories may be used, when appropriate, by students in all graduate programs. Students registered in one of these categories are not permitted to register for any other courses during the same semester.

**GR 596S MASTER'S SUMMER RESEARCH. 0(0-0) Sum.** For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

**GR 597 MASTER'S EXAMINATION ONLY. 0(0-0) F,S,Sum.** For graduate students in master's programs not requiring a thesis who have completed all requirements except the final oral examination by the beginning of the term in which the degree is to be awarded.

**GR 598 MASTER'S THESIS PREPARATION ONLY. 0(0-0) F,S,Sum.** For graduate students who have completed all course work, research and residence requirements and who are writing a thesis.

**GR 695 DOCTORAL PRELIMINARY EXAMINATION ONLY. 0(0-0) F,S, Sum.** For doctoral students who have scheduled no formal course work during a given term, but who are preparing for and taking preliminary written and oral examinations.

**GR 696S DOCTORAL SUMMER RESEARCH. 0(0-0) Sum.** For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to dissertation research.

**GR 697 DOCTORAL DISSERTATION RESEARCH. 0(0-0) F,S.** For doctoral students who have scheduled no formal course work during a given term, who have passed the preliminary examinations, who have completed at least six hours of departmental research on the doctoral program and who are devoting full time to the dissertation. Students so registered are full-time.

**GR 698 DOCTORAL DISSERTATION PREPARATION. 0(0-0) F,S,Sum.** For graduate students who have completed all course work, research and residence requirements and who are writing a dissertation.

# Pest Management

## GRADUATE FACULTY

*Professors:* J. T. Ambrose, C. S. Apperson, J. J. Arends, C. W. Averre III, R. C. Axtell, J. S. Bacheler, M. K. Beute, J. R. Bradley Jr., R. L. Brandenburg, W. M. Brooks, R. I. Bruck, G. A. Carlson, H. D. Coble, F. T. Corbin, J. M. Davis, E. J. Dunphy, H. J. Gold, F. Gould, F. P. Hain, G. G. Kennedy, W. M. Lewis, H. M. Linger, L. D. King, J. R. Meyer, T. J. Monaco, D. P. Schmitt, W. A. Skroch, P. S. Southern, R. E. Stinner, T. B. Sutton, J. W. Van Duyn, A. D. Worsham;
*Professor (USDA):* R. A. Reinert;
*Associate Professors:* J. E. Bailey, M. M. Peet

The concept of integrated pest management (IPM) combines the theoretical and practical aspects of cultural, biological and chemical control into effective systems that maintain pest populations at levels that minimize economic and environmental damage. This approach and its implementation are opening new career opportunities for broadly informed individuals who understand the basic biology and ecology of pests and the systems with which they are associated.

Graduate study in integrated pest management draws upon faculty from several departments, especially plant pathology, entomology, crop science and horticultural Science. Each student's advisory committee must include a member of the IPM graduate faculty. Additional information may be obtained by contacting a member of the IPM Graduate Faculty or the Director, Office of Academic Programs, 115 Patterson Hall, Box 7642, North Carolina State University, Raleigh, North Carolina 27695-7642.

Students are advised to review course listings in such relevant departments as animal science, crop science, economics and business, entomology, horticultural science, plant pathology, soil science, the biomathematics program and the College of Forest Resources.

# Philosophy

## *FOR GRADUATES AND ADVANCED UNDERGRADUATES*

**PHI(PSY) 525 INTRODUCTION TO COGNITIVE SCIENCE. Preq.: Grad. standing or CI. Credit for both PHI(PSY) 425 and PHI(PSY) 525 is not allowed. 3(3-0) F.** Philosophical foundations and empirical fundamentals of cognitive science, an interdisciplinary approach to human cognition. The computational

model of mind, mental representation, cognitive architecture, the acquisition and use of language.

**PHI 588 ADVANCED TOPICS IN PHILOSOPHY. Preq.: Must have grad. standing. 3(3-0).** Detailed investigation of selected advanced topics in philosophy. Topics determined by faculty members in consultation with head of department.

*FOR GRADUATES ONLY*

**PHI 691 ADVANCED INDEPENDENT STUDY IN PHILOSOPHY. 1-6.** Independent study of an advanced topic in philosophy under the supervision of a faculty member.

# Plant Physiology

## GRADUATE FACULTY

*Professor* C. D. Raper, ***Coordinator***
Box 7619, (919) 515-2644

*Professors:* W. F. Boss, F. T. Corbin, R. C. Fites, J. S. Huang, W. A. Jackson, C. S. Levings III, D. M. Pharr, E. C. Sisler, S. L. Spiker, W. F. Thompson, R. J. Volk;
*Professors (USDA):* S. C. Huber, D. W. Israel, D. E. Moreland, R. F. Wilson;
*Associate Professors:* H. V. Amerson, R. B. Boston, M. A. Conkling, M. M. Peet, R. Wells;
*Associate Professors (USDA):* E. L. Fiscus, T. W. Rufty Jr.;
*Assistant Professors:* G. P. Fenner, D. Robertson;
*Assistant Professors (USDA):* K. O. Burkey, M. G. Redinbaugh

The plant physiology program is an interdepartmental offering. Although not a formal degree program, students may elect to major or minor in the plant physiology program at both the master's and Ph.D. levels. Students entering the program should have appropriate knowledge in plant biology, chemistry, mathematics and physics. Some formal training in genetics, physical chemistry and statistics is normally expected.

When majoring in plant physiology, students will be closely affiliated with the same department as their major professor. As such, they will be required to meet respective departmental requirements for teaching, written and oral examinations, and seminar attendance. Departments currently participating in this program are: biochemistry, botany, crop science, forestry, genetics, horticultural science, plant

pathology and soil science. The chair or co-chair of the student's advisory committee must be a member of the Plant Physiology Faculty.

This program is administered by the Plant Physiology Executive Committee. Additional information about the program may be obtained by writing to one of the listed faculty members or to the coordinator.

Course requirements for this program include two core areas as summarized below. Students majoring in the program are encouraged to develop background training in all of the indicated courses, while those minoring in plant physiology must meet the minimum requirements for each core area.

Group I (At least two of the listed courses)

**BO 510 PLANT ANATOMY**
**BO 551 ADVANCED PLANT PHYSIOLOGY I**
**BO 552 ADVANCED PLANT PHYSIOLOGY II**

Group II

**BCH 540 PROTEINS**

At least two of the following courses:

**BCH 541 NUCLEIC ACIDS**
**BCH 542 METABOLISM**

*or*

**BCH 544 INTERMEDIARY METABOLISM**
**BCH 543 BIOCHEMICAL REGULATORY PROCESSES**
**BCH 555 PLANT BIOCHEMISTRY**

# Political Science and Public Administration

*Professor* M. S. Soroos, ***Head of the Department***

For listings of graduate faculty and information about the two programs, see the political science section and the public administration section.

# Solid State Sciences (Minor Program)

## GRADUATE FACULTY

***University Professor*** G. Lucovsky, ***Chair***

*Professors:* K. J. Bachmann, S. M. Bedair, J. Bernholc, R. F. Davis, R. E. Fornes, J. R. Hauser, J. J. Hren, M. A. Littlejohn, R. M. Kolbas, J. Narayan, R. J. Nemanich, M. A. Paesler, G. Rozgonyi, P. E. Russell, D. E. Sayers, J. F. Schetzina, A. F. Schreiner, E. O. Stejskal, M. H. Whangbo, J. J. Wortman;

The university offers courses of study leading to a minor in solid state sciences as part of the Master of Science and the Doctor of Philosophy degrees. This option is available to all graduate students pursuing research in the broad area of solid state science and requires that a member of the solid state sciences faculty serve on the student's research committee.

Solid state sciences is an interdisciplinary area of research that applies and extends concepts from the traditional academic disciplines of chemistry, electrical and computer engineering, materials science and engineering, and physics to basic and applied problems with a primary focus on solid state materials. At NCSU, there are a significant number of such research programs that involve faculty and students in more than one of the academic departments listed above. This minor program can be customized to provide a course complement for these ongoing programs, as well as for any additional solid state materials research programs as they are initiated, developed and implemented.

To fulfill the academic requirements for a minor in solid state sciences, each master's student must successfully complete at least three, and each doctoral student, four of the courses in the solid states sciences curriculum. A partial listing of courses in this program includes: CH 501, 503 Advanced Inorganic Chemistry I, II; CH 531, 631 Chemical Thermodynamics I, II; CH 533 Chemical Kinetics; CH 537 Quantum Chemistry; ECE 530 Physical Electronics; ECE 539 Integrated Circuit Technology and Fabrication; ECE 623 Optical Properties of Semiconductors; ECE 624 Electronic Properties of Solid State Devices; ECE (PY) 627 Semiconductor Thin Films Technology; MAT 512 Scanning Electron Microscopy; MAT 515 Fundamentals of Transmission Electron Microscopy; MAT 560 Materials Science and Processing of Semiconductor Devices; MAT 595 Advanced Materials Experiments; MAT 612 Advanced Scanning Electron Microscopy and Surface Analysis; MAT 660 Defects, Diffusion and Ion Implantation in Semiconductors; MAT 692 Advanced Topics in Materials Science and Engineering; PY (ECE) 552, 553 Introduction to the Structure of Solids I, II. In addition, other courses (for example, special topics courses in any one of the participating departments) may also be substituted into an individual student's designated solid state sciences minor program at the discretion of his/her committee.

# Water Resources

**Minor Program**

**WATER RESOURCES COMMITTEE**

J. D. Gregory, ***Chair***
Box 8002, (919) 515-7567, E-mail: jim_gregory@ncsu.edu

J. E. Parsons (Biological and Agricultural Engineering), J. M. Burkholder (Botany), M. R. Overcash (Chemical Engineering), W. S. Galler (Civil Engineering), J. B. Weber (Crop Science), R. B. Palmquist (Economics), F. P. Hain (Entomology), R. E. Carawan (Food Science), S. R. Raval (Landscape Architecture), D. G. Evans (Marine, Earth and Atmospheric Sciences), J. W. Gilliam (Soil Science), C. B. Smith (Textile Engineering, Chemistry and Science), T. W. Joyce (Wood and Paper Science), S. C. Mozley (Zoology)

The graduate minor in water resources is an interdisciplinary, interdepartmenal minor that is designed to provide a specialization in water resources for students who are majoring in the many disciplines of natural resources, engineering, technology and social sciences that are related to or involve water management. The ever-increasing demands of good water management in all elements of our society continue the need for well-trained professionals in water resources. Such professionals should have a strong grounding in a major discipline coupled with a broad understanding of and appreciation for the complex physical, biological, and social aspects of water resources management. The graduate minor in water resources will expose students to several different courses and faculty members in water resources that are outside his/her major field of study.

A graduate student may enroll in the water resources minor by including it on the plan of graduate work. A graduate faculty member from outside the student's major department or program must be appointed to serve as the minor representative on his/her advisory committee. The minor representative may be a member of the Water Resources Committee or another faculty member from a department represented on the Water Resources Committee who is active in teaching/research related to water resources. The minimum course requirements for a graduate minor in water resources are described below.

***Master's Degree*** –Three courses (minimum of eight credit hours) from water resources areas outside the student's major field of study approved by the student's minor representative. ***Doctor of Philosophy Degree*** –Three courses (minimum of eight credit hours) from water resources areas outside the student's major field of

study approved by the student's minor representative. These courses shall be in addition to those previously taken at the master's level when that degree included a water resources minor. Recommended Course--A course in the legal, institutional, or economic aspects of water resources recommended for each minor program.

A water resources minor will normally be composed of courses from the list below. The student may select one or more courses from several subject areas or concentrate all courses in one area. Other courses that are water resources-oriented may be included when approved by the student's minor representative. Such courses may be: (1) Other North Carolina State University courses; (2) Transfer courses from other institutions; (3) Courses taken through Interinstitutional Registration at Duke University and the University of North Carolina at Chapel Hill. Additional information on appropriate courses may be obtained from any member of the Water Resources Committee.

Requests for information on water resources-oriented graduate programs should be directed to the departments represented on the Water Resources Committee. For additional information on the water resources minor, contact the chair of the commmittee.

## WATER RESOURCES COURSES

*Legal, Institutional and Economic Aspects of Water Resources*
FOR 472 RENEWABLE RESOURCE POLICY AND MANAGEMENT
EC 436 ENVIRONMENTAL ECONOMICS
ECG 515 ENVIRONMENTAL AND RESOURCE POLICY
PA 520 ENVIRONMENTAL POLICY

*Planning of Water Resources and Related Systems*
CE 504 WATER TRANSPORTATION
CE 575 MODELING & ANALYSIS OF ENVIRONMENTAL SYSTEMS
FOR 584 THE PRACTICE OF ENVIRONMENTAL IMPACT ASSESSMENT
LAR 512 LANDSCAPE RESOURCE MANAGEMENT
LAR 530 ADVANCED SITE PLANNING

*Municipal and Industrial Water Management*
CE 484 WATER SUPPLY AND WASTEWATER SYSTEMS
CE 571 THEORY OF WATER AND WASTE TREATMENT
CE 572 DESIGN OF WATER AND WASTEWATER FACILITIES
CHE 598 WASTE MINIMIZATION
T(TC,TAM) 401 ENVIRONMENTAL ASPECTS OF THE TEXTILE INDUSTRY
WPS 460 ENVIRONMENTAL ISSUES IN THE PAPER INDUSTRY
WPS 525 POLLUTION ABATEMENT IN FOREST PRODUCTS INDUSTRIES
WPS 625 WASTEWATER TREAT. PAPER INDUSTRY

*Agricultural and Forest Water Management*
BAE 471 LAND RESOURCES ENVIRON. ENGINEERING

BAE 472/572 IRRIGATION AND DRAINAGE
BAE 578 AGRICULTURAL WASTE MANAGEMENT
FOR 401 WATERSHED AND WETLANDS HYDROLOGY
SSC 461 SOIL PHYSICAL PROPERTIES AND PLANT GROWTH
SSC 511 SOIL PHYSICS
SSC 562 ENVIRONMENTAL APPLICATION OF SOIL SCIENCE

*Biological and Ecological Aspects of Water Resources*
BO(ZO) 560 PRINCIPLES OF ECOLOGY
BO 574 PHYCOLOGY
BO 590F THE ECOLOGY OF FRESHWATER PLANTS
MEA(ZO) 520 PRINCIPLES OF BIOLOGICAL OCEANOGRAPHY
ZO 441 BIOLOGY OF FISHES
ZO(FW) 420 FISHERY SCIENCE
ZO 460 AQUATIC NATURAL HISTORY LABORATORY
ZO (ENT) 509 ECOLOGY OF STREAM INVERTEBRATES
ZO 519 LIMNOLOGY
ZO (FW) 586 AQUACULTURE I
ZO (FW) 587 AQUACULTURE I LABORATORY
ZO 593 AQUATIC ECOLOGY SEMINAR

*Hydrologic, Meteorologic, Oceanographic, and Water Quality Aspects of Water Resources*
BAE 473 INTRODUCTION TO SURFACE/WATER QUALITY MODEL
BAE(SSC) 671 THEORY OF DRAINAGE–SATURATED FLOW
BAE(SSC) 674 THEORY OF DRAINAGE–UNSATURATED FLOW
CE 574 CHEMISTRY AND MICROBIOLOGY FOR ENGINEERS I
CE 580 FLOW IN OPEN CHANNELS
CE 582 COASTAL HYDRODYNAMICS
CE 583 ENGINEERING ASPECTS OF COASTAL PROCESSES
CE 584 HYDRAULICS OF GROUNDWATER
CE 585 URBAN STORMWATER MANAGEMENT
CE 586 ENGINEERING HYDROLOGY
CE 644 GROUND WATER CONTAMINANT TRANSPORT
FOR 501 WATERSHED HYDROLOGY
MEA 455 MICROMETEOROLOGY
MEA 481 PRINCIPLES OF GEOMORPHOLOGY
MEA 555 METEOROLOGY OF THE BIOSPHERE
MEA 560 PRINCIPLES OF PHYSICAL OCEANOGRAPHY
MEA 561 INTRODUCTION TO PHYSICAL OCEANOGRAPHY
MEA 565 HYDROGEOLOGY
MEA 566 HYDROLGEOLOGY OF GROUNDWATER POLLUTION AND PROTECTION
MEA 569 THE PHYSICAL DYNAMICS OF ESTUARIES
MEA 571 PRINCIPLES OF CHEMICAL OCEANOGRAPHY
MEA 574 BIOGEOCHEMISTRY

# GRADUATE FACULTY*

Abbate, Angelo Rudy, M.L.A., Associate Professor of Landscape Architecture.
Abrams, Charlie Frank, Jr., Ph.D., Professor of Biological and Agricultural Engineering.
Abt, Robert C., Ph.D., Associate Professor of Forestry.
Adams, David Arthur, Ph.D., Professor Emeritus of Forestry.
Adams, Dewey Allen, Ed.D., Professor of Occupational Education.
Adams, John Peter, Ph.D., Adjunct Professor of Food Science.
Adams, William M., V.M.D., Professor Emeritus of Food Animal and Equine Medicine.
Ade, Harald, Ph.D., Assistant Professor of Physics.
Adler, Kenneth B., Ph.D., Professor of Anatomy, Physiological Sciences and Radiology.
Afify, Elsayed M., Ph.D., Professor of Mechanical and Aerospace Engineering.
Agrawal, Anup, Ph.D., Associate Professor of Business Management.
Agrawal, Dharma Prakash, D.Sc., Professor of Electrical and Computer Engineering.
Agris, Paul F., Ph.D., Professor of Biochemistry.
Ahmad, Shuaib Haroon, Ph.D., Professor of Civil Engineering.
Akroyd, H. Duane, Ph.D., Associate Professor of Occupational Education.
Alder, Ruth M. Ayend, Ph.D., Associate Professor of Foreign Languages and Literatures.
Alexander, Samuel Thomas, Ph.D., Associate Professor of Electrical and Computer Engineering.
Alexander, Winser E., Ph.D., Professor of Electrical and Computer Engineering.
Allen, Howard Lee, Jr., Ph.D., Professor of Forestry.
Allen, Jonathan C., Ph.D., Associate Professor of Food Science.
Allen, Steven G., Ph.D., Professor of Business Management.
Almond, Glen W., Ph.D., Associate Professor of Food Animal and Equine Medicine.
Alonso, Silvia Gonzalez-Quevedo, Ph.D., Associate Professor of Foreign Languages and Literatures.
Alston-Mills, Brenda, Ph.D., Associate Professor of Animal Science.
Alvarez, Raul, M.S., Professor Emeritus of Industrial Engineering.
Ambrose, John Thomas, Ph.D., Professor of Entomology.
Amein, Michael, Ph.D., Professor Emeritus of Civil Engineering.
Amerson, Henry Van, Ph.D., Associate Professor of Forestry.
Amiran, Eyal Yosef, Ph.D., Assistant Professor of English.
Amoozegar, Aziz, Ph.D., Associate Professor of Soil Science.
Anderson, Charles Edward, Ph.D., Professor Emeritus of Marine, Earth and Atmospheric Sciences.
Anderson, Charles Eugene, Ph.D., Professor of Botany.
Anderson, Clifton A., Ph.D., Professor Emeritus of Industrial Engineering.
Anderson, James, Ph.D., Professor of Counselor Education.
Anderson, John R., Jr., Ph.D., Professor of Crop Science.
Anderson, Kenneth E., Ph.D., Assistant Professor of Poultry Science.
Anderson, Kevin Lindsay, Ph.D., Professor of Food Animal and Equine Medicine.
Anderson, Marshall W., Ph.D., Adjunct Professor of Statistics.
Anderson, Norman Dean, Ph.D., Professor of Mathematics and Science Education.
Anderson, Ruth D., Ph.D., Associate Professor of Communication.
Andrews, Matthew Tucker, Ph.D., Associate Professor of Genetics.
Aneja, Viney P., Ph.D., Research Associate Professor of Marine, Earth and Atmospheric Sciences.
Apperson, Charles Smith, Ph.D., Professor of Entomology.
Apple, Jay Lawrence, Ph.D., Professor Emeritus of Plant Pathology.

**Membership in the Graduate Faculty may be in either of two categories: (1) full status or (2) associate status. Full status permits a faculty member to engage in any and all phases of the graduate programs of the University. Associate members may teach courses at the graduate level and serve as chair of master's advisory committees.*

Archie, Joseph Patrick,, Jr., Ph.D., Adjunct Associate Professor of Mechanical and Aerospace Engineering.
Arends, James Jay, Ph.D., Professor of Entomology.
Argenzio, Robert Alan, Ph.D., Professor of Anatomy, Physiological Sciences and Radiology.
Armstrong, Frank Bradley, Ph.D., Professor Emeritus of Biochemistry.
Armstrong, Jeffrey Dyer, Ph.D., Associate Professor of Animal Science.
Arnold, John F., Ph.D., Associate Professor of Curriculum and Instruction.
Aronson, Arthur L., Ph.D., Professor of Anatomy, Physiological Sciences and Radiology.
Arya, Satya Pal Singh, Ph.D., Professor of Marine, Earth and Atmospheric Sciences.
Ash, Sarah Liberman, Ph.D., Visiting Assistant Professor of Animal Science.
Aspnes, David E., Ph.D., Professor of Physics.
Atchley, William R., Ph.D., William Neal Reynolds Professor of Genetics.
Atkins, Clarke E., D.V.M., Associate Professor of Companion Animal and Special Species Medicine.
Atkinson, Maxine P., Ph.D., Associate Professor of Sociology and Anthropology.
Aubrecht, Lyn G., Ph.D., Visiting Assistant Professor of Curriculum and Instruction.
Auciello, Orlando, Ph.D., Adjunct Professor of Materials Science and Engineering.
Aurand, Leonard William, Ph.D., Professor Emeritus of Food Science.
Austin, David F., Ph.D., Associate Professor of Philosophy and Religion.
Austin, William Wyatt, Jr., Ph.D., Professor Emeritus of Materials Science and Engineering.
Averre, Charles Wilson, III, Ph.D., Professor of Plant Pathology.
Axtell, Richard Charles, Ph.D., Professor of Entomology.
Aycock, Robert, Ph.D., Professor Emeritus of Plant Pathology.
Ayoub, Mahmoud Amin, Ph.D., Professor of Industrial Engineering.
Bacheler, Jack S., Ph.D., Professor of Entomology.
Bachmann, Klaus Jurgen, Ph.D., Professor of Materials Science and Engineering.
Bahler, Dennis R., Ph.D., Associate Professor of Computer Science.
Bai, Stephen A., Ph.D., Associate Professor of Anatomy, Physiological Sciences and Radiology.
Bailey, Douglas A., Ph.D., Associate Professor of Horticultural Science.
Bailey, Jack Eugene, Ph.D., Associate Professor of Plant Pathology.
Bailey, John Albert, Ph.D., Professor of Mechanical and Aerospace Engineering.
Bailey, Kermit Lavon, M.P.D., Assistant Professor of Graphic Design.
Baines, Barbara Joan, Ph.D., Professor of English.
Baird, Jack Vernon, Ph.D., Professor Emeritus of Soil Science.
Baker, George A., III, Ed.D., Joseph D. Moore Distinguished Professor of Adult and Community College Education.
Baker, James Robert, Ph.D., Professor of Entomology.
Baker-Ward, Lynne, Ph.D., Associate Professor of Psychology.
Baliga, B. Jayant, Ph.D., Professor of Electrical and Computer Engineering.
Balik, Charles Maurice, Ph.D., Associate Professor of Materials Science and Engineering.
Ball, David Stafford, Ph.D., Associate Professor of Economics.
Ball, Hershell Ray, Jr., Ph.D., Professor Emeritus of Food Science.
Ballinger, Walter Elmer, Ph.D., Professor Emeritus of Horticultural Science.
Ballington, James Ralph, Jr., Ph.D., Professor of Horticultural Science.
Banker, James Roderick, Ph.D., Professor of History.
Banks, Harvey Thomas, Ph.D., Drexel Professor and University Professor of Mathematics.
Banks-Lee, Pamela, Ph.D., Associate Professor of Textile and Apparel Management.
Baran, Mesut Ethem, Ph.D., Visiting Assistant Professor of Electrical and Computer Engineering.
Barbercheck, Mary E., Ph.D., Assistant Professor of Entomology.
Barclay, William John, Ph.D., Professor Emeritus of Electrical and Computer Engineering.
Barefoot, Aldos Cortez, Jr., D.F., Professor Emeritus of Multidisciplinary Studies.
Barker, James Cathey, Ph.D., Professor of Biological and Agricultural Engineering.

Barker, Kenneth Reece, Ph.D., Professor of Plant Pathology.
Barker, Roger Lee, Ph.D., Professor of Textile Engineering, Chemistry and Science.
Barkley, Key Lee, Ph.D., Professor Emeritus of Psychology.
Barlaz, Morton A., Ph.D., Assistant Professor of Civil Engineering.
Barnes, Donald Warren, Jr., Ph.D., Associate Professor Emeritus of Architecture.
Barnes, Harold John, Ph.D., Professor of Food Animal and Equine Medicine.
Barnett, Ortus Webb, Jr., Ph.D., Professor of Plant Pathology.
Barnhardt, Robert Alexander, Ed.D., Professor of Textile and Apparel Management.
Barrax, Gerald W., M.A., Professor of English.
Barrick, Elliott Ray, Ph.D., Professor Emeritus of Animal Science.
Bartelt, Dana A., M.P.D., Adjunct Assistant Professor of Landscape Architecture.
Barthalmus, George Timothy, Ph.D., Professor of Zoology.
Bartholomew, William Victor, Ph.D., Professor Emeritus of Soil Science.
Bartley, Jon W., Ph.D., Professor of Accounting.
Batchelor, Peter, M.C.P., Professor of Architecture.
Bateman, Durward F., Ph.D., Professor of Plant Pathology.
Batra, Subhash K., Ph.D., Professor of Textile and Apparel Management .
Batte, Edward Guy, D.V.M., Professor Emeritus of Microbiology, Pathology and Parasitology.
Baugh, John Wesley, Jr., Ph.D., Assistant Professor of Civil Engineering.
Baughman, Gerald Robert, Ph.D., Associate Professor of Biological and Agricultural Engineering.
Baumer, David L., Ph.D., Associate Professor of Business Management.
Beasley, David Beach, Ph.D., Professor of Biological and Agricultural Engineering.
Beck, Keith R., Ph.D., Professor of Textile Engineering, Chemistry and Science.
Beckmann, Robert L., Ph.D, Associate Professor of Botany.
Bedair, Salah Mohamed, Ph.D., Professor of Electrical and Computer Engineering.
Beeler, Joe Robert, Jr., Ph.D., Professor of Materials Science and Engineering.
Beers, Burton Floyd, Ph.D., Professor of History.
Beezer, Bruce Gerald, Ed.D., Professor of Educational Leadership and Program Evaluation.
Beghin, John Christopher, Ph.D., Associate Professor of Agricultural and Resource Economics.
Behlow, Robert Frank, D.V.M., Professor Emeritus of Animal Science.
Behnke, Wallace P., B.S., Adjunct Associate Professor of Textile Engineering, Chemistry and Science.
Beichner, Robert, Ph.D., Assistant Professor of Physics.
Bell, Norman Robert, M.S., Associate Professor Emeritus of Electrical and Computer Engineering.
Bell, Thomas Alexander, M.S., Professor Emeritus of Food Science.
Benson, David Michael, Ph.D., Professor of Plant Pathology.
Benson, Geoffrey Alan, Ph.D., Associate Professor of Agricultural and Resource Economics.
Benson, Ray Braman, Jr., Ph.D., Professor of Materials Science and Engineering.
Bentley, Peter John, Ph.D., Professor Emeritus of Anatomy, Physiological Sciences and Radiology.
Bereman, Robert Deane, Ph.D., Professor of Chemistry.
Berenson, Sarah Burke, Ph.D., Associate Professor of Mathematics and Science Education.
Berger, Roger L., Ph.D., Professor of Statistics.
Berger, Vicki, Ph.D., Adjunct Assistant Professor of History.
Berkhoff, Herman A., Ph.D., Professor of Microbiology, Pathology and Parasitology.
Berkstresser, Gordon Abbott,, III, Ph.D., Professor of Textile and Apparel Management.
Berlam, Robert A., Ed.D., Adjunct Assistant Professor of Adult and Community College Education.
Bernhard, Richard Harold, Ph.D., Professor of Industrial Engineering.
Bernholc, Jerzy, Ph.D., Professor of Physics.
Bernold, Leonhard E., Ph.D., Associate Professor of Civil Engineering.
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Barbara D. Wills-Duncan, *Raleigh*

**Ex-officio**
Derrick E. Griffith

**Class of 1997**
Roderick D. Adams, *Durham*
G. Irvin Aldridge, *Manteo*
Mark L. Bibbs, *Chapel Hill*
Lois G. Britt, *Mount Olive*
John F. A. V. Cecil, *Asheville*
Bert Collins, *Durham*
John A. Garwood, *North Wilkesboro*
Wallace N. Hyde, *Raleigh*
Jack P. Jordan, *Mount Gilead*
Ellen A. Newbold, *Rose Hill*
Maxine H. O'Kelley, *Burlington*
D. Wayne Peterson, *Wake Forest*
H. D. Reaves, *Fayetteville*
Harold H. Webb, *Raleigh*

**Members Emeriti (Terms Expire 1995)**
Philip G. Carson, *Asheville*
James E. Holshouser Jr., *Southern Pines*
Robert L. Jones, *Raleigh*
John R. Jordan Jr., *Raleigh*

# History of the University of North Carolina

In North Carolina, all the public educational institutions that grant baccalaureate degrees are part of the University of North Carolina. North Carolina State University is one of 16 constituent institutions of the multi-campus state university.

The University of North Carolina, chartered by the N.C. General Assembly in 1789, was the first public university in the United States to open its doors and the only one to graduate students in the eighteenth century. The first class was admitted in Chapel Hill in 1795. For the next 136 years, the only campus of the University of North Carolina was at Chapel Hill.

In 1877, the N.C. General Assembly began sponsoring additional institutions of higher education, diverse in origin and purpose. Five were historically black institutions, and another was founded to educate American Indians. Several were created to prepare teachers for the public schools. Others had a technological emphasis. One is a training school for performing artists.

In 1931, the N.C. General Assembly redefined the University of North Carolina to include three state-supported institutions: the campus at Chapel Hill (now the University of North Carolina at Chapel Hill), North Carolina State College (now North Carolina State University at Raleigh), and Woman's College (now the University of North Carolina at Greensboro). The new multi-campus University operated with one board of trustees and one president. By 1969, three additional campuses had joined the University through legislative action: the University of North Carolina at Charlotte, the University of North Carolina at Asheville, and the University of North Carolina at Wilmington.

In 1971, the General Assembly passed legislation bringing into the University of North Carolina the state's ten remaining public senior institutions, each of which had until then been legally separate: Appalachian State University, East Carolina University, Elizabeth City State University, Fayetteville State University, North Carolina Agricultural and Technical State University, North Carolina Central University, the North Carolina School of the Arts, Pembroke State University, Western Carolina University, and Winston-Salem State University. This action created the current 16-campus University. (In 1985, the North Carolina School of Science and Mathematics, a residential high school for gifted students, was declared an affiliated school of the University).

The UNC Board of Governors is the policy-making body legally charged with "the general determination, control, supervision, management, and governance of all affairs, of the constituent institutions." It elects the president, who administers the University. The 32 voting members of the Board of Governors are elected by the General Assembly for four-year terms. Former board chairmen and board members who are former governors of North Carolina may continue to serve for limited periods as non-voting members emeriti. The president of the UNC Association of Student Governments, or that student's designee, is also a non-voting member.

Each of the 16 constituent institutions is headed by a chancellor, who is chosen by the Board of Governors on the president's nomination and is responsible to the president. Each

institution has a board of trustees, consisting of eight members elected by the Board of Governors, four appointed by the governor, and the president of the student body, who serves ex-officio. (The NC School of the Arts has two additional ex-officio members.) Each board of trustees holds extensive powers over academic and other operations of its institu tion on delegation from the Board of Governors.

## Historical Sketch of North Carolina State University

On March 7, 1887, the North Carolina General Assembly passed the act which authorized the establishment of the North Carolina College of Agriculture and Mechanic Arts. The Watauga Club of Raleigh and the statewide farmers' movement had convinced the legislature of the need to transfer the funds received by the state under the provisions of the Morrill Land-Grant Act of 1862 from the University of North Carolina in Chapel Hill to a new land-grant college in Raleigh. The cornerstone of A. and M. College was laid in August, 1888, and its doors were officially opened on October 3, 1889.

**Alexander Q. Holladay**, the college's first president (1889-1899), and a faculty of five offered courses in agriculture, horticulture, pure and agricultural chemistry, English, bookkeeping, history, mathematics, physics, practical mechanics and military science. The first freshman class numbered about fifty students. By the end of the institution's first decade the resident enrollment had reached 300.

During the administration of **George T. Winston** (1899-1908) a new curriculum in textiles was developed and normal courses were offered in the summer for public school teachers, both men and women. The Agricultural Extension Service was established during the administration of **Daniel H. Hill** (1908-1916) and enrollment grew to more than 700. In 1917, during the administration of **Wallace C. Riddick** (1916-1923), the institution's name was changed to North Carolina State College of Agriculture and Engineering. The introduction of the word engineering was intended to reflect the increasing emphasis on the professional and theoretical as well as the practical aspects of technical education.

In 1923 a major reorganization of the administration of the college was begun, and President Riddick resigned to become the first dean of the new School of Engineering. **Eugene Clyde Brooks** (1923-1934), the fifth president of State College, continued the reorganization with the creation of the School of Agriculture (later renamed the School of Agriculture and Forestry), the School of Science and Business, the School of Education, the School of Textiles and the Graduate School. Resident enrollment rose to nearly 2,000 in 1929 before the Depression caused a drop to approximately 1,500 in 1933. The first women graduates of State College received their degrees in 1927.

In the midst of the Depression, the General Assembly of 1931 attempted to promote economy and to prevent unnecessary duplication among the three leading state institutions of higher education by establishing a single consolidated administration for the University of North Carolina in Chapel Hill, North Carolina State College of Agriculture and Engineering, and North Carolina College for Women in Greensboro. Dr. Frank Porter Graham, president of the University of North Carolina, was elected president of the consolidated university, and

Dr. Brooks, with the title of vice president, continued as chief administrative officer at State College. Among the consequences of consolidation were the phasing out of the School of Engineering at Chapel Hill and the School of Science and Business at Raleigh. A general college, later called the Basic Division, was established to provide two years of basic courses in humanities, social sciences and natural sciences as a foundation for students in the various degree-granting technical and professional schools.

Colonel **John W. Harrelson** (1934-1953), Class of 1909, was the first alumnus to become administrative head of State College. Under the consolidated organization his title was Dean of Administration; later it was changed to Chancellor. During Harrelson's administration the institution experienced the beginning of extraordinary growth in the aftermath of World War II. Two new schools were established: the School of Design and the School of Forestry. A multi-million dollar expansion program was completed during the administration of **Carey H. Bostian** (1953-1959), and the program of student activities was greatly enlarged, as the enrollment passed 5,000.

The faculty and student population more than doubled during the administration of **John T. Caldwell** (1959-1975) and another new school was organized: the School of Physical Sciences and Applied Mathematics (now Physical and Mathematical Sciences). The School of General Studies, the successor to the Basic Division, was renamed the School of Liberal Arts and was authorized to offer a full range of bachelor's and master's degree programs in the humanities and social sciences. The name of the institution itself was changed in 1965 to North Carolina State University, signifying its new role as a comprehensive university.

NCSU's enrollment passed 20,000 during the administration of Chancellor **Joab L. Thomas** (1976-1981). The School of Veterinary Medicine was established, the name of the School of Liberal Arts was changed to School of Humanities and Social Sciences, and North Carolina State University was recognized as one of two major research universities within the statewide University of North Carolina.

**Bruce R. Poulton** (1982-1990) became chancellor in the fall of 1982. A major expansion of the University's research budget, the establishment of a substantial endowment to provide enlarged resources for research equipment and endowed professorships, and the addition of the 1,000-acre Centennial Campus occurred during this administration. All of the schools were renamed colleges except for the School of Design and The Graduate School. In addition, the School of Education became the College of Education and Psychology.

In 1990 **Larry K. Monteith**, an alumnus and former Dean of the College of Engineering, became chancellor and NCSU's eleventh chief administrative officer. Among his early initiatives were the creation of the Division of Undergraduate Studies and the First Year Experience Program. The College of Textiles and ABB (Asea Brown Boveri), NCSU's first corporate partner, moved to Centennial Campus in 1991. In 1992, the College of Management was established.

## BOARD OF TRUSTEES
## North Carolina State University

| | *Term Expires* |
|---|---|
| William L. Burns Jr., *Durham, Chairman* | 1995 |
| Keith R. Harrod, *Raleigh, Vice Chairman* | 1995 |
| William A. Klopman, *Greensboro, Vice Chairman* | 1997 |
| Annabelle L. Fetterman, *Clinton, Secretary* | 1995 |
| Alan T. Dickson, *Charlotte* | 1995 |
| Flora H. Grantham, *Smithfield* | 1997 |
| Clarence Lightner, *Raleigh* | 1995 |
| Wendell H. Murphy, *Rose Hill* | 1997 |
| Robert N. Spilman, *Bassett, VA* | 1997 |
| Edgar S. Woolard Jr., *Wilmington, DE* | 1995 |
| N. E. Wilson Jr., *Burlington* | 1997 |
| Smedes York, *Raleigh* | 1997 |
| Bobby Johnson Jr., *President, Student Government, NCSU* | 1995 |

# Mission of North Carolina State University

The unique mission of North Carolina State University is to serve the citizens of North Carolina as the State's only research university in the land-grant tradition. Since its founding in 1887, NCSU has been committed to science and technology as pathways to human betterment and has served as an innovative educational resource, providing leadership for positive intellectual, social, and technological change. Faithful to its founding mission, the University must now meet the challenges posed by the increasing complexity of our global society and the accelerated growth in knowledge and technology. At the same time, it must continually address the effects of these developments on the environment and on the social and economic well-being of the people of North Carolina, the nation, and the world. Spurred by these new challenges, NCSU will continue to fulfill its mission through the integrated functions of teaching, research, and extension, its unique form of public service.

Teaching, research, and public service will continue to be mutually enriching enterprises at NCSU. The activities of research and extension interact to provide students with an environment for learning that stresses creativity, problem solving, social responsibility, and respect for human diversity. The educational and extension functions join to apply, test, and disseminate the new knowledge generated by research.

During the University's first hundred years, its distinctive mandate has led to preeminence in science, technology, and engineering. This mandate will continue to shape future development, necessitating excellence in the full spectrum of disciplines that provide the intellectual and critical foundations for understanding, anticipating, and responding to public needs.

Undergraduate education is a major responsibility of North Carolina State University. Core education is provided in science and the humanities, with specializations offered in physical,

social, and life sciences, in the humanities, and in professional and technical disciplines. The atmosphere of a research university provides distinctive opportunities for undergraduates to benefit from the experience of research in the classroom, laboratory, and informal settings. Exposure to the discovery and synthesis of new information provides students with a basis for identifying and solving society's problems and builds a critical foundation for their personal growth, cultural enrichment, and professional development.

As a national center for doctoral studies, NCSU embraces the responsibility to maintain excellence in graduate research and education. Students work as partners with faculty in the creation, expansion, conservation, and transmission of knowledge. Graduate education will continue to evolve as the University builds on its traditional and preeminent strengths in science, technology, and engineering and as it develops further strengths in complementary disciplines.

Research and scholarly inquiry form the foundation for education and public service at NCSU. Faculty and students in all disciplines engage in the art and science of discovery in a climate of free inquiry and creativity, extending the boundaries of knowledge and horizons of human intellect. The research mandate of NCSU is signified in its national classification as a Research University I.

The University's land-grant philosophy is manifest in its commitment to active stewardship of the human and natural resources of the State. NCSU has been an integral part of significant economic and technological changes in North Carolina for the past one hundred years. This stewardship is expressed currently through public service activities in all the University's colleges and schools, whereby the expertise resident among the faculty and students is disseminated across the State through extension, technical assistance, professional development, lifelong education, and technology transfer programs. Loyal to the vision of its founders in the nineteenth century, NCSU will continue to strive through extension and public service to improve the quality of life for North Carolinians into the twenty-first century.

NCSU's dual designations as land-grant university and a Research University I form the basis for the unique role of NCSU in The University of North Carolina. North Carolina State University stands on the threshold of a new century with deep appreciation for the significance of these mandates and the commitment to excellence and change that they jointly require.

# Policy on Illegal Drugs

The following policy on illegal drugs was adopted by the North Carolina State University Board of Trustees on April 16, 1988:

## PURPOSE

Reflecting its concern over the threat which illegal drugs constitute to higher education communities, the Board of Governors of the University of North Carolina adopted a policy on illegal drugs on January 15, 1988. The Board of Governors' policy requires each constituent institution's Board of Trustees to develop a policy on illegal drugs applicable to all students, faculty members, administrators, and other employees. The policy for each campus must address particular circumstances and needs while being fully consistent with specified minimum requirements for enforcement and penalties.

To assist North Carolina State University in its continuing efforts to meet the threat of illegal drugs, and to comply with the Board of Governors' policy, the Board of Trustees adopts the policy set forth below. This policy is intended to demonstrate the University's primary commitment to education, counseling, rehabilitation, and elimination of illegal drugs, as well as its determination to impose penalties in the event of violation of state and federal drug laws consistent with all due process protection rights.

## EDUCATION, COUNSELING AND REHABILITATION

North Carolina State University shall maintain a program of education designed to help all members of the University community avoid involvement with illegal drugs. The educational program shall emphasize the incompatibility of the use or sale of illegal drugs with the goals of the University, the legal consequences of involvement with illegal drugs, the medical and psychological implications of the use of illegal drugs, and the ways in which illegal drugs jeopardize an individual's present accomplishments and future opportunities. Specific elements of the education program are:

1. Publicizing the University's policy in the Student Code of Conduct, the undergraduate and graduate catalogs, and other publications distributed to students, faculty, administrators, and other employees. The latter publications include the official bulletin, the Student Handbook, the Faculty Handbook, the Advisers' Handbook, and the Human Resources newsletter.
2. Continuing and expanding the drug education program conducted by Student Health Service.
3. Continuing development of courses on drug education.
4. Continuing the drug education component of the employees' Wellness Program.
5. Increasing the awareness and utilization of the University's Employee Assistance Program (EAP).

The University shall disseminate information about drug counseling and rehabilitation services that are available to members of the University community. Persons who voluntarily avail themselves of such services shall be assured that applicable professional standards of confidentiality will be observed and that such participation will not be the basis for disciplinary action. Specific counseling and rehabilitation efforts include:

1. Continuing the evaluation and referral services of the Counseling Center for out-patient and in-patient rehabilitation.

2. Continuing the consultation and evaluation portions of the Student Health Service's drug education program.

3. Utilizing the Employee Assistance Program's referral to existing community-based counseling and rehabilitation services.

## ENFORCEMENT AND PENALTIES

Students, faculty members, administrators, and other employees are responsible, as citizens, for knowing about and complying with the provisions of North Carolina law that make it a crime to possess, sell, deliver, or manufacture those drugs designated collectively as "controlled substances" in Article 5 of Chapter 90 of the North Carolina General Statutes. The University will initiate its own disciplinary proceedings against a student, faculty member, administrator, or other employee when the offense is deemed to affect the interests of the University. Penalties will be imposed by the University in accordance with procedural safeguards applicable to disciplinary actions against students, faculty members, administrators, and other employees, as required by Section 502D (3) and Section 603 of the University Code, by Board of Governors' policies applicable to other employees exempt from the State Personnel Act, and by regulations of the State Personnel Commission. The penalties to be imposed by the University may range from written warnings with probationary status to expulsions from enrollment and discharges from employment. However, the following minimum penalties, as prescribed by the Board of Governors, shall be imposed for the particular offenses described.

*Trafficking in Illegal Drugs*

1. For the illegal manufacture, sale or delivery, or possession with intent to manufacture, sell or deliver, of any controlled substance identified in Schedule 1, N.C. General Statutes 90-89, or Schedule 11, N.C. General Statutes 90-90 (including, but not limited to, heroin, mescaline, lysergic acid diethylsmide, opium, cocaine, amphetamine, methoqualine), any student shall be expelled and any faculty member, administrator or other employee shall be discharged.

2. For a first offense involving the illegal manufacture, sale or delivery, or possession with intent to manufacture, sell or deliver, of any controlled substance identified in Schedules III through VI, N.C. General Statutes 90-91 through 90-94 (including, but not limited to, marijuana, phenobarbital, codeine), the minimum penalty shall be suspension from enrollment or from employment for a period of at least one semester or its equivalent.* (*Employees subject to the State Personnel Act are governed by regulations of the State Personnel Commission. Because the minimum penalty specified in this section and required by the Board of Governors exceeds the maximum period of suspension without pay that is permitted by the State Personnel Commission regulations, the penalty for a first offense for employees subject to the State Personnel Act is discharge.) For a second offense, any student shall be expelled and any faculty member, administrator, or other employee shall be discharged.

*Illegal Possession of Drugs*

1. For a first offense involving the illegal possession of any controlled substance identified in Schedule I, N. C. General Statutes 90-89, or Schedule II, N.C. General Statutes 90-90, the minimum penalty shall be suspension from enrollment or from employment for a period of at least one semester or its equivalent.* (See * above.)

2. For a first offense involving the illegal possession of any controlled substance identified in Schedules III through VI, N.C. General Statutes 90-91 through 90-94, the minimum penalty shall be probation, for a period to be determined on a case-by-case basis. A person on probation must agree to participate in a drug education and counseling program, consent to regular drug testing, and accept such other conditions and restrictions, including a program of community service, as the Chancellor or the Chancellor's designee deems appropriate. Refusal or failure to abide by the terms of probation shall result in suspension from enrollment or from employment for any unexpired balance of the prescribed period of probation.

3. For second or other subsequent offenses involving the illegal possession of controlled substance, progressively more severe penalties shall be imposed, including expulsion of students and discharge of faculty members, administrators or other employees.

## SUSPENSION PENDING FINAL DISPOSITION

When a student, faculty member, administrator, or other employee has been charged by the University with a violation of policies concerning illegal drugs, he or she may be suspended from enrollment or employment before initiation or completion of regular disciplinary proceedings if, assuming the truth of the charges, the Chancellor or, in the Chancellor's absence, the Chancellor's designee concludes that the person's continued presence within the University community would constitute a clear and immediate danger to the health or welfare of other members of the University community; provided, that if such a suspension is imposed, an appropriate hearing of the charges against the suspended person shall be held as promptly as possible thereafter.

## COORDINATOR OF DRUG EDUCATION

The University Counsel will serve as coordinator of drug education and, acting under the authority of the Chancellor, will be responsible for overseeing all action and programs relating to this institutional policy.

## IMPLEMENTATION AND REPORTING

This North Carolina State University policy on illegal drugs was effective on the beginning of the fall semester of 1988.

Annually the Chancellor shall submit to the Board of Trustees a report on campus activities related to illegal drugs for the preceding year. The report shall include, as a minimum, the following: (1) a listing of the major education activities conducted during the year; (2) a report on any illegal drug-related incidents, including any sanctions imposed; (3) an assessment by the Chancellor of the effectiveness of the campus program; and (4) any proposed changes in the policy on illegal drugs. A copy of the report shall be provided to the President.

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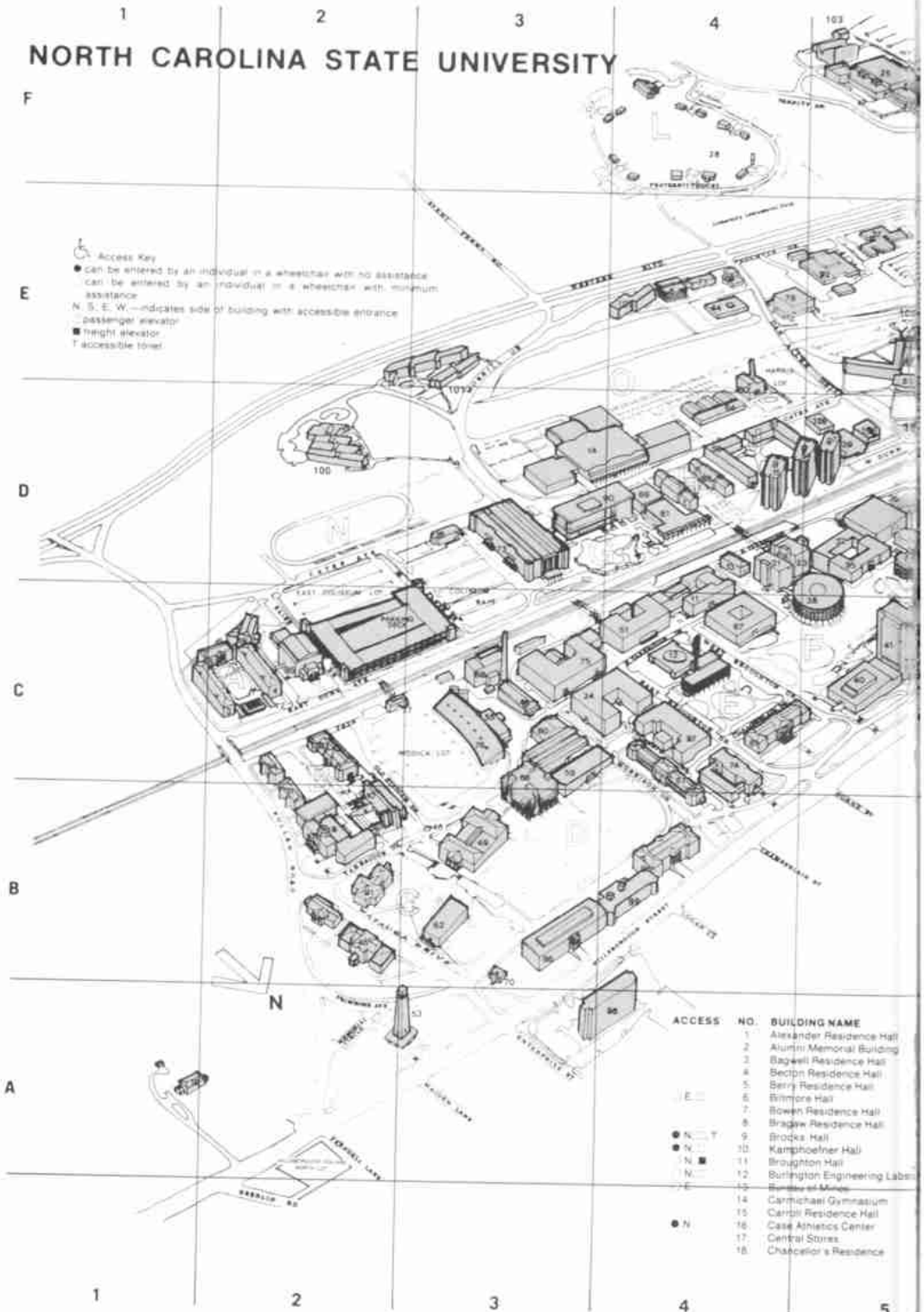
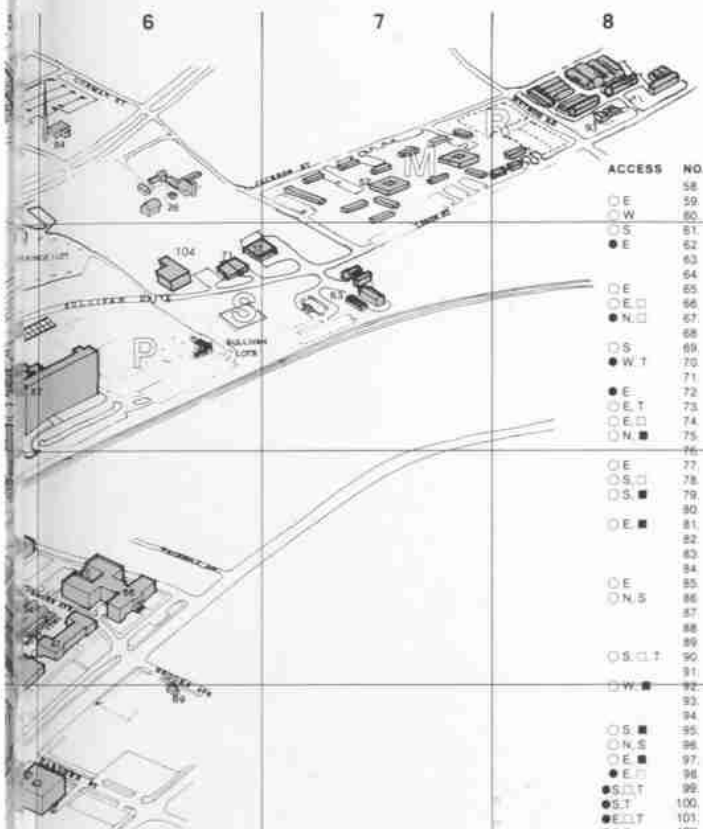
# NORTH CAROLINA STATE UNIVERSITY






| ACCESS | NO. | BUILDING NAME | GRID | CODE |
|---|---|---|---|---|
| ● W, □, T | 19. | Clark Hall Infirmary | 2-C | |
| □ S, ■ | 20. | Clark Laboratories | 5-D | CL |
| □ N, □ | 21. | Cox Hall | 4-D | COX |
| □ N, T | 22. | Dabney Building | 5-D | |
| □ N, □ | 23. | Dabney Hall | 4-D | DAB |
| ● W, ■ | 24. | Daniels Hall | 4-C | DAN |
| ● W, □, T | 25. | McKimmon Extension Continuing Education Center | 5-F | |
| | 26. | Farm Unit 5 | 6-F | |
| □ N | 27. | Field House | 2-C | |
| | 28. | Fraternity Court | 4-F | |
| □ S, ■ | 29. | Gardner Hall | 5-D | GA |
| ● N, □, T | 30. | Bostian Hall | 5-D | |
| | 31. | Gold Residence Hall | 2-C | |
| | 32. | Williams Hall Addition | 5-D | AGH |
| | 33. | Greenhouse—Biological Sciences | 5-D | BSG |
| | 34. | Greenhouse—Horticulture | 5-D | HGH |
| | 35. | Greenhouse—840 Method Rd. | 8-F | |
| | 36. | Greenhouse—Plant Pathology | 5-D | PPG |
| □ E | 37. | Grimes Animal Health Lab | 5-E | GHL |
| □ N, □, T | 38. | Harrelson Hall | 5-D | HA |
| ● N, □, T | 39. | Harris Hall | 5-D | |
| □ W, □ | 40. | D. H. Hill Library—Original Wing | 5-C | DHL |
| □ W, □, T | 41. | D. H. Hill Library—Book Stack Tower | 5-C | |
| □ N, S, □ | 42. | D. H. Hill Library—Erdahl-Cloyd Wing<br>North Campus Bookshop | 5-C<br>5-C | |
| ● N, □, T | 43. | Hillsborough Building | 5-C | HLB |
| □ W | 44. | Hodges Wood Products Lab | 4-E | HWP |
| | 45. | Holladay Hall | 2-B | |
| | 46. | Information Center, Visitor Parking | 3-B | |
| □ S, ■ | 47. | Kilgore Hall | 6-D | KI |
| | 48. | Laundry/Copy Center | 3-C | |
| | 49. | Leazar Hall | 3-B | LEZ |
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| | 52. | E. S. King Village (17 Apt. Bldgs. A-Q) | 7-F | |
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| | 57. | 1911 Building | 4-C | |
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| | 59. | Page Hall | 3-C | PA |
| □ W | 60. | Park Shops | 3-C | PS |
| □ S | 61. | Patterson Hall | 4-C | PT |
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| | 64. | Physical Plant Shops (Armory) | 4-D | |
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| □ S | 69. | Price Music Center | 4-D | PMC |
| ● W, T | 70. | Primrose Hall | 3-B | |
| | 71. | Print Shop/University Graphics | 6-E | |
| ● E | 72. | Quad. Snack Bar | 2-C | |
| □ E, T | 73. | Wm. Neal Reynolds Coliseum | 3-D | |
| □ E, □ | 74. | Ricks Hall | 4-C | RI |
| □ N, ■ | 75. | Riddick Engineering Labs | 3-C | RD |
| | 76. | Riddick Stadium | 3-C | |
| □ E | 77. | Robertson Wing, Biltmore Hall | 4-E | |
| □ S, □ | 78. | Schaub Food Science Building | 4-E | SFS |
| □ S, ■ | 79. | Scott Hall | 5-D | SC |
| | 80. | Steam Plant | 4-E | |
| □ E, ■ | 81. | NCSU Bookstores | 4-D | |
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| | 83. | Syme Residence Hall | 2-C | |
| | 84. | Television Center | 6-F | TVS |
| □ E | 85. | Thompson Theater/Craft Center | 2-C | TT |
| □ N, S | 86. | Tompkins Hall | 3-B | T |
| | 87. | Tucker Residence Hall | 4-D | |
| | 88. | Turlington Residence Hall | 4-D | |
| | 89. | Turner House | 6-C | |
| □ S, □, T | 90. | University Student Center | 3-D | USC |
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| □ W, ■ | 92. | Weaver Laboratories | 5-E | DSW |
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| ● E, □, T | 101. | Wood Residence Hall | 3-D | |
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| ● N, T | 103. | Solar Demonstration House | 5-F | |
| | 104. | Administrative Services Center | 6-E | |
| | 105. | Research Facility (on Centennial Campus) (Not Shown) | | |
| | 106. | Pullen Hall | | |
| | 107. | Jordan Hall | | |
| | 108. | Pulp & Paper Labs | | |
| | 109. | Student Center Annex | | |

| COURTS AND FIELDS | | GRID |
|---|---|---|
| | A. | Bagwell-Becton-Berry Quad | 2-C |
| | B. | Gold-Welch-Syme-Brooks Court | 2-C |
| | C. | Mary E. Yarbrough Court | 3-B |
| | D. | Court of North Caroline | 3-B |
| | E. | Gardner Arboretum | 4-C |
| | F. | University Plaza (Brickyard) | 5-C |
| | G. | University Student Center Plaza | 4-D |
| | H. | Turlington-Alexander Court | 4-D |
| | J. | Tucker-Owen Court | 4-D |
| | K. | Lee-Sullivan-Bragaw Court | 5-E |
| | L. | Fraternity Court | 4-F |
| | M. | E. S. King Village Court | 7-F |
| | N. | Paul H. Derr Track | 2-D |
| | O. | Miller Fields | 4-E |
| | P. | Doak Field | 6-E |
| | Q. | McKimmon Center Court | 5-F |
| | R. | The Big Acre | 8-F |
| | S. | Tennis Courts | 6-E |

| PARKING LOTS | GRID |
|---|---|
| Brooks Ave. Lot | 6-C |
| Carmichael Lot | 3-D |
| Coliseum Bays | 3-D |
| East Coliseum Lot | 2-C |
| Friendly Drive Lot | 6-D |
| Harris Lot | 4-E |
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| Riddick Lot | 3-C |
| Sullivan Lots | 6-E |
| West Lot | 6-E |
| Additional West Lot Parking | 5-E |
| Yarbrough Lot | 3-C |
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## Accreditation by the Southern Association of Colleges and Schools

NCSU is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools to award the associate, baccalaureate, master's and doctoral degrees.

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