Clemson Graduate School Catalog, 1971-1972

Clemson University

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### DEADLINE DATES

For those who expect to receive the Master's degree or Doctor of Philosophy degree on:

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<td>December 2, 1971</td>
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CLEMSON UNIVERSITY

RECORD

ANNOUNCEMENTS OF
THE GRADUATE SCHOOL
FOR
1971-1972
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CHECK LIST ON GRADUATE SCHOOL PROCEDURES

The graduate student should carefully note this check list as well as deadline dates on inside front cover.

1. Select in consultation with the appropriate Department Head a major advisor and advisory committee. (See pages 25, 26)

2. Submit Plan for Graduate Study (G. S. Form 2, see page 26)

3. If necessary, submit request for changes in Plan for Graduate Study. Minor changes may be accomplished by memorandum signed by the advisory committee, department head and college dean.

4. Satisfy any prescribed language requirement and qualifying examination prerequisite to admission to candidacy. (See page 32, 36, 37, 38)

5. Apply for admission to candidacy for a degree (G. S. Form 4) after completing at least half the prescribed course work. (See page 26)

6. Submit completed thesis (if required) or dissertation to advisory committee chairman and arrange for final examination by the advisory committee. (See pages 29, 30, 32, 38)

7. Pay binding fee to the Bursar and submit approved copies of thesis to the Graduate School. Doctoral candidates pay for abstract publication in Dissertation Abstracts. (See page 30)

The final responsibility for following Graduate School procedures rests with the graduate student. Special problems should be referred to the Graduate Dean.
# COURSES OF STUDY*

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*The courses listed in this Bulletin in the 600 series are described in the general University Catalog, but as 300 and 400 level courses. A copy of the general Catalog may be obtained from the Director of Admissions.
## COURSES OF STUDY (Continued)

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*The Master of Business Administration degree is offered jointly by Furman University and Clemson University. Courses in this program are taught on the Furman University campus, Greenville, S. C., by the faculty of both universities. Requests for information concerning this program should be addressed to the Director, Clemson-Furman MBA Program, Furman University, Greenville, S. C. 29613.*
CLEMSON UNIVERSITY BOARD OF TRUSTEES

Life Members

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James F. Byrnes ________________________________ Columbia
Winchester Smith _______________________________ Williston
Robert R. Coker ________________________________ Hartsville
James C. Self ________________________________ Greenwood
Frank J. Jervey ________________________________ Clemson
Patrick N. Calhoun ____________________________ Charlotte, N. C.

Term Expires 1972

Paul Quattlebaum, Jr. ____________________________ Charleston
W. Gordon McCabe, Jr. __________________________ Greenville
T. Kenneth Cribb ______________________________ Spartanburg

Term Expires 1974

A. M. Quattlebaum ______________________________ Florence
L. D. Holmes _______________________________ Johnston
E. Oswald Lightsey ______________________________ Hampton

A. W. Rigsby, Secretary ___________________ Clemson
UNIVERSITY CALENDAR

SESSION 1971-72
FIRST SEMESTER

August 16, 17  Mon., Tues. a.m. Orientation, new students
August 18  Wednesday Registration, all students
August 19  Thursday a.m. Late registration
August 20  Friday Late registration fee applies
August 21  Saturday Classes begin, regular schedule
August 22  Sunday Last day for registration
August 23  Monday Last day to add a subject
August 24  Tuesday Last day to order diploma
for mid-year grad.

September 2  Thursday Last day to drop a subject
without record of drop

October 11  Monday Preliminary reports due
November 10  Wednesday Last day to drop a subject
November 10  Wednesday Last day to withdraw without
November 24  Wednesday having grades recorded
Thanksgiving holidays begin
after last class

November 29  Monday Classes resume
December 6  Monday Examinations begin
December 16  Thursday Mid-year graduation

SECOND SEMESTER

January 3  Monday Orientation, new students
January 4  Tuesday Registration, all students
January 5  Wednesday Late registration
January 6  Thursday Late registration fee applies
January 6  Thursday Classes begin, regular schedule
January 12  Wednesday Last day for registration
January 12  Wednesday Last day to add a subject
January 19  Wednesday Last day to order diploma
for May graduation

February 2  Wednesday Last day to drop a subject
without record of drop
February 28  Monday Preliminary reports due
March 10  Friday Spring holidays begin after
March 20  Monday Classes resume
March 31  Friday Last day to withdraw without
March 31  Friday having grades recorded
April 5  Wednesday Last day to drop a subject
April 24  Monday Examinations begin
May 5  Friday Commencement

SUMMER SESSIONS 1972
FIRST SESSION
(Classses meet Monday-Friday)

May 15  Monday Registration
May 16  Tuesday Classes begin
June 21, 22  Wed., Thurs. Examinations

SECOND SESSION
(Classses meet Monday-Friday except as indicated)

June 26  Monday Orientation, new students
June 27  Tuesday Registration
June 28  Wednesday Classes begin
July 29  Saturday Classes meet
August 2, 3  Wed., Thurs. Examinations
August 5  Saturday Graduation
SESSION 1972-73

FIRST SEMESTER

August 21, 22 Mon., Tues. a.m. Orientation, new student
August 23 Wednesday Registration, all students
August 24 Thurs., a.m. Late registration
August 25 Friday Late registration fee applies
August 25 Friday Classes begin, regular schedule
August 31 Thursday Last day for registration
August 31 Thursday Last day to add a subject
September 7 Thursday Last day to order diploma for mid-year graduation
September 21 Thursday Last day to drop a subject without record of drop
October 16 Monday Preliminary reports due
November 15 Wednesday Last day to withdraw without having grades recorded
November 15 Wednesday Thanksgiving holidays begin after last class
November 22 Wednesday Last day to drop a subject
November 22 Wednesday Thanksgiving holidays begin after last class
November 27 Monday Classes resume
December 11 Monday Examinations begin
December 21 Thursday Mid-year graduation

SECOND SEMESTER

January 8 Monday Orientation, new students
January 9 Tuesday Registration, all students
January 10 Wednesday Late registration
January 11 Thursday Late registration fee applies
January 11 Thursday Classes begin, regular schedule
January 17 Wednesday Last day for registration
January 17 Wednesday Last day to add a subject
January 24 Wednesday Last day to order diploma for May graduation
February 7 Wednesday Last day to drop a subject without record of drop
March 5 Monday Preliminary reports due
March 16 Friday Spring holidays begin after last class
March 26 Monday Classes resume
April 6 Monday Last day to withdraw without having grades recorded
April 6 Friday Last day to drop a subject
April 11 Wednesday Honors and Awards Day — classes suspended at 12 noon
April 30 Monday Examinations begin
May 11 Friday Commencement

SUMMER SESSIONS 1973

FIRST SESSION

(Classes meet Monday-Friday)

May 21 Monday Registration
May 22 Tuesday Classes begin
June 27, 28 Wed., Thurs. Examinations

SECOND SESSION

(Classes meet Monday-Friday except as indicated)

July 2 Monday Orientation, new students
July 3 Tuesday Registration
July 4 Wednesday Classes begin
August 4 Saturday Classes meet
August 8, 9 Wed., Thurs. Examinations
August 11 Saturday Graduation
PERSONNEL

OFFICERS OF ADMINISTRATION

Robert Cook Edwards, B.S., LL.D. ---------------------------- President

Victor Hurst, Ph.D. --------------- Vice-President for Academic Affairs and Dean of the University

Stanley Gosanko Nicholas, B.S.M.E. ---- Vice-President for Development

Allen Wood Rigsby, M.A., LL.B. ------------- Vice-President for Executive Affairs and University Counsel

Walter Thompson Cox, B.S. _______ Vice-President for Student Affairs

Melford A. Wilson, B.S. _______ Vice-President for Business and Finance and Comptroller

Claud Bethune Green, Ph.D. ___________ Dean of Undergraduate Studies

Arnold Edward Schwartz, Ph.D. ___________ Dean of Graduate Studies and University Research

Samuel Marsh Willis, Ph.D. ___________ Dean of University Extension

William Henry Wiley, Ph.D. _______ Dean, College of Agricultural Sciences

Harlan Ewart McClure, M.Arch. _______ Dean, College of Architecture

Harold Fochone Landrith, Ed.D. ___________ Dean, College of Education

Linvil Gene Rich, Ph.D. ___________ Dean, College of Engineering

William Henry Davis McGregor, Ph.D. ___________ Dean, College of Forest and Recreation Resources

Wallace Dabney Trevillian, Ph.D. ___________ Dean, College of Industrial Management and Textile Science

Headley Morris Cox, Ph.D. ___________ Dean, College of Liberal Arts

Geraldine Labecki, Ed.D. ___________ Dean, School of Nursing

Henry Elliott Vogel, Ph.D. _______ Dean, College of Physical, Mathematical and Biological Sciences
THE GRADUATE COUNCIL

Arnold E. Schwartz, Ph.D., Associate Professor of Civil Engineering and Dean of Graduate Studies and University Research, Chairman, ex-officio

Robert M. Allen, Ph.D., Professor of Forestry, and Head, Department of Forestry, 1973

Claude W. Bolen, Ph.D., Professor of History, 1973

Willie C. Godley, Ph.D., Professor of Animal Science, 1971

Henry W. Graben, Ph.D., Associate Professor of Physics, 1973

Vernon S. Hodges, M.Arch., Associate Professor of Architecture, 1971

Arthur K. Jensen, Ph.D., Associate Professor of Education and Director of Vocational Education Media Center, 1971

Gayle D. Riggs, Ph.D., Assistant Professor of Industrial Management, 1972

Averette S. Tombes, Ph.D., Associate Professor of Zoology, 1972

James S. Wolf, Ph.D., Associate Professor of Materials Engineering, 1972

Student Representatives:
   Gayle B. Sawyer, A.B., Department of Education, 1971
   W. Larry Vick, M.S., Department of Agricultural Engineering, 1971
GENERAL INFORMATION

INTRODUCTION

Clemson is the land-grant university of South Carolina, and is fully accredited by the Southern Association of Colleges and Schools. The graduate curriculums under the Colleges of Agricultural Sciences, Engineering, Architecture, Education, Forest and Recreation Resources, Industrial Management and Textile Science, Liberal Arts, and Physical, Mathematical and Biological Sciences form a background of education for the hundreds of occupations which Clemson graduates enter.

The government of the University is vested in a Board of Trustees. In accord with the Thomas G. Clemson will, the Board includes six members elected by the Legislature and a self-perpetuating group of seven life members. The function of the Board is legislative. The Board determines the general policy of the University and directs the expenditure of its funds.

The President of the University is the chief executive and administrative officer.

THE GRADUATE SCHOOL

The Graduate School exists to formulate policies and standards, and to unify administrative procedures concerning all graduate work at Clemson. The Dean of Graduate Studies and University Research serves as chairman of the Graduate Council, a policy-making body appointed from graduate faculties and students of the University.

The aims of graduate programs at Clemson are to provide comprehensive training in special fields, to offer instruction in the methods of independent investigation, and to foster the spirit of research scholarship. Graduate study is much more than a continuation of undergraduate work. Its true spirit is one of inquiry and the desire to add to human knowledge. Graduate study should therefore be contemplated only by students who have already demonstrated in their undergraduate programs unusual intellectual attainments and the power of independent thought and investigation.
THE UNIVERSITY LIBRARY

The Robert Muldrow Cooper Library is essentially a consolidation of special libraries, agricultural and biological sciences, science and technology and carefully selected smaller collections in the social sciences and the humanities. The collection consists of more than 400,000 volumes of books, periodicals and government publications. In addition to the main library there are departmental libraries.

Forty-five newspapers and 5000 serial titles — periodicals, reports, bulletins and the like — are received regularly. About 700 of these are foreign publications and 1800 are abstracted in Chemical Abstracts. Microfilm and microcard readers are provided for consulting material in microtext.

Library service is maintained for 95 hours a week in the Main Library. With the exception of adjustments in the schedule during holiday periods, the library hours are as follows:

- Monday through Friday: 7:45 a.m. to 11:00 p.m.
- Saturday: 7:45 a.m. to 6:00 p.m.
- Sunday: 2:00 p.m. to 11:00 p.m.

The new library building which was occupied in 1966 is modern in every respect and was designed for quiet reading, convenient reference service and easy access to research materials.

The library policy governing undergraduate students applies to graduate students also. However, a graduate student may be granted the privilege of indefinite loan for one semester subject to recall. In the application of this privilege the following points are important:

1. The privilege is not given automatically but must be requested for each book — otherwise a two-week due date will be stamped in the book.

2. The date stamped in the book indicates the date the book is due. After that date overdue fines apply.

Since overdue notices are sent as a favor to the borrower, failure to receive such a notice does not excuse him from
the payment of fines. Circumstances may prevent the library from sending overdue notices.

3. If a book is recalled, regulations apply the same as for undergraduate students.

4. The privilege applies only to those books in which his major research is concentrated.

   This privilege should be used with a very great deal of discretion.

THE COMPUTER CENTER

The Clemson University Computer Center operates an IBM System/360 Model 50 with 512K bytes of core storage, which is available to graduate students for course work and research. The office of the Center, located in the basement of the Plant and Animal Science Building, is open from 8:00 a.m. to 11:00 p.m., Monday through Friday, 8:00 a.m. to 6:00 p.m. Saturday, and 2:00 p.m. to 11:00 p.m. Sunday. Shorter hours are observed during holiday periods. Every effort is made to schedule work so as to give users timely turn around. Short student jobs can receive five turn arounds per day. All but the very longest jobs turn around within 24 hours. Programming assistance is available at the Center when needed. The Center supports FORTRAN, COBOL, PL/1, ALGOL, and a number of simulation and special-purpose languages. A large library of statistical and mathematical routines is available to users.

STUDENT HEALTH SERVICE

Payment of the Student Health Service fee is required of all students living in University residence halls and all full-time students even though they do not reside in University housing. The Student Health Service maintains a new building with a complete outpatient department and a 34-bed hospital. The staff consists of three full-time physicians, including the director, a psychiatrist, ten full-time registered nurses and a full-time registered laboratory technician and a full-time registered X-ray technician. In
addition, a sufficient number of nurses’ aides, secretarial workers, orderlies and maids for 24-hour-a-day operations are employed. The best of modern equipment is available for student use.

The Student Health Service at Clemson University has several important functions. All of these are aimed at keeping the student in good health so that he may effectively pursue his school work. There is, of course, the basic function of medical care for the ill and injured. This is a vital part of its work. In addition to this, the Student Health Service attempts to put strong emphasis on health rather than illness. This begins with the entrance medical form. In laying out this form an attempt is made to get information, examinations and preventive medical procedures carried out to better equip the staff in protecting the student from illness and to serve as a guide for the care of pre-existing medical problems.

As the student progresses through his academic experiences, other procedures may be required or highly recommended. These are primarily an effort to teach the individual self-responsibility for maintenance of his own health and locate possible hidden diseases. The Health Service also has the position as the source of medical information as well as responsibility for indicated medical action: diagnostic, therapeutic and preventive.

The medical fee paid by each student covers the services of the University physicians and health service staff for most illnesses and injuries occurring on the campus. There are certain things, however, that it does not include, such as fees for routine physical examinations for employment or transfer to another school and fees for outside physicians when called in for consultation, medical or surgical services performed away from the University or for accidents occurring off the campus. The fee also covers medication for acute illness but not for chronic illness lasting over two weeks or for pre-existing illness. Although ambulance transportation to a general hospital for serious illness or injury occurring on campus will, of course, be arranged, the expense for this service is the responsibility of the student. Transportation for less urgent ailments and routine visits can be arranged through the Health Service at the expense of the student.
The right of the Director of the Student Health Service, with the approval of the proper University authority, to obtain any of these extra services in behalf of any student under his care is hereby expressly reserved.

The Student Government, with full approval of the administration, offers a plan of accident and sickness insurance to full-time students. Each year, prior to the beginning of the fall semester, complete information on this insurance plan will be sent to students. This insurance is inexpensive and is designed to cover major medical expense not covered by the Health Service. It is highly recommended.

**HOUSING**

**Application for Dormitories and Advance Payment.** An application for dormitory accommodations will be forwarded to those students who are accepted by the University for the fall semester. These applications are to be completed and returned with a $60 advance room payment to the Residence Hall Office at the earliest practicable date.

Students who have made an advance payment and later decide not to enroll or to live in the dormitory may obtain a refund of the advance payment provided notification of intent and request for refund is received by the Residence Hall Office prior to July 1. When such notification and refund request is not received by the deadline date, no refund of advance payment will be made.

Refund of the advance payment will not be made to students who apply for assignments after July 1.

Normally, dormitory accommodations are available to those students who enter the University at the beginning of the second semester; therefore, the advance payment is not now required of students entering at this time.

**Dormitories**

**West Campus.** The University has available 3,606 spaces in eleven residence halls. These halls are air-conditioned and most can be provided with individual telephones. Each room in Benet,
Young, Cope, Geer, and Sanders Halls has walk-in type clothes lockers, individual study desks, single beds, and chairs. A lavatory is also installed in each room. Rooms in new annexes “A” and “F” of Johnstone Hall are equipped similarly to those in the hall above. Donaldson, Bowen, Wannamaker, Bradley, and Norris Halls are carpeted, and furnished with clothes lockers, individual study desks, single beds, and chairs. Rooms in Johnstone Hall other than new “A” and “F” annexes are furnished with individual clothes lockers, bunk-type beds, a study table and chairs. A lavatory is installed in each room.

See Graduate Expenses for rates.

East Campus. The University has available 1,584 spaces in five residence halls. Two of these halls, Mauldin and Barnett, are modern four-story structures with wall-to-wall carpeting, air-conditioning, and a rooftop deck. Each will house 144 students in 72 rooms. Rooms are arranged in suites of six, accommodating 12 students. Each suite provides a study, bath, washing and drying facilities. Each room contains two closets, two chests of drawers with wall-hung mirrors, single beds, individual study desks, lamps, and chairs. The other three, Manning Hall, Lever Hall, and Hi-Rise No. 3, are eleven-story structures, fully carpeted and air-conditioned. Each will accommodate 432 students. Rooms are arranged in suites of six accommodating 12 students. Each room contains two closets, two chests of drawers with wall-hung mirrors, single beds, individual study lamps, desks, and chairs. Draperies are to be provided by occupants. Studies and laundry room are available on each floor. The first floor is designed for group living. It includes lounges, a kitchenette, T.V., and recreational rooms. The basement floor includes club rooms, storage areas, and a large room equipped with coin-operated washers and dryers.

Both men residence halls and women residence halls are located on the East Campus.

Assignment Preference. Graduate students will be assigned to sections reserved for them as long as space is available. Priority of room assignments is given to continuing students who file application and make advance payments during the priority periods established by the Dormitory Office.
Notification of Assignments. As soon as room assignments are made, students are advised of the assignment and furnished information regarding occupancy.

Assignment Changes. Students who desire to move from the assigned room may apply at the Dormitory Office to change rooms. A fee of $4 is charged for moving; charges will also be made for students moving from a lower- to a higher-rated room. Rental refunds are made to students moving from a higher- to a lower-rated room on a prorated basis.

Opening and Closing of Dormitories. The University dormitories officially open for students at 8 a.m., the day prior to matriculation date for new students and close at 8 p.m., the day scheduled for graduation exercises of the term or semester. Dormitory fees cover only the time between the day before matriculation and the scheduled date of graduation exercises or end of term when no graduation exercises are scheduled.

For official holidays which occur during the course of a semester, the University reserves the right to close certain halls and to require students remaining on the campus to move to another hall for the duration of the holiday period. For the period between semesters the University reserves the right to close the dormitories.

Student Responsibility for Damages. The University holds resident students responsible for any damages other than normal wear that occur to their rooms and furnishings. Damages will be assessed by the University and the student will be billed for repairs or replacements. Students should inform University officials immediately upon occupancy of any conditions reflecting prior damages which have not been corrected.

Extra Residence Hall Charges. Extra charges are made to students who occupy residence halls before or after the dates established for a semester or term.

Students who are required by the University to be on campus prior to and after the scheduled term or semester may upon the
approval of the Vice-President for Student Affairs be exempted from paying the extra residence hall charges.

**Reservation of Right to Change Fees and Regulations.** The University reserves the right to make changes in its fees, charges, rules, and regulations.

**Clemson House**

The University operated Clemson House Hotel has several rooms available for resident graduate students. Rates are comparable to those of the dormitories provided two students share a room. No deposit is required, however the room fee is payable in advance on a monthly basis. Rooms are available upon the arrival of the student and are **not subject to holiday closings** whereas dormitory residents may be required to move during these periods. Unmarried students who intend to remain on campus between semesters are particularly urged to reside at the Clemson House in preference to the dormitories.

**Married Student Housing**

Clemson provides comfortable and economical housing for its married students. There are three housing areas consisting of 139 single Prefab units, 100 East Campus apartments contained in 50 duplex buildings, and 50 Littlejohn apartments in 11 buildings.

All married student housing units have two bedrooms, living room, kitchen and bath. East Campus apartments are the newest and are equipped with stove and refrigerator. The Littlejohn apartments and Prefabs are not equipped with stoves and refrigerators.

Booklets describing these facilities are available and will be furnished upon request by the Housing Office of the University. Monthly rental fees are: Prefabs, $36; Littlejohns, $51 for interior and $54 for end units; East Campus, $69.

Graduate assistants and graduate fellows are given priority over undergraduate students in assignments to married student housing. To qualify for this priority their applications must be received at the Housing Office before April 20 for first semester housing; before November 1 for second semester housing; or before March 1 for summer housing.
STUDENT FOOD SERVICE

The University Dining Halls provide several food service plans for the students:

1. A 5-Day Board Plan (15 meals) Monday through Friday—holidays excluded. The fee for this plan is $440 per year and may be paid in two installments—one-half at the beginning of the first semester and the remainder at the beginning of the second semester.

2. A 7-Day Board Plan (21 meals) Monday through Sunday—holidays excluded. The fee for this plan is $550 per year and may be paid in two installments—one-half at the beginning of the first semester and the remainder at the beginning of the second semester.

Both the 5-Day and 7-Day Board Plans will begin the first day of classes and end on the day which is scheduled for graduation. (These dates are listed in the University Calendar appearing in this catalog.) Individual meals may be obtained in the student dining halls prior to the day classes begin.

3. Students who are not on a board plan may purchase tickets for individual meals at prevailing prices. Except on special occasions, a-la-carte service will not be offered in the Student Dining Halls.

GRADUATE EXPENSES

Full-Time Students. The 1970-1971 semester charges for regular full-time graduate students are shown below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition</td>
<td>$75</td>
</tr>
<tr>
<td>Matriculation Fee (Non-Refundable)</td>
<td>5</td>
</tr>
<tr>
<td>University Fee*</td>
<td>205</td>
</tr>
<tr>
<td>Medical Fee</td>
<td>25</td>
</tr>
<tr>
<td>Room Fee</td>
<td>150-210</td>
</tr>
<tr>
<td>Board</td>
<td>220-275</td>
</tr>
</tbody>
</table>

Total for Semester $665-795

*Subject to increase.
Part-Time Students. Graduate students taking less than 12 credit hours during a semester will be charged for each of the items in the following schedule:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition (per semester hour)</td>
<td>$6.00</td>
</tr>
<tr>
<td>Matriculation Fee (non-refundable)</td>
<td>5.00</td>
</tr>
<tr>
<td>University Fee (per semester hour)</td>
<td>14.00</td>
</tr>
<tr>
<td>Medical Fee (optional for non-dormitory students)</td>
<td>25.00</td>
</tr>
</tbody>
</table>

Students who elect not to pay the hospital fee are responsible for arranging their own medical care.

Graduate Assistants and Staff. Graduate assistants and staff members will pay a total charge of $10.00 per semester hour. These charges are in lieu of tuition, matriculation, maintenance, activity and library fees. Graduate assistants receive medical treatment by paying the medical fee of $25.00. A graduate assistant is defined as a student with a baccalaureate degree from an approved institution who contracts to devote a minimum of ten working hours per week to the University for at least a full semester.

Graduation Fees

The thesis binding fee, diploma fee, fee for rental of cap and gown, and fee for publication of dissertation abstract are not included in the above charges. Fees for these items are listed on page 30.

Athletic Contests and University Concerts. Part-time students taking less than 12 hours and graduate assistants may be admitted to home athletic games upon payment of the faculty rate and to the University concerts upon purchase of a student season ticket.

Settlement of University Fees. The entire semester’s expenses are due and payable at the beginning of each semester, and no student is officially enrolled until all semester expenses have been satisfied. In special cases the University will accept at the beginning of a semester a non-interest bearing promissory note for a portion of the semester residence-hall rent and semester-plan board fee. Amounts up to $65 for room rent and $115 for board fee may
be included in the note. In such cases, a note for the first semester charges will be due October 10, and a note for the second semester charges will be due March 1.

A $60 advance payment of room rent is required for a room reservation for the fall semester. This payment must be made by cash, check or money order and should be sent to the Residence Halls Manager's Office with the completed “Student Application for Room Reservation” card not later than July 1. The $60 advance payment of room rent will be deducted from the amount otherwise due for the first semester's expenses. All other transactions relating to payments should be conducted with the Accounting Division. All checks and money orders should be made payable to Clemson University. A personal check given in payment of University expenses which is returned by the bank unpaid, immediately creates an indebtedness to the University.

The University reserves the right to adjust charges to current costs.

Past Due Student Accounts. Any indebtedness to the University which becomes past due immediately jeopardizes the student's enrollment, and no such student will be permitted to graduate or register for a subsequent semester or summer school term. Further, any student who fails to pay all indebtedness to the University may not be issued an honorable discharge, transcript, or diploma.

Reservation of Right to Change Fees and Regulations. The University reserves the right to make changes in its fees, charges, rules, and regulations.

REGULATIONS AND PROCEDURES

Every graduate student and every prospective graduate student is expected to make himself thoroughly familiar with these regulations and the requirements for degrees. Failure to follow the regulations and requirements almost inevitably results in complications which cause a great deal of inconvenience to the student.
In addition to the general regulations, the candidate for an advanced degree will comply with the specific requirements of the department in which he is pursuing his advanced studies.

The University and its various colleges, schools and departments reserve the right to change the rules regulating the admission to, instruction in, and graduation from the University or its various divisions, and any other regulations affecting the student body. Such regulations become effective whenever the proper authorities may determine and will apply not only to prospective students but also to those who may at such time be matriculated in the University. The University also reserves the right to withdraw courses, to change instructors, or to change fees at any time.

Except as they apply to undergraduate students only, graduate students are subject to the usual procedures and regulations of the University and to those outlined on the following pages.

**ADMISSION**

For admission to the University's graduate programs a degree-seeking student must have the Bachelor's degree from an institution with a scholastic rating satisfactory to the University, and have the approval of the Head of the Department in which he plans to do his major work. With the exception of some advanced professional programs, a satisfactory score on the Graduate Record Examination is also required.

In all programs admission is restricted to those students whose academic records clearly indicate that they are prepared to benefit from graduate study. Neither a transcript exceeding minimum requirements nor satisfactory scores on the Graduate Record Examination alone will assure a student’s admission. Rather his total record must indicate the likelihood of successful graduate study.

An undergraduate student lacking less than a full semester of work to complete the requirements for his baccalaureate degree may apply for admission to a graduate program and if admitted, be allowed to enroll in courses for graduate credit. These courses must be over and above those required for his Bachelor's degree and should not cause his total load of course work to exceed 15 semester hours.
Students with grade-point ratios of 3.0 or higher may enroll in graduate-level courses during their senior year and may choose to use these courses to meet requirements for the Bachelor's degree. However, courses used for this purpose may not later be counted toward an advanced degree. Alternatively, students who take such courses in excess of the requirements for their undergraduate degrees may request that these courses be included as a part of their graduate program if they are subsequently admitted to the Graduate School at Clemson.

Enrollment in any course is subject to approval by the department offering the course. Undergraduate students desiring to enroll in graduate courses must have written approval from the Dean of Graduate Studies prior to registration in these courses.

Applicants accepted for graduate study may be admitted as graduate students in full standing or as graduate students not seeking a degree. Students in this latter category are primarily public school teachers who require graduate work for certification, or recertification. Only graduate students in full standing may become candidates for advanced degrees.

Credentials submitted for admission become the property of the University and are not returned.

An applicant for admission to the Graduate School must register for courses within twelve months after his application has been accepted; otherwise his admission will be withdrawn.

Students who have been admitted to the Master's program but subsequently desire to enroll in a Ph.D. program must apply for admission by submitting Graduate School Form 10.

Students holding both Bachelor's and Master's degrees from Clemson University are usually encouraged to pursue doctoral programs at other institutions.

Applications for admission should be submitted at least four weeks prior to the first date for matriculation listed in the general University catalog.

The Director of Admissions and Registration will not permit enrollment in courses of the 600 series or above until the student has been officially admitted to the Graduate School.
Enrollment in any course is subject to approval by the department offering the course.

Eligibility of University Employees to Pursue Graduate Study. With the approval of his Dean or Director, a qualified employee of Clemson University may pursue graduate work for credit. However, no member of the faculty or staff who has a rank higher than Instructor or its equivalent may be considered as a candidate for an advanced degree at this institution.

The Extension Service uses classifications that vary somewhat from those used in the teaching faculty and the following rules apply to members of that Service.

1. All Extension staff members except specialist leaders, supervisors, and administrators may, if otherwise qualified, be admitted to a Master's degree program at Clemson.

2. All Extension staff members except assistant specialists, associate specialists, specialists, specialist leaders, and administrators may, if otherwise qualified, be admitted to a Doctoral program at Clemson.

3. County agents, associate and assistant agents may, if otherwise qualified, be admitted to either degree program.

MEDICAL EXAMINATIONS

Completion of a medical history and physical examination record is required of all new students entering Clemson University for the first time. This examination must be completed by the student and the student’s own physician or the health service of the school from which he graduates or transfers. This examination must be reported on a special form provided for this purpose by the University and mailed directly to the Director of Student Health Service. This should be received at least four weeks prior to matriculation to give time for processing; otherwise registration may be delayed. Incomplete forms will be returned.

The University requires that all new students have a current tetanus toxoid series or booster (within five years), a smallpox
vaccination (within four years) and also immunization against poliomyelitis. The oral (Sabin) type vaccine is preferred. All new students are also required to have a skin test for tuberculosis within one year prior to admission. If this test is positive, a chest X-ray is also required. All positive reactors will then be required to have an annual chest X-ray. These follow-up X-rays after admission will be done at the Student Health Service.

PROGRAM OF STUDY

As soon as a student enrolls he should acquaint himself thoroughly with the degree requirements and the regulations of the Graduate School published in the graduate catalog, particularly the deadline dates. Each advisor and student should by all means have a current copy of the graduate catalog.

The Major Advisor. Before the student registers he must, with the aid and approval of the department head, select a major advisor. In departments with large faculties it may be advisable to assign all new graduate students to one professor until the student decides upon his particular interest. This advisor recommends and approves courses to be taken during the student's first semester. The course work selected should be of a fundamental or "core" nature so that the advisory committee will have maximum flexibility to formulate the students' programs of study.

The Advisory Committee. An advisory committee will approve the student's preliminary study plans, supervise his graduate program, administer his preliminary and/or final comprehensive examination, and initiate the recommendation for the awarding of the degree. One member of the committee will be designated as chairman and normally he will direct the student's dissertation or thesis, if required. This committee is selected by the department head, major advisor, and student. Prior to the submission of a plan of study the department head will forward his recommendation to the dean of his college, who will, if he approves, then transmit the recommendation to the Graduate Dean. A minimum of three faculty members shall be selected for a student seeking
a Master's degree and a minimum of four faculty members shall be selected for a student seeking a Ph.D. degree. Qualifications of faculty for membership on the advisory committee should be discussed with the college dean. The student and faculty members are notified of the committee appointments by the Graduate Dean.

**Filing of Preliminary Study Plans.** Preliminary study plans must be filed with the Graduate School by those students who are in degree programs. No students shall receive both graduate and undergraduate credit for the same course. Each student is to submit a preliminary plan of study as soon as possible (GS Form 2). Master's degree candidates should do this early in their second semester* and Ph.D. candidates no later than the beginning of their second year* of study. Before a plan of study is approved it must be reviewed and **signed** by the advisory committee. All committee members should meet to discuss the plan of study and agree unanimously on its content. The plan of study is then submitted to the college dean for his approval and for appropriate distribution of copies.

**Admission to Candidacy for a Degree.** Admission to the Graduate School does not qualify a student as a candidate for an advanced degree. Such candidacy depends upon the acceptance by the Graduate Dean of a written request for admission to candidacy. This request (GS Form 4) may be filed by the student as follows: for the Master's degree, after he has completed fifteen hours of course work; for the Doctoral degree, after he has completed a major share of his course work and has successfully completed his preliminary examinations.

All students desiring admission to candidacy must have received full status admission to the Graduate School, have a satisfactory academic standing, and have on file an approved preliminary plan of study.

**Multiplication of Higher Degrees.** The duplication of higher degrees is discouraged on the same basis as the duplication of the

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*An academic semester is defined as a minimum of nine credit hours of course work taken during a given semester. An academic year is defined as the total of two academic semesters.
Bachelor's degree. Thus a student holding a Master's degree may not as a rule become a candidate for another Master's degree of the same designation, regardless of the field of study; nor may the holder of an M.A. or M.S. degree in a given field, received at another institution, become a candidate for a different Master's degree in the same field at Clemson.

**Continuous Enrollment.** Graduate students, other than those involved in summer studies only, will be required to maintain a continuous enrollment in the Graduate School unless excused by the Graduate Dean. Registration for one credit hour per enrollment will satisfy this requirement.

**Credit Loads.** University upper limits on graduate student loads per semester are:

Full-time staff .............................................. 6 credits  
Graduate assistants ......................................... 10 credits  
Full-time students .......................................... 15 credits

In the event of scheduling difficulties the limits may be exceeded in a particular semester if the average number of credits for the year does not exceed the upper limits. Special permission from the Graduate Dean is needed if the upper limits are to be exceeded. Such a request must first be approved by the head of the department in which the student registered.

Within the limits set forth above, reasonable credit loads may be worked out for conditions other than those specifically stated. Major deviations from these limits must receive approval from the Graduate Dean.

Maximum load for Summer School is one credit hour per week of session. An employee working full time during the summer may carry no more than four semester hours during the two summer sessions and not more than three semester credits during either session.

**Academic Standards.** Graduate students are graded on the same A-B-C-D-F scale as undergraduates. Nonetheless, a graduate student is expected to do superior work and the only satisfactory
grades for graduate students are A and B. Grades on thesis and dissertation research are on a "Pass — Incomplete — Fail" basis.

A minimum grade of C must be made on all course work to obtain graduate credit. An average grade of B must be achieved on all work taken exclusive of languages or ROTC while enrolled in the Graduate School before a student can become a candidate for an advanced degree. Candidates who fail to maintain a "B" average become ineligible for graduation and are placed on probation. Students who remain on probation for two consecutive semesters will not be permitted to continue a graduate program without the written approval of the Graduate Dean.

A grade lower than the specified minimum can be raised to count toward an advanced degree only by repetition of the course. A re-examination is not permitted.

A graduate student must understand that he can be dropped from the Graduate School at any time for failure to maintain an adequate academic status.

Auditing by Graduate Students. A regularly enrolled student may audit one additional course a semester, provided approval is obtained from the professor offering the course, the head of the department, and dean of the school in which the course is offered. Forms for requesting such approval are available at the Office of Admissions and Registration. Graduate assistants, and those graduate students who enroll for at least six hours, will not be charged for auditing. Other part-time students will be charged (1) one-half tuition fee and one-half maintenance and activity fee or one-half summer school fee (where applicable), and (2) full library fee charged part-time students.

Audited courses do not carry credit and the fact that a course has been audited is not noted on the graduate student's official record. Audited courses do not count against allowable credit-hour loads.

Graduate auditors are not required to stand tests or examinations. However, the professor, at his own discretion, may demand or deny the auditor's participation in class to whatever extent he deems desirable.
A graduate student may not by audit satisfy a stated prerequisite for a graduate course. Additionally, a graduate student may not establish credit through examination in any course for which he was previously registered as an auditor.

**Acceptance of Transfer Credit.** The credit requirements for advanced degrees must be satisfied through registration at Clemson University, except that on the recommendations of the student's major advisor and the approval of the Graduate Dean, a student may earn in some accredited institution other than Clemson 6 credits in campus courses toward one of the Master's degrees and as many as 48 credits toward a Doctor's degree.

Credit may be transferred for work completed at off-campus centers of accredited institutions provided such courses are accepted in degree programs at those institutions. Transfer credit will not be accepted for courses in which a grade lower than B, or its equivalent, has been received.

No credit toward graduate degrees may be obtained by correspondence or extension study. All transfer credits must be verified by an official transcript from the college at which the work was done.

Transcripts certifying to graduate courses completed at another institution must be received in the Graduate School office prior to the date of filing application for the degree. The degree will not be conferred at the close of the term during which the student has been registered elsewhere.

**Theses and Dissertations.** Each candidate for an advanced degree in each curriculum requiring a thesis must prepare this thesis under the direction of a major advisor. Six hours of credit are required for the research leading to the required Master of Science or Master of Arts thesis. Fifteen hours of credit are required for the Master of Architecture thesis. Eighteen hours of research credit are required for the Doctor of Philosophy degree.

Three copies of the thesis must be presented to the chairman of the student's advisory committee in sufficient time for the chairman to arrange for a final examination to be held at least three
weeks prior to the date on which the degree is expected. A doctoral dissertation must be completed and delivered to the student's advisory committee at least two weeks prior to the final examination. Three copies of the Master's thesis and four copies of the doctoral dissertation must be submitted to the Graduate School by the deadline for the date on which the degree is conferred. A binding fee of $15.00 must be paid to the Bursar and the Bursar's receipt submitted to the Graduate School office at the time the thesis or dissertation is submitted. If the student desires, he may have additional copies bound for himself at a cost of $5.00 a copy. The responsibility for placing the thesis in proper final form rests with the student and the chairman of his advisory committee. A statement of special procedures for writing a thesis or dissertation at Clemson University may be obtained from the Graduate School office.

The student will prepare two additional copies of the abstract and title sheet to be submitted to the Graduate School. Ordinarily this abstract should not exceed five hundred words in length. It should be written and edited in such a way that it will be suitable for publication.

Doctoral students must pay a fee of $25 to the Bursar for publication in Dissertation Abstracts. An additional fee of $15.00 is required if copyright is desired.

**Restriction on Use of Theses and Dissertations.** Unpublished theses and dissertations submitted to the Graduate School in partial fulfillment of the requirements for graduate degrees and deposited in the University Library are, as a rule, open to the public for reference purposes. However, extended quotations or summaries may be published only with the permission of the author and the Graduate Dean.

**Application for a Diploma.** A formal application for a diploma is placed by the student with the Dean of Admissions and Registration at the time he is admitted to candidacy for a degree.

**Graduate Degrees and Teachers' Certificates.** Prospective students should understand that the material in this bulletin applies only to requirements for graduate degrees and has no direct relation to certificates for public school teachers. The Graduate School
gives no assurance that a program for a graduate degree and a pro-
gram for a certificate will coincide. Students interested in certifi-
cates should, at the outset of their work, confer with the Dean of
the College of Education.

DEGREES

Courses are offered leading to the degree of Master of Arts,
Master of Science, and Doctor of Philosophy.

In addition, courses are offered leading to the professional de-
grees of Master of Agriculture, Master of Agricultural Education,
Master of Architecture, Master of City and Regional Planning,
Master of Fine Arts, Master of Forestry, and Master of Industrial
Education. The Master of Business Administration degree is offer-
ed jointly by Furman University and Clemson University.

REQUIREMENTS FOR THE MASTER OF SCIENCE
AND MASTER OF ARTS DEGREES

To receive the Master of Science degree a student must spend
the equivalent of at least one academic semester in graduate resi-
dence at the University. All course work which is to be credited
toward a Master of Science or Master of Arts degree must have
been completed not more than six calendar years prior to the date
on which the degree is to be awarded; except that when approved
by the student's department head and the Dean of Graduate Stud-
ies and University Research, as many as six semester hours of
course work completed outside the six-year limit of time may
be validated by written re-examination. Such examination will
be under the direction of the department regularly offering the
course or courses for which the student seeks validation. Course
work completed outside the six-year limit of time at an institution
other than Clemson University may not be transferred to Clemson
for graduate credit.

Course Work Required. In addition to such supplementary or
supporting courses as may be required, the degree program will
consist of a minimum of thirty semester hours, including six se-
mester hours of research which will provide the basis for the thesis if a thesis is required. Of the remaining required semester hours, at least half must come from courses 800 or above. A minimum of twelve hours must be in the student's major field.

**Language Requirement.** A reading knowledge of one approved foreign language is a departmental requirement for all Master of Arts degrees and certain Master of Science degrees. The required reading knowledge is equivalent to that provided by two years of study of the language at the college level, and evidenced by a score above the 25 percentile on the Graduate School Foreign Language Test (ETS). Students who have within the last five years completed the equivalent of twelve semester hours of study of a language at an accredited college with average grades of B may be exempted from this examination upon the recommendation of the Head of the Department of Modern Languages. Languages accepted by all departments are French and German; under certain conditions Spanish, Russian, or the classical languages may be accepted.

**Study in Absentia.** Although thesis research is normally performed at Clemson University, it is recognized that Clemson University may not have on its campus certain specialized equipment or facilities which would be desirable for advanced training at the Master's level. Thus, for those cases in which theses or other advanced study is required and the facilities to pursue such study are not available on the Clemson University campus, permission may be granted for study in absentia. The requirements to be satisfied in such cases are identical to those listed under: "**Requirements for the Doctor of Philosophy Degree, Residence Requirements,**" with the exception that the off-campus research supervisor need not hold the Ph.D. degree so long as he is qualified and certified for his supervisory position by the department and college involved and by the Graduate Dean.

**Final Examination.** Each candidate for the Master's degree, after the completion of the thesis, if required, and at least three weeks before the degree is to be awarded, must pass an examination as may be required by the student's advisory committee.
The examination, which may be oral and/or written will ascertain the general knowledge of the candidate with particular reference to the major and minor subjects and the thesis or research report. The Graduate School will be notified of the time and place of the examination at least ten days prior to the time scheduled. Included with those members of the faculty and staff invited to attend the examination will be the members of the Graduate Council and the Graduate Dean. Immediately after the examination the examining committee will notify the Graduate Dean of the findings. This notification will be made on GS Form 7.

**REQUIREMENTS FOR THE PROFESSIONAL DEGREES**

Requirements for the professional degrees include all those for the Master of Science except the foreign language proficiency and the submission of a thesis. A minimum of thirty semester hours of course work must be completed with at least half of the required hours selected from courses numbered 700 or above.* Additional requirements for the professional degrees are listed in sections describing specific colleges which offer the degree.

**REQUIREMENTS FOR DOCTOR OF PHILOSOPHY DEGREE**

Work leading to the Doctor of Philosophy degree is planned in such a way as to give the student a comprehensive knowledge of his fields of specialization and a mastery of the methods of research. The degree is not awarded solely on the basis of course work completed, residence or other routine requirements. The final basis for granting the degree will be the student's grasp of the subject matter of a broad field of study, his competency to plan and conduct research, and his ability to express himself adequately and professionally in oral and written language.

The advisory committee will aid the student in planning his course work to achieve the required competence. This planning

*Applies to courses taken after August 15, 1970. Courses taken prior to that date must be numbered 800 or above to satisfy this requirement.
will include the selection of specific courses, and their sequence. Work in the minor field or fields should normally consist of from 12 to 24 hours in courses carrying graduate credit. If the direction of the student's study or research interest should change as his work progresses, he may request the appointment of a new major advisor.

**Residence Requirements.** Doctoral work, dealing with research and study as it does, requires an intense dedication and devotion of the subject of inquiry. The desired level of concentration and concern cannot be achieved where the student holds, throughout the period of his study, full-time employment not concerned with research in his field. In special circumstances, however, full-time employment may be combined with a portion of the doctoral research.

**Doctoral research is normally to be conducted on the Clemson University campus** and the following minimum requirements and/or conditions must be met in order that the student receive the Doctor of Philosophy degree:

a. The student must complete two consecutive academic semesters of academic work in the doctoral program given on the Clemson University campus.

b. No credit toward the doctoral degree may be obtained by correspondence or extension study.

c. All transfer credits, up to a maximum of 48 hours, must be verified by an official transcript from the institution at which the work was done. Transfer credit will not be allowed for courses in which a grade lower than B has been received.

**Under special circumstances, it may appear desirable that doctoral research be conducted external to the Clemson University campus.** If such research is to be performed under the immediate direction of a Clemson University faculty member acting as dissertation advisor and supervisor, then in order to accommodate the student, as well as to exercise proper and necessary control over this most important phase of doctoral study, the following additional requirements will be made:
a. The student must have the written consent of his university dissertation advisor, full advisory committee, department head, college dean, and the Dean of Graduate Studies and University Research. Prior to his departure from the campus, the student must submit in writing to his committee for their approval a plan for his research effort. Such plan should include a discussion of his problem and the intended scope of his investigation and should be structured in terms of a specific time frame.

b. The advisory committee may require a statement from an appropriate officer of the organization at which the student will be located agreeing to one or all of the following: 1) the student's plan to complete dissertation research using the organization's equipment and facilities, 2) the apportioning of at least 25 percent or other appropriate amount of the student's employment hours to his dissertation research and, 3) the release of patent rights or copyrights by the organization, arising from discoveries or concepts which evolve during the course of the student's doctoral research.

c. The student may be required to travel to Clemson University, not at the expense of Clemson University, to meet with his dissertation advisor and advisory committee as often as is deemed necessary by the committee. Further, the student may, at the discretion of his dissertation advisor and advisory committee, be required to return to the Clemson University campus subsequent to the performance of the mechanics of his research for the purpose of comprehensive review and analysis of his research.

d. The student must maintain continuous enrollment at Clemson University each semester while the research is in progress. It will be his responsibility to make suitable arrangements with his department to maintain this continuous registration. Normally the student will not be required to register for summer sessions; however, he must be registered for the term which involves the review of his completed dissertation and/or his final examination.

If doctoral research is to be conducted external to the Clemson University campus, but under the immediate direction of a dissertation supervisor who is an employee of an organization other than Clemson University; then in order to accommodate the student, as well as to exercise proper and necessary control over this most
important phase of doctoral study, the following requirement (addi-
tional to those above) will be made:

a. An employee, having an earned Ph.D. and engaged in the
general subject area of the student's research, must be designated
by an officer of the organization to supervise the student's research
work and recommended for appointment as an adjunct professor of
Clemson University. A resumé of the research supervisor must be
submitted to the student's full advisory committee for their review
and recommendation to the Graduate Dean.

b. The research supervisor will be required to submit a final
statement regarding the dissertation research, as well as interim
reports, if the committee deems such as being necessary. It is to be
emphasized that the off-campus research supervisor cannot serve
as the student's dissertation advisor.

Time Limit. All work for a Doctor of Philosophy degree must
be completed within a period of seven years. If a student begins
his doctoral program after receiving the Master's degree, all work
above the Master's level must be completed within a six-year
period.

Language Requirement. The normal language requirement for
the Ph.D. degree is a command of two approved languages equiva-
 lent to that provided by two years study of each language at the
college level, and evidenced by scores above the 25 percentile on
the Graduate School Foreign Language Tests (ETS). Students who
have within the last five years completed the equivalent of twelve
semester hours of study of a language at an accredited college
with average grades of B may be exempted from this examination
upon the recommendation of the Head of the Department of
Languages. Languages accepted by all departments are French
and German; under certain conditions Spanish, Russian, or the
classical languages may be accepted. A combination of two Ro-
mance languages is not normally acceptable. As alternative to
this requirement, one of two other plans may be chosen, subject
to approval by the advisory committee:

1. Command in depth of a single approved language, as evidenced
by a score above the 75 percentile on the GSFLT (EST). Students
who have completed a sequence of the equivalent of 18 semester
hours of study in a language with average grades of B, at least half of it within the previous five years, may be exempted from this examination upon the recommendation of the Head of the Department of Languages.

2. Command of one approved language, as evidenced by a score above the the 25 percentile on the GSFLT (ETS), plus at least six (6) semester hours of approved courses in a "broadening area" selected in consultation with the student's advisory committee and approved by his college dean and by the Graduate Dean. The term "broadening area" is defined for this purpose as a single well-defined area of the humanities or social sciences, and the courses selected are to be sufficiently related to provide a unified pattern of study. They must be at the graduate level, the 400 level, or by special permission of the Graduate Dean at the 300 level. They must be taken for credit and must be passed with grades of B or better; however, they carry no credit toward a graduate degree. Courses taken while an undergraduate may not be used to satisfy this requirement. Courses to be presented in satisfaction of this requirement are to be listed in the student's preliminary plan of study (GS Form 2).

The Graduate School Foreign Language Tests of the Educational Testing Service (GSFLT-ETS) are administered in Clemson by the University Testing Center according to the national schedules set by ETS.

All language requirements must have been satisfied prior to the student's preliminary or qualifying examination and prior to his admission to candidacy for the degree.

**Qualifying Examinations Before Admission to Candidacy.** The student must undertake such preliminary or qualifying examinations as may be prescribed by his department before he applies for admission to candidacy for his degree. These examinations may be written, oral, or a combination of both. The function of the examinations is to obtain objective evidence of an adequate intellectual mastery of the areas of major and minor specialization.

Immediately after the examination the examining committee will notify the Graduate School of its findings. The student's
performance on these examinations will determine whether the committee recommends acceptance of his application for admission to candidacy.

Should the student fail to pass his preliminary examinations he may be given the opportunity to undergo the examinations a second time. A second failure shall result in the student being declared ineligible for the Doctor of Philosophy degree at Clemson University.

Some departments have both qualifying and comprehensive examinations. Information about these examinations may be obtained from the individual departments.

**Final Doctoral Oral Examination.** The candidate for the Doctor of Philosophy degree must pass a final oral examination at least three weeks prior to the time of the convocation at which he plans to obtain the degree. The examination will be conducted by the student's advisory committee, and all faculty members are invited to participate. The Graduate School will be notified of the time and place of the examination at least ten days prior to the time scheduled.

This final examination demands a broad and penetrating interpretation by the student of his research project and conclusions. It may include examination of the student in his major and minor fields of specialization.

**FINANCIAL AID FOR GRADUATE STUDY**

**Research and Teaching Assistantships** are available to outstanding graduate students. Teaching assistantships are normally awarded for the academic year* while research assistantships may be granted for longer periods. Stipends range from $3,000 to $5,400 and tuition is reduced. Application forms are obtainable from the Graduate School or from departmental heads and should be com-

*Teaching assistants are usually awarded stipends during the summer months for performance of departmental duties provided they continue to work towards their degree.
pleted and filed early in the academic year before the student expects to enroll. Recipients of assistantships are selected by the respective academic departments and will be notified by the department.

**Graduate Fellowships and Grants-in-aid** are also available.

All fellowship awards are made by the heads of departments concerned. Information about grants-in-aid is obtainable from the Graduate School.

**Alumni Fellowships** ranging upward to $1,200 are awarded in all fields of study. These fellowships are made possible through gifts to the Alumni Loyalty Fund.

**The Alexander P. and Lydia Anderson Fellowship.** A $350 award for study in the biological sciences.

**Army Corps of Engineers Graduate Fellowships.** The U. S. Army Corps of Engineers has arranged with the Clemson University Graduate School to employ graduate students who have completed their academic studies for a one-year period to work on their thesis or dissertation. The topics must concentrate on a subject of current analytical or informational need related to the mission of the Corps of Engineers. This will cover the full range of engineering and nonengineering professional disciplines involved in studies, special investigations, design and research in all phases of construction engineering including ways to enhance esthetic and living aspects of structures.

**Belle W. Baruch Graduate Research Fellowships.** Four $3,000 fellowships plus $1,000 for tuition and supplies for study in forestry and natural resources biology.

**Stuart F. Brown Fellowship.** A $1,000 award given by the Whitinsville Spinning Ring Company to a student in the College of Industrial Management and Textile Science.

**Tennessee Eastman Kodak Fellowship.** An award of $2,000 to $3,000 plus tuition and fees to an American citizen in the Master's degree program in Chemical Engineering.
Environmental Health Traineeships. Traineeships are awarded for a three-year period by the University for doctoral study on behalf of the Public Health Service. Under special circumstances, an additional year of support may be awarded. These traineeships are specifically for students interested in a career involving some aspect of environmental health.

General Shale Products Company Fellowship. A $2,400 award to a student in Ceramic Engineering.

Gregg-Graniteville Fellowship. A $5,000 grant from the Gregg-Graniteville Foundation to the College of Industrial Management and Textile Science, including a $3,000 award to a student in textiles, plus fees, and the remainder in support of his textile research program.

David Jennings Fellowship. An award varying from $1,000 to $2,500 per year to students in the College of Industrial Management and Textile Science.

E. C. McArthur Memorial Fellowship. An award of $600 per year plus research materials given by the South Carolina Association of Soil Conservation District Supervisors to a student in Agricultural Engineering.

National Defense Education Act Fellowships. Three-year fellowships for doctoral study in particular areas are awarded annually by the University on behalf of the Department of Health, Education, and Welfare. Announcement of the availability of these fellowships is made in early February. Inquiries should be addressed to the Graduate School.

Federal Water Quality Administration Traineeships. Awards are made by this agency to students studying in the water pollution program. Inquiries about these awards should be directed to the Graduate School.
South Carolina National Bank Fellowships. An annual grant of $2,500 makes possible awards ranging from $500 to $2,500 to qualified graduate students in the College of Industrial Management and Textile Science.

The J. E. Sirrine Textile Foundation Fellowships. Fellowships of $1,000 to $3,000 per year (depending on student’s needs) are awarded to encourage outstanding young men to undertake graduate work in one of the graduate programs administered by the College of Industrial Management and Textile Science.

Alan G. Stanford Fellowship. An award of $500 to a student in Electrical Engineering.

Textile Research Institute Research Fellowship. An award of up to $3,000 plus tuition and fees to a student in the sciences or engineering. The recipient’s dissertation research will be conducted on a textile-oriented program.

Union Carbide Research Assistantship. An award of $2,000 to $3,000 plus tuition and fees to a qualified graduate student (American citizen) in Chemical Engineering.

Warwick Chemical Foundation Fellowship. Income from a fund, donated in memory of Manfred Caranci, available annually for awards to students in Chemistry.

Other Fellowships: Governmental agency Fellowships, in which the student makes direct application, are as follows: National Science foundation, Public Health Service, and Department of Interior fellowships. Information on these fellowships may be obtained from the Graduate School.

Other Funds: Limited assistance may also be available from the Clemson Foundation, Clemson Student Loan Funds, and National Defense Student Loan Programs. Contact the Student Aid Office prior to June 1 for further information.
In addition to the Master of Science and Ph.D. degrees, the College of Agricultural Sciences offers post-baccalaureate degree programs that are designed primarily to meet the continuing education needs of individuals whose interests lie outside of a research-oriented profession. Individuals who are interested in such professional training and development include extension service personnel; vocational agriculture teachers; technical education center teachers; and management, executive, sales, and service personnel of agri-business firms.

These programs are designed to fulfill the following objectives: (a) provide university graduate level professional training of a non-research-oriented nature, and (b) provide a program of continuing education adapted to the needs of agriculture.

Upon successful completion of the professional degree program, students will be awarded the degree of Master of Agriculture or Master of Agricultural Education with a major in the following areas of study:

- Agricultural Economics
- Agronomy — Crops and Soils
- Animal Science
- Dairy Science
- Entomology
- Horticulture
- Plant Pathology
- Poultry Science

A minimum of 30 semester hours is required. At least one-half of the credit hours in the student's program must come from courses numbered 700 or above.* The student's program of study must be approved by his advisory committee.

Both a major field of study of at least 12 semester hours and a minor field of at least 6 semester hours are required.

All candidates for the degree of Master of Agriculture, or Master of Agricultural Education will be required to take a course in

*Applies to courses taken after August 15, 1970. Courses taken prior to that date must be numbered 800 or above to satisfy this requirement.
applied statistics, if such a course has not been a part of the student's undergraduate degree program. In addition, a knowledge of research methods will be required and may be acquired through a research methods or a special problems type course.

AGRICULTURAL ECONOMICS

The Department of Agricultural Economics offers the Master of Science, Master of Agriculture, and Doctor of Philosophy degrees.

Graduate work in agricultural economics is of increasing importance since it enables the student to attain a higher degree of specialized professional competence and to secure a greater mastery of techniques for applying quantitative economic analysis to agricultural firm and industry problems. Industry, government, and universities offer challenging opportunities in research, development, education, management and other related areas for persons with advanced training in agricultural economics.

In addition to applicants from undergraduate programs in agricultural economics and other related agricultural programs, the department encourages applications from other students with Bachelor's degrees in fields that provide a well rounded background in general economics. In many cases, such students may be admitted to full graduate status without prerequisites other than those required of all graduate students. Special emphasis in the program of graduate study is placed on the economics of agricultural production and marketing, economic development, analysis of programs and policies affecting agriculture, and statistical techniques used in solving economic problems of the agricultural industry.

AgEc 602—ECONOMICS OF AGRICULTURAL PRODUCTION—
3 cr. (3 and 0) F

AgEc 603—LAND ECONOMICS—3 cr. (3 and 0)

AgEc 651—AGRICULTURAL COOPERATION—2 cr. (2 and 0) F

AgEc 652—AGRICULTURAL POLICY—3 cr. (3 and 0) FS

AgEc 656—PRICES—3 cr. (3 and 0) FS

AgEc 660—AGRICULTURAL FINANCE—2 cr. (2 and 0) FS

AgEc 701—AGRIBUSINESS MANAGEMENT PRINCIPLES—
3 cr. (3 and 0) S

A survey of concepts and principles of management of agri-business firms. Included are such topics as decision theory, information systems, systems analysis and organization theory with special applications of these
concepts to the organization, administration, and management of agriculturally-related businesses.

AgEc 802—AGRICULTURAL PRODUCTION ECONOMICS PROBLEMS—3 cr. (3 and 0)

An advanced study of production theory and its quantitative application including consideration of factors promoting change in input and output combinations on farms and among areas; relationship of economic theory to analysis of production activity; alternative approaches to explanation of input-output relations. **Prerequisite:** Permission of instructor.

AgEc 804—WATER RESOURCE POLICIES—3 cr. (3 and 0)

A study of the economic, social and legal aspects of the control, use, development and management of water resources, with special emphasis upon public policies relating thereto.

AgEc 806—ECONOMIC DEVELOPMENT IN AGRICULTURAL AREAS—3 cr. (3 and 0)

AgEc 807—MARKET STRUCTURE IN AGRICULTURAL INDUSTRIES—3 cr. (3 and 0)

A study of market structure and other approaches as they relate to agricultural marketing. Students will undertake individual assignments in the field of their interest. **Prerequisite:** Permission of instructor.

AgEc 808—APPLIED QUANTIFICATIONS IN AGRICULTURAL ECONOMICS—3 cr. (3 and 0)

A survey of the mathematical tools requisite for a concise description of the principles in the economics of agriculture. Models are formulated as media for empirical research. Microeconomic theory under the assumptions of perfect competition is emphasized. The relations among demand, supply, cost, revenue, and productivity are examined in a framework for agriculture. **Prerequisite:** Permission of instructor.

AgEc 814—CONTEMPORARY ECONOMIC PROBLEMS—3 cr. (3 and 0)

A critical review of the nature of contemporary economic problems, the background out of which they developed, the remedies which have been applied, and possible alternatives. Special emphasis will be given to problems relating to agriculture and rural life.

AgEc 851—SEMINAR IN RESEARCH METHODOLOGY—1 cr. (1 and 0)

A survey of logic and the scientific method; the formulation, initiation and carrying out of research problems in economics and business; methods and problems of obtaining and analyzing economic data; the role of electronic computers and data processing systems, and group discussions of the proposed thesis problems of individual students. (Required of all graduate students who have not already had a comparable course.)

AgEc 891—RESEARCH—Credits to be arranged.

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AgEe 904—SEMINAR IN RESOURCE ECONOMICS—3 cr. (3 and 0)
Study of special problems and recent periodical literature relating to the control, management, development and use of land and water resources in the United States and in other parts of the world. Prerequisite: Agricultural Economics 603 or 804.

AgEe 906—SEMINAR IN AREA ECONOMIC DEVELOPMENT—3 cr. (3 and 0)
A study of recent research developments in the field of economic development, including a review of research publications, journal articles, and other literature, with special emphasis given to a critical examination of objectives, analytical techniques and procedures used in area or regional development efforts. Prerequisite: Agricultural Economics 806.

AgEe 907—AGRICULTURAL MARKETING PROBLEMS—3 cr. (3 and 0)
An advanced study in the theory of, and the research related to consumer behavior; economic consequences of individuals' and firms' decisions upon supply and demand; general interdependency among economic variables. Prerequisite: Agricultural Economics 807.

AgEe 991—DOCTORAL RESEARCH—Credit to be arranged.
(See also courses listed under Economics.)

AGRONOMY

U. S. Jones, Department Head

The Department of Agronomy offers the Master of Science, Master of Agriculture, and Doctor of Philosophy degrees.

Opportunities exist for B.S. or B.A. degree graduates with majors in chemistry, biology, plant science, physics, geology, general science or soils. Graduate programs include courses in soil chemistry, soil physics, soil genesis, soil fertility, soil microbiology, plant breeding and genetics as well as fundamental research problems relating to these subjects. Facilities include X-ray diffraction, differential thermal analysis equipment, a cytogenetics laboratory, controlled environmental chambers, and graduate student laboratories in an air-conditioned building.

Some agronomists are trained as chemists; others have strong training in physics, geology and mathematics; some are plant physiologists, geneticists or microbiologists. An agronomist played a major role in the development of streptomycin and aureomycin.

Teaching in undergraduate courses is a departmental requirement of all graduate students in Agronomy.

Gen 602—GENETICS—4 (3 and 3) FS
Gen 651—GENETICS—3 cr. (3 and 0) S
Gen 801—CYTOGENETICS—3 cr. (2 and 3) S, even numbered years.

A study of the classical and contemporary problems of chromosome structure, behavior and transmission. Topics will include recombination, interspecific hybridization, euchromatin and heterochromatin, polyploidy, mutable genetic systems, and structural and numerical aberrations of chromosomes and the effects upon breeding systems of plants and animals. **Prerequisite:** Gen 302 or equivalent.

Agron 601—FERTILIZERS—3 cr. (3 and 0) F

Agron 603—SOIL CLASSIFICATION—2 cr. (1 and 3) F

Agron 605—PLANT BREEDING—3 cr. (2 and 2) S

Agron 607—PRINCIPLES OF WEED CONTROL—3 cr. (2 and 2) F

Agron 608—SOIL AND PLANT ANALYSIS—3 cr. (1 and 6) S

Agron 610—COTTON AND OTHER FIBER CROPS—2 cr. (2 and 0) F, odd numbered years.

Agron 611—GRAIN CROPS—2 cr. (2 and 0) F, even numbered years.

Agron 612—TOBACCO AND SPECIAL USE CROPS—2 cr. (2 and 0) S, even numbered years.

Agron 620—FORAGE AND PASTURE CROPS—3 cr. (3 and 0) S

Agron 622—FORAGE CROPS LABORATORY—1 cr. (0 and 2) S

Agron 652—SOIL FERTILITY AND MANAGEMENT—2 cr. (2 and 0) S

Agron 655—SEMINAR—1 cr. (1 and 0) F

Agron 656—SEMINAR—1 cr. 1 and 0) S

Agron 801—CROP PHYSIOLOGY AND NUTRITION—3 cr. (3 and 0) F, odd numbered years.

The application of basic concepts and physiologic aspects of growth and culture to crop management practices.

Agron 802—PEDOLOGY AND SOIL CLASSIFICATION—3 cr. (2 and 3) S, odd numbered years.

Deals with the factors of soil genesis, soil morphology, and soil classification. A study is made of such factors of soil formation as parent material, topography, climate and organisms. Particular attention is given to the classification of Southeastern soils.

Agron 804—THEORY AND METHODS OF PLANT BREEDING—3 cr. (3 and 0) F, even numbered years.

Concepts and principles of plant breeding and genetics as applied to the development and maintenance of improved crop varieties. Theoretical considerations of the various breeding methods are emphasized.
Agron 805—SOIL FERTILITY—3 cr. (3 and 0) S, even numbered years.
A study of the essential nutrients in the soil-plant system with emphasis on mechanisms of retention and transport; supplies and availability; reactions and interactions; deficiency diagnosis and remedies. Concepts and techniques for evaluating soil fertility problems will be studied.

Agron 806—SPECIAL PROBLEMS—Credit to be arranged.
Accumulation of up to 3 semester hours permitted at a rate of 1, 2 or 3 hours per semester for 3, 6 or 9 hours of lab work per week, at the discretion of the major professor.

Mechanics and strategy of research should be stressed.

Agron 807—SOIL PHYSICS—3 cr. (2 and 3) F, even numbered years.
A study of fundamental principles of soil physics, methods of physical analysis of soils, and applications of soil physics in Agriculture.

Agron 808—SOIL CHEMISTRY—3 cr. (2 and 3) F, even numbered years
Principles and theories concerning the structure and chemical properties of soil colloids, ionic exchange and membrane phenomena, chemical equilibria, soil acidity, oxidation-reduction relations, soil chemistry of plant nutrients.

Agron 812—CROP ECOLOGY AND LAND USE—3 cr. (3 and 0) F, even numbered years.
Basic concepts of, and factors affecting, the adaptation and distribution of crop plants. Study of the microclimate and crop response to environmental factors, with modifications of microclimate by agricultural operations. Interactions among crop plants, and between weeds and crop plants under field conditions.

Agron 820—PESTICIDE RESIDUES IN SOIL, WATER AND AIR—3 cr. (3 and 0) S, odd numbered years.
A study of the accumulation, decomposition and/or attenuation of pesticides in man’s environment. Includes pesticide structures and properties; sorption-desorption by soil; diffusion and transport in water; volatility, and diffusion in air; and chemical-, bio- and photodegradation. Prerequisites: Introductory courses in Organic and Physical chemistry or permission of instructor.

Agron 825—SEMINAR—1 cr. (1 and 0) FS.
Presentation and discussion of special topics and original research in the field of agronomy. (Credit may be earned for more than one semester by doctoral candidates.)

Agron 891—RESEARCH—Credit to be arranged, FS.

Agron 991—DOCTORAL RESEARCH—Credit to be arranged. FS.
The Doctor of Philosophy degree is offered.

The graduate program in Animal Physiology utilizes the faculties of the five departments listed above. Physiological processes of both vertebrates and invertebrates are considered. Areas of greatest research emphasis are reproduction, endocrinology and environment.

Students enrolling in Animal Physiology should have a strong background in the biological sciences, and at least one course in organic chemistry.

The student will organize his program of study from the courses listed below and from supporting fields as deemed proper by the advisory committee.

AnPh 801—ELECTRON MICROSCOPY OF ANIMAL AND PLANT TISSUES—3 cr. (1 and 6)

Theory of and practice in: preparing animal, plant and microbial specimens for electron microscope observations; thin-sectioning; section staining; operating the electron microscope; photographing, developing and printing micrographs; interpreting electron micrographs. Emphasis will be placed on a special problem in which the student selects a tissue of interest, studies it with the electron microscope, prepares and interprets electron micrographs.

AnPh 802—VERTEBRATE PHYSIOLOGY—3 cr. (2 and 3) S

A comparative physiology course dealing with all classes of mammals and fowl. Processes of ingestion, digestion, secretion, excretion, respiration, circulation and metabolism. Endocrinology and reproduction will be reviewed briefly. Rats, rabbits, chickens and humans are used as laboratory subjects.

AnPh 803—ANIMAL PHYSIOLOGY—4 cr. (3 and 3) F

A comprehensive course in animal physiology covering circulation, respiration, digestion, excretion and metabolism. Endocrinology and reproduction will be reviewed briefly.
AnPh 804—ANIMAL PHYSIOLOGY—4 cr. (3 and 3) S
A continuation of Animal Physiology 803 covering muscles, nerves, special senses, skin and bones.

AnPh 805—PHARMACOLOGY—3 cr. (2 and 3)
The action of drugs upon the various biological systems of the mammal will be described. Drugs will be discussed by classes and discussions will include methods of action, uses, general dosage levels, and toxicity. The laboratory exercises will demonstrate the actions of drugs upon the mammalian systems. Both classroom and student experimentation will be employed.

AnPh 806—EXPERIMENTAL ANIMAL PHYSIOLOGY—3 cr. (1 and 6) S
Demonstration and practice of research methodology in animal physiology. Emphasis is on the scientific approach for using animals or specific organs of intact animals as experimental units. The selection and use of animal techniques and practices, including surgical procedures for altering physiological and endocrinological activities with large and small animals. Prerequisite: Zool 760 or equivalent.

AnPh 807—SPECIAL PROBLEMS IN ANIMAL PHYSIOLOGY—(1-3 and 0)
Original investigation of special problems in animal physiology not related to a thesis and designed to provide experience and training in research. This may include a comprehensive review of literature which relates to a research project.

AnPh 808—MAMMALIAN AND AVIAN ENDOCRINOLOGY—3 cr (3 and 0) S
A study of the interrelationships of the nervous and endocrine systems as they influence growth and development, body metabolism, body regulatory mechanisms, behavior, and reproduction in mammals and birds, and lactation in mammals. Emphasis will be on the integrating actions of hormones as they affect production. The theoretical and practical aspects of exogenous administration of hormones (natural and synthetic) on body functions will be discussed.

AnPh 851—ANIMAL PHYSIOLOGY SEMINAR I—1 cr. (1 and 0) S
Major topics will be current research and developments in animal physiology. Student and faculty research will be discussed as well as the literature on animal physiology.

AnPh 852—ANIMAL PHYSIOLOGY SEMINAR II—1 cr. (1 and 0) F
This course is a continuation of AnPh 851 and will include further discussion of current research and literature on topics selected by instructor and students.

AnPh 991—DOCTORAL RESEARCH—Credit to be arranged.
Bioch 606—PHYSIOLOGICAL CHEMISTRY—4 cr. (3 and 3)
Bioch 819—INTERMEDIARY METABOLISM—3 cr. (3 and 0)
Bioch 817—CHEMISTRY AND METABOLISM OF HORMONES—
2 cr. (2 and 0)
DySc 653—ANIMAL REPRODUCTION—3 cr. (3 and 0)
DySy 655—ANIMAL REPRODUCTION LABORATORY—1 cr. (0 and 3)
DySc 803—PHYSIOLOGY OF REPRODUCTION AND MILK SECRETION—3 cr. (3 and 0)
Micro 811—BACTERIAL CYTOLOGY AND PHYSIOLOGY—
3 cr. (3 and 0)
Micro 813—BACTERIAL CYTOLOGY AND PHYSIOLOGY LABORATORY—2 cr. (0 and 6)
Zool 658—CELL PHYSIOLOGY—3 cr. (2 and 3)
Zool 660—GENERAL PHYSIOLOGY—3 cr. (2 and 3)
Zool 661—GENERAL ANATOMY—3 cr. (3 and 0)
Zool 675—GENERAL ENDOCRINOLOGY—3 cr. (2 and 3)
Zool 801—ANIMAL HISTOLOGY—3 cr. (2 and 3)
Zool 806—COMPARATIVE ANIMAL PHYSIOLOGY—3 cr. (3 and 0)
Zool 808—RADIOBIOLOGY—3 cr. (2 and 3)
Zool 809—TOXICOLOGY—3 cr. (2 and 3)
Zool 830—HISTOCHEMISTRY—CYTOCHEMISTRY—3 cr. (2 and 3)

ANIMAL SCIENCE
R. F. Wheeler, Department Head

The Department of Animal Science offers the Master of Science and Master of Agriculture degrees.

The Department participates in Interdepartmental Ph.D. Programs in Animal Physiology and Nutrition.

An Sc 601—BEEF PRODUCTION—3 cr. (3 and 0)
An Sc 603—BEEF PRODUCTION LABORATORY—1 cr. (0 and 3)
An Sc 608—PORK PRODUCTION—3 cr. (3 and 0)
An Sc 610—PORK PRODUCTION LABORATORY—1 cr. (0 and 3)
An Sc 652—ANIMAL BREEDING—3 cr. (3 and 0)
An Sc 802—TOPICAL PROBLEMS—1-3 cr. (1-3 and 0)
   A critical study of animal science experiments and interpretation of their results.
An Sc 803—MEAT TECHNOLOGY—3 cr. (3 and 0)
   Biochemistry, histology and microbiology of fresh, frozen, cured, smoked and processed meats. Quality of meats, and meat products, processing methods, nutritive value, and research techniques will be given emphasis. Prerequisites: An Sc 353 and 355.
An Sc 804—METHODS IN ANIMAL BREEDING—3 cr. (3 and 0)
   Gene and zygotic frequency; systems of mating; heritabilities; genetic consequences of selection; and criteria for evaluating improvement in beef cattle, swine, and sheep. Prerequisite: An Sc 452.
An Sc 805—NUTRITION OF MEAT ANIMALS—3 cr. (3 and 0)
   Deals with the metabolism of carbohydrates, lipids, proteins, inorganic elements, and vitamins in the nutrition of beef cattle, swine and sheep; the nutrient requirements of meat animals with special emphasis on the properties and functions of nutrients. Prerequisite: Nutr 401.
An Sc 891—RESEARCH—Credit to be arranged.

DAIRY SCIENCE
W. A. King, Department Head

The Dairy Science Department offers the Master of Agriculture and Master of Science degrees. The Doctor of Philosophy degree is offered in Animal Physiology and in Nutrition on an interdepartmental basis.

The curriculum in dairy science emphasizes studies of a fundamental and technical nature superimposed upon a core of basic science courses. The student becomes familiar with the production of quality milk and its use as a raw material and its manufacture into many food products. The biological nature of foods makes a background in the chemical and biological sciences highly desirable for advanced study in this field.

Majors in biology, chemistry, chemical engineering, or food technology will find an M.S. degree in Dairy a logical supplement to their undergraduate work, giving them the specialist's training now required in most industries. Because of the basic nature of the curriculum, such a degree

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would lead to employment opportunities in most food fields. Minors may be taken in zoology, bacteriology, chemistry, industrial management, economics, statistics, physiology, nutrition, genetics, and food technology.

DySc 602—DAIRY MANUFACTURES—4 cr. (3 and 3) S, 1972 and alternate years.

DySc 604—PLANT MANAGEMENT—3 cr. (2 and 3) S, 1971 and alternate years.

DySc 606—CHEMICAL AND PHYSICAL NATURE OF MILK—
3 cr. (2 and 3) S

DySc 607—MARKET MILK—3 cr. (2 and 3) S, 1972 and alternate years.

DySc 652—DAIRY CATTLE FEEDING AND MANAGEMENT—3 cr.
(2 and 3) S, 1971 and alternate years.

DySc 653—ANIMAL REPRODUCTION—3 cr. (3 and 0) F

DySc 655—ANIMAL REPRODUCTION LABORATORY— 1 cr. (0 and 3) F.

DySc 801—TOPICAL PROBLEMS—1 and 3. cr. F, S, SS.
Topics of interest to the graduate students. The course is designed to give experience with problems in dairying not covered by thesis research. Credit varies with the problems selected.

DySc 802—GENETICS OF DAIRY CATTLE IMPROVEMENT—3 cr.
(3 and 0) S, 1972 and alternate years.

Topics include a study of inheritance in dairy cattle; improvement of economic characters through selection; results of experiments on mating systems; methods of evaluating the transmitting ability of bulls and cows; evaluating the genetic potential of young animals; and evaluation of breed association and governmental programs for the improvement of dairy cattle.

DySc 803—PHYSIOLOGY OF REPRODUCTION AND MILK SECRETION
—3 cr. (3 and 0) S, 1972 and alternate years.

The effects of hormones on gametogenesis, fertilization, embryological development, pregnancy and lactation. Comparative anatomy of mammary glands and physiology of lactation in various species will be considered. Emphasis will be placed on critically evaluating the most recent scientific literature in these areas for content, experimental methods, and authors' conclusions; and on selecting a problem, reviewing related literature and writing a research proposal for solving the problem.

DySc 805—NEWER KNOWLEDGE OF DAIRY NUTRITION—3 cr.
(3 and 0) F, 1971 and alternate years.

The application of the latest information on digestion, metabolism and the nutritional requirements of dairy cattle.
DySc 807—FERMENTED DAIRY PRODUCTS—3 cr. (2 and 3) S, 1973 and alternate years.
The biological and chemical changes involved in the processing and aging of cheese and fermented dairy products.

DySc 808—INDUSTRIAL DAIRY SCIENCE—3 cr. (3 and 0)
Provides advanced managerial training for operating dairy and food plants. Managerial policy and decision making are emphasized.

DySc 891—RESEARCH—Credit to be arranged, F, S, SS

ENTOMOLOGY
S. B. Hays, Department Head

The Master of Science, Master of Agriculture, and Doctor of Philosophy degrees are offered.

Ent 601—FIELD CROP AND STORED PRODUCT INSECTS—3 cr. (2 and 3)

Ent 602—FRUIT, NUT, AND VEGETABLE INSECTS—3 cr. (2 and 3)

Ent 605—INSECT MORPHOLOGY—4 cr. (3 and 3) F

Ent 610—INSECT TAXONOMY—3 cr. (1 and 6)

Ent 655—MEDICAL AND VETERINARY ENTOMOLOGY—3 cr. (2 and 3) S

Ent 668—INTRODUCTION TO RESEARCH—2 cr. (1 and 3) S

Ent 808—TAXONOMY OF IMMATURE INSECTS—3 cr. (1 and 6) F
Identification of immature insects with particular emphasis on the Holometabola. Each student will make and submit an identified collection of immature insects.

Ent 809—RECENT ADVANCES IN ENTOMOLOGY I—1 cr. (1 and 0) F
A review of the current literature in the fields of Entomology. Needs and changes in future research in Entomology will be discussed.

Ent 810—RECENT ADVANCES IN ENTOMOLOGY II—1 cr. (1 and 0) S
A continuation of Ent 809.

Ent 856—MEDICAL ENTOMOLOGY—3 cr. (2 and 3) S
Disease vectors of animals with emphasis on insects and related Arthropod disease carriers. Prerequisite: Ent 301 or permission of instructor.
Ent 860—PRINCIPLES OF INSECT CONTROL—3 cr. (3 and 0) F ’70 and alternate years.

The mechanical, physical, cultural, biological, chemical and legal aspects of insect control.

Ent 861—INSECT TOXICOLOGY—3 cr. (2 and 3) S ’73 and alternate years.

History, development, application, chemical nature and mode of action of insecticides. Prerequisite: Organic Chemistry.

Ent 862—INSECT PHYSIOLOGY—3 cr. (2 and 3) ’72 and alternate years.

The physiology of nutrition, digestion, respiration, excretion, nervous and hormonal systems. Prerequisite: Organic Chemistry.

Ent 863—SPECIAL PROBLEMS IN ENTOMOLOGY—3-6 cr. F, S, S S

Original investigation of special problems in entomology not related to a thesis but designed to provide experience and training in research. Emphasis will be placed on insect toxicology, insect physiology, medical entomology and biological control of insects.

Ent 890—RESEARCH TECHNIQUES IN AGRICULTURE—3 cr. (2 and 3)

Designed to give the student a comprehensive understanding of research procedures and techniques in solving problems in the various fields of agriculture. Special attention will be given to the design of experiments, interpretation of results and report writing. The student will be expected to prepare a written report on a selected problem.

Ent 891—RESEARCH—Credit to be arranged. F, S, S S

Ent 991—DOCTORAL RESEARCH—Credit to be arranged. F, S, S S

ENVIRONMENTAL HEALTH

Degrees are not awarded in Environmental Health. Courses listed below are used as part of the major or minor work to support health oriented programs for students pursuing degrees in curricula such as Agronomy and Soils, Agricultural Engineering, Chemical Engineering, Environmental Systems Engineering, Entomology, Zoology, Nutrition, Physiology, and Water Resources Engineering.

EnH 671—MAN AND HIS ENVIRONMENT—2 cr. (2 and 0)

The interactions of man with his environment will be surveyed. Health factors such as urbanization, population growth, pathogens, insects and other vectors, ionizing radiation, and toxic chemical residues will be emphasized. The effects of air, water, food, and solid wastes contacts will be considered. Prerequisite: Permission of instructor.
EnH 672—ENVIRONMENTAL PLANNING AND CONTROL—2 cr.
(2 and 0)
Application of planning and design to effective environmental control. Topics such as land use, water supply and treatment, wastewater treatment and disposal, and solid waste disposal will be considered from the standpoint of control. Not intended for graduate students in engineering. **Prerequisite:** Permission of the instructor.

EnH 893—ENVIRONMENTAL HEALTH SEMINAR I—1 cr. (1 and 0)
A discussion of current advances and research developments in the area of environmental health. Both the students and the staff will participate. **Prerequisite:** Graduate standing.

EXPERIMENTAL STATISTICS
W. P. Byrd, Chairman

Courses in Experimental Statistics are offered as support for students majoring in other areas. A minor is offered at the master's and doctoral levels. Courses to be used to satisfy the minor should be approved at the beginning of the student's program.

Students who elect a minor at the doctoral level will be expected to demonstrate competence in the theoretical basis as well as the application of statistics.

ExSt 662—STATISTICS APPLIED TO ECONOMICS—3 cr. (3 and 0) S

ExSt 801—STATISTICAL METHODS—4 cr. (3 and 3) F, S, SS
Role and application of statistics in research including estimation, test of significance, analysis of variance, multiple comparison techniques, basic designs, mean square expectations, variance components analysis, simple and multiple linear regression and correlation, and non-parametric procedures. **Prerequisite:** Permission of instructor.

ExSt 803—REGRESSION AND LEAST SQUARES ANALYSIS—3 cr.
(3 and 0) F
Regression analysis; simple and multiple linear, curvilinear and multiple curvilinear; curve fitting; least squares and computer techniques for fitting of constants and analysis of planned experiments. **Prerequisite:** ExSt 801.

ExSt 804—SAMPLING—3 cr. (3 and 0) F
The principles of scientific sampling; finite population sampling; simple random, stratified, multistage, and systematic sampling; optimum allocation; and methods of obtaining, processing and reporting survey informa-
tion. Sampling as related to the environment, natural resources, and social and economic problems will be considered. **Prerequisite:** ExSt 801.

**ExSt 805—DESIGN AND ANALYSIS OF EXPERIMENTS—3 cr.**

(3 and 0) S

Review of the basic designs and analysis; data transformations; single degree of freedom, orthogonality, and responses in ANOVA; covariance; factorials, split-plot arrangements, confounding, fractional replication, response surfaces; incomplete blocks; and introduction to least squares analysis of experiments. Uses of standard computer programs for selected analyses will be considered. **Prerequisite:** ExSt 801.

**FOOD SCIENCE**

W. P. Williams, Department Head

Advanced degrees are not awarded in Food Science. Courses may be taken as a minor or to supplement a major in other fields.

FdSc 612—FOOD QUALITY CONTROL—2 cr. (2 and 0)

F, 1972 and alternate years.

FdSc 613—BIOCHEMISTRY OF FOODS—2 cr. (2 and 0)

S, 1972 and alternate years.

FdSc 614—FOOD QUALITY CONTROL LABORATORY—2 cr. (1 and 3)

S, 1972 and alternate years.

FdSc 615—HUMAN NUTRITION—2 cr. (2 and 0)

S, 1972 and alternate years.

FdSc 616—FOOD ANALYSIS—2 cr. (1 and 3)

S, 1972 and alternate years.

**GENETICS**

Advanced degrees are not awarded in Genetics. Courses are offered as a minor for students majoring in other areas. See Agronomy for a listing of available courses.

**HORTICULTURE**

T. L. Senn, Department Head

The Department of Horticulture offers the Master of Science and Master of Agriculture degrees.
Graduate study in horticulture is designed to acquaint the student with the important biological principles underlying the production and post-harvest physiology and handling of horticultural crops. This includes not only the study of the economic product prior to harvest, but also through its harvesting, storage, marketing and processing. Scientific knowledge obtained in horticultural research as well as that available in the related fields of botany, plant physiology, biochemistry and genetics serve to give the student a broad base for future work in his chosen field.

Graduate study is carried on in pomology, vegetable crops, floriculture and ornamental horticulture, and postharvest physiology and handling, as well as plant physiology at the doctoral level. Prior to admission for graduate work, acceptable courses on the undergraduate level are recommended. While students need not major in horticulture as undergraduates, deficiencies in this respect must be made up by taking courses as directed by the departmental advisors and the graduate committee of the Department of Horticulture.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hort 608</td>
<td>FLORAL DESIGN AND RETAIL MARKETING</td>
<td>2 cr.</td>
<td>(1 and 3)</td>
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<tr>
<td>Hort 610</td>
<td>FLORICULTURE</td>
<td>3 cr.</td>
<td>(2 and 3) S</td>
</tr>
<tr>
<td>Hort 605</td>
<td>NUT TREE CULTURE</td>
<td>2 cr.</td>
<td>(2 and 0) F, even numbered years.</td>
</tr>
<tr>
<td>Hort 606</td>
<td>NURSERY TECHNOLOGY</td>
<td>3 cr.</td>
<td>(2 and 3) S</td>
</tr>
<tr>
<td>Hort 607</td>
<td>LANDSCAPE DESIGN</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
</tr>
<tr>
<td>Hort 612</td>
<td>TURF MANAGEMENT</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
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<tr>
<td>Hort 651</td>
<td>SMALL FRUIT CULTURE</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
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<tr>
<td>Hort 652</td>
<td>COMMERCIAL POMOLOGY</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
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<tr>
<td>Hort 656</td>
<td>TRUCK CROPS</td>
<td>3 cr.</td>
<td>(3 and 0) S, even numbered years</td>
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<tr>
<td>Hort 660</td>
<td>LANDSCAPE DESIGN</td>
<td>5 cr.</td>
<td>(3 and 6) F</td>
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<tr>
<td>Hort 664</td>
<td>FOOD PRESERVATION</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
</tr>
<tr>
<td>Hort 668</td>
<td>INTRODUCTION TO RESEARCH</td>
<td>2 cr.</td>
<td>(1 and 3) S</td>
</tr>
<tr>
<td>Hort 801</td>
<td>PROBLEMS IN SMALL FRUIT PRODUCTION</td>
<td>3 cr.</td>
<td>(3 and 0) F, 1971 and alternate years.</td>
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<td></td>
<td>A study of selected problems encountered in the production of blueberries, strawberries, brambles and grapes.</td>
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<tr>
<td>Hort 802</td>
<td>RESEARCH SYSTEMS IN HORTICULTURE</td>
<td>3 cr.</td>
<td>(2 and 3) F</td>
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<tr>
<td></td>
<td>A study of current trends, developments, and techniques in horticultural research. <strong>Prerequisite:</strong> Ch 220 or Ch 223, 227.</td>
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</tbody>
</table>
Hort 803—EXPERIMENTAL OLERICULTURE—3 cr. (3 and 0)  
F, 1971 and alternate years.
A systematic study of sources of information on research developments in vegetable crops.

Hort 804—SCIENTIFIC ADVANCES IN ORNAMENTAL HORTICULTURE—3 cr. (3 and 0) S, '73 and alternate years.
Discussions on topics from current scientific periodicals and on other research and developments in ornamental horticulture.

Hort 805—PHYSIOCHEMICAL PROCEDURES FOR DETERMINING QUALITY IN HORTICULTURAL CROPS—3 cr. (2 and 3) F, '72 and alternate years.
Subject matter will include the study of special titrations, organoleptic evaluations, refractometry, colorimetry, and quality evaluations with succulometers and texturometers. The effect of acids, sugars, salts, and other chemical constituents on quality of horticultural crops will be evaluated.

Hort 806—POSTHARVEST PHYSIOLOGY AND HANDLING OF HORTICULTURAL CROPS—3 cr. (3 and 0) S
Principles, developments, and application of research findings dealing with the physiology of maturation and storage of horticultural crops are emphasized. A concept of quality is formed through a study of the factors affecting physical and biological changes occurring in horticultural crops. Prerequisite: Bot 352.

Hort 807—POMOLOGY—3 cr. (3 and 0) S, '73 and alternate years.
A study of the growth and development of deciduous fruits with emphasis on the peach and apple. Prerequisite: Hort 352.

Hort 808—SPECIAL INVESTIGATIONS IN HORTICULTURE—2 cr.  
(2 and 0) S, SS
Special research investigations in horticulture not related to a thesis, but designed to provide opportunities for research experience and training. Prerequisite: Hort 802 or Hort 805.

Hort 809—SEMINAR I—1 cr. (1 and 0) F
A review of current topics in horticulture with special emphasis on the preparation, organization, and presentation of material by the students.

Hort 810—SEMINAR II—1 cr. (1 and 0) S
A continuation of Hort 809.

Hort 811—QUANTITATIVE EXPOSITION OF PLANT DEVELOPMENT—  
2 cr. (1 and 3) S.
Principles and application of quantitative morphology and crop production analysis. Techniques for visually detecting minute daily changes in plant development are studied and formulated. Graphic and statistical
evaluation is made of the influence of specific environmental factors and their interactions on plant development. Practical and theoretical applications of the derived systems of observation and analysis are considered.

Hort 891—RESEARCH—Credit to be arranged. F, S, SS.

Hort 991—DOCTORAL RESEARCH—Credit to be arranged. F, S, SS.

NUTRITION

W. A. King, Dairy Science, Chairman
B. D. Barnett, Poultry Science
R. F. Wheeler, Animal Science
W. P. Williams, Food Science

The Master of Science and Doctor of Philosophy degrees are offered.

Graduate work in Nutrition encompasses four departments from which a student may select courses and his area of study. A core of basic courses in biochemistry and nutrition will be required for all students and additional course work will be taken in areas of special interest. The latter includes nutrition of small animals, humans, poultry, and dairy and meat animals. Minors are available in animal physiology, biochemistry, and other areas.

Teaching is an integral part of graduate work in Nutrition and is required of all graduate students.

Students enrolling for a degree in Nutrition will choose from those listed below and from others deemed appropriate by the advisory committee.

An Sc 805—NUTRITION OF MEAT ANIMALS—3 cr. (3 and 0)
Bioch 810—BIOCHEMICAL TECHNIQUES—3 cr. (1 and 6)
Bioch 815—LIPIDS—2 cr. (2 and 0)
Bioch 817—CHEMISTRY AND METABOLISM OF HORMONES—2 cr. (2 and 0)
Bioch 819—INTERMEDIARY METABOLISM—3 cr. (3 and 0)
Ch 826—CHEMISTRY OF ENZYMES—3 cr. (3 and 0)
Ch 829—CHEMISTRY AND METABOLISM OF THE CARBOHYDRATES —2 cr. (2 and 0)
Dy Sc 805—NEWER KNOWLEDGE OF DAIRY NUTRITION—3 cr. (3 and 0)
Topics of interest to graduate students in various fields of nutrition. This course is designed to give experience in nutrition not covered by other courses or by thesis research. Credit varies with problems selected.

Nutr 808—MONOGASTRIC NUTRITION—3 cr. (3 and 0)

Basic concepts and current research related to nutrient requirement and metabolism of poultry, swine, and other monogastric species.

Nutr 809—POLYGASTRIC NUTRITION—3 cr. (3 and 0)

Microbiological, biochemical and physiological processes of digestion with special attention to synthesis of amino acids and proteins, B-vitamins, and the relation of such processes to digestion of proteins, lipids and fibrous and non-fibrous feed ingredients. Properties and functions of nutrients for dairy and beef cattle, sheep, and horses. Nonprotein nitrogen compounds and growth-promoting substances are emphasized.

Nutr 812—METABOLISM OF NUTRIENTS—3 cr. (3 and 0)

The metabolism of nutrients as applicable to mammals and birds is discussed. The role of nutrients in metabolic pathways and the effects of deficiencies upon these pathways are included. The role of nutrition in metabolic diseases are emphasized. Prerequisite: General biochemistry and nutrition.

Nutr 813—NUTRITION TECHNIQUES WITH LARGE ANIMALS—2 cr. (1 and 3)

In vivo and in vitro methods for evaluating nutrient utilization in beef and dairy cattle, sheep, swine, and horses.

Nutr 814—NUTRITION TECHNIQUES WITH LABORATORY ANIMALS—2 cr. (1 and 3)

Nutritional techniques employing small laboratory animals. Metabolism and nutrient deficiencies are studied. To be taken concurrently with Nutr 812 or later.

Nutr 816—AMINO ACIDS AND PROTEIN NUTRITION—2 cr. (2 and 0)

Nutrition of the amino acids, nonprotein nitrogen, and proteins as related to humans and domestic animals. Essentiality, interrelationships, and metabolism of amino acids are emphasized.

Nutr 818—VITAMINS AND MINERALS—4 cr. (3 and 3)

Dietary vitamins and mineral requirements of humans and domestic
animals. Laboratory materials include development of nutritional imbal-
ances and chemical and biological assays of nutrients. **Prerequisite:** Gen-
eral biochemistry and nutrition.

**Nutr 851—NUTRITION SEMINAR I—1 cr. (1 and 0) F**

Major topics will be current research and developments in nutrition. Both student research and nutrition literature will be discussed. Topics are selected by the instructor and students. Some discussion of the history and men of nutrition will also be included.

**Nutr 852—NUTRITION SEMINAR II—1 cr. (1 and 0) S**

**Nutr 891—RESEARCH—Credit to be arranged. (May be taken more than one semester). FS, SS**

**Nutr 991—DOCTORAL RESEARCH—Credit to be arranged. (May be taken more than one semester). FS, SS**

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**PLANT PATHOLOGY**

**W. M. Epps, Department Head**

**Master of Science, Master of Agriculture, and Doctor of Philosophy degrees are offered.**

Students who desire to pursue graduate work in Plant Pathology should have sound undergraduate training in the biological and physical sciences, especially botany and chemistry. This training may be obtained in an undergraduate curriculum in botany, microbiology, biology, chemistry, or one of the agricultural plant sciences such as agronomy, forestry, or horti-
culture. Undergraduate courses in plant pathology are desirable but not essential.

**Pl Pa 601—PLANT PATHOLOGY—3 cr. (2 and 3) FS**

**Pl Pa 605—FOREST PATHOLOGY—3 cr. (2 and 3) F**

**Pl Pa 651—BACTERIAL PLANT PATHOGENS—3 cr. (2 and 3) S, odd numbered years.**

**Pl Pa 656—PLANT ViroLOGY—3 cr. (3 and 0) S, even numbered years.**

**Pl Pa 658—PLANT PARASITIC NEMATODES—3 cr. (2 and 3) F, odd numbered years.**

**Pl Pa 800—ADVANCED PLANT PATHOLOGY I—3 cr. (3 and 0) F, odd numbered years.**

The economic and social importance and history of Plant Pathology. The reproduction, genetics and variability of the major groups of plant
pathogens. The infection process, the response of the host to infection, and the effects of the environment on disease development. **Prerequisite:** Pl Pa 601 or 605.

**Pl Pa 801—ADVANCED PLANT PATHOLOGY II**—3 cr. (3 and 0) S, even numbered years.

The epidemiology and control of plant diseases, including a practical and theoretical coverage of chemical, physical, and biological means of plant disease control. **Prerequisites:** Pl Pa 601 or 605; Organic Chemistry.

**Pl Pa 804—PHYSIOLOGICAL PLANT PATHOLOGY**—3 cr. (3 and 0) F, even numbered years.

This course is designed to acquaint the student with the interaction of pathogen and host in the development of plant diseases. Emphasis will be given to the factors that influence infection and the development of the pathogen within the host. **Prerequisites:** Bot 652; Pl Pa 701 or 705; organic chemistry.

**Pl Pa 805—SPECIAL PROBLEMS IN PLANT PATHOLOGY**—Credits to be arranged. FS, SS

Original investigation of special problems in plant pathology which are not related to a thesis but designed to provide experience and training in research. **Prerequisite:** Permission of instructor.

**Pl Pa 807—SEMINAR**—1 cr. (1 and 0) FS

A study of areas of plant pathology and plant physiology not covered by formal courses, with special emphasis on the review of literature, and organization and presentation of material by students.

**Pl Pa 808—TECHNIQUES AND METHODS IN PLANT PATHOLOGY I**—1 cr. (0 and 3) F, odd numbered years.

An introduction to the techniques and methods used in research in Plant Pathology. **Prerequisites:** Pl Pa 601 or 605 or concurrent registration in Pl Pa 601 or 605.

**Pl Pa 809—TECHNIQUES AND METHODS IN PLANT PATHOLOGY II**—1 cr. (0 and 3) S, even numbered years.

A continuation of Pl Pa 808 with emphasis on more advanced methods and techniques. **Prerequisites:** Organic Chemistry; Pl Pa 601 or 605; Pl Pa 808 or permission of instructor.

**Pl Pa 811—PLANT DISEASE DIAGNOSIS I**—1 cr. (0 and 3) SS, odd numbered years.

A comprehensive study of procedures used in the diagnosis of plant diseases, followed by practice in the diagnosis of all types of diseases of cultivated and wild plants. Emphasis on diseases of spring and early summer. **Prerequisites:** Pl Pa 601 or 605; Micr 301 or permission of instructor.
Pl Pa 812—PLANT DISEASE DIAGNOSIS II—1 cr. (0 and 3) SS, even numbered years.

A comprehensive study of procedures used in the diagnosis of plant diseases followed by practice in the diagnosis of all types of diseases of cultivated and wild plants. Emphasis on diseases of mid-summer.

Pl Pa 891—RESEARCH—Credit to be arranged.

Pl Pa 991—DOCTORAL RESEARCH—Credit to be arranged.

PLANT PHYSIOLOGY
W. M. Epps, Chairman
U. S. Jones, Agronomy and Soils
C. J. Umphlett, Botany
T. L. Senn, Horticulture

The Doctor of Philosophy degree is offered.

Graduate work in Plant Physiology encompasses the Department of Botany in the College of Physical, Mathematical, and Biological Sciences and the Departments of Agronomy and Soils, Horticulture, and Plant Pathology and Physiology in the College of Agricultural Sciences. A student may select courses and his major area of study in any of the above departments.

POULTRY SCIENCE
B. D. Barnett, Department Head

The Poultry Science Department offers the Master of Science and Master of Agriculture degrees.

The Doctor of Philosophy degree is offered in Animal Physiology and in Nutrition on an interdepartmental basis.

The Master of Science degree is offered with emphasis in nutrition, physiology, pathology, products technology or management. The student should have a sound background in biology. Agricultural training is helpful but not essential.

Strong research programs in the areas mentioned above provide students with a wide selection of thesis problems.

Students choosing to emphasize products technology will work in a cooperative program with the Department of Food Science and Biochemistry.

Courses are selected from the following and from supporting areas deemed proper by the advisory committee.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS 601</td>
<td>ANIMAL ENVIRONMENTAL TECHNOLOGY</td>
<td>2 cr. (2 and 0)</td>
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</tr>
<tr>
<td>PS 603</td>
<td>ANIMAL ENVIRONMENTAL TECHNOLOGY LAB</td>
<td>1 cr. (0 and 3)</td>
<td></td>
</tr>
<tr>
<td>PS 651</td>
<td>POULTRY NUTRITION</td>
<td>3 cr. (2 and 3)</td>
<td></td>
</tr>
<tr>
<td>PS 654</td>
<td>POULTRY BREEDING</td>
<td>3 cr. (2 and 3)</td>
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</tr>
<tr>
<td>PS 655</td>
<td>POULTRY PRODUCTS GRADING AND TECHNOLOGY</td>
<td>3 cr. (2 and 3)</td>
<td></td>
</tr>
<tr>
<td>PS 656</td>
<td>INCUBATION AND BROODING</td>
<td>2 cr. (2 and 0)</td>
<td></td>
</tr>
<tr>
<td>PS 657</td>
<td>INCUBATION AND BROODING LAB</td>
<td>1 cr. (0 and 3)</td>
<td></td>
</tr>
<tr>
<td>PS 658</td>
<td>AVIAN MICROBIOLOGY AND PARASITOLOGY</td>
<td>4 cr. (3 and 3)</td>
<td></td>
</tr>
<tr>
<td>PS 660</td>
<td>SEMINAR</td>
<td>2 cr. (2 and 0)</td>
<td></td>
</tr>
<tr>
<td>PS 804</td>
<td>POULTRY PATHOLOGY</td>
<td>3 cr. (1 and 6) S</td>
<td>PS 458 or permission of instructor</td>
</tr>
<tr>
<td>PS 805</td>
<td>SEMINAR</td>
<td>1 cr. (1 and 0) F</td>
<td></td>
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</tbody>
</table>

**WILDLIFE BIOLOGY**

S. B. Hays, Department Head

The Master of Science degree is offered.

Students desiring to pursue graduate work in Wildlife Biology should have sound undergraduate training in the biological or related sciences. Programs of study are designed to emphasize the relationship between wild animals and their changing environments. Additional course work for a major in Wildlife Biology is usually taken in Experimental Statistics, Botany, Zoology or other related areas.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB 612</td>
<td>WILDLIFE MANAGEMENT</td>
<td>3 cr. (2 and 3) FS</td>
<td></td>
</tr>
<tr>
<td>WB 809</td>
<td>WILDLIFE BIOLOGY SEMINAR</td>
<td>1 cr. (1 and 0) F</td>
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</tr>
</tbody>
</table>

A review of the current literature regarding the problems encountered in applied wildlife biology.
WB 810—WILDLIFE BIOLOGY SEMINAR—II—1 cr. (1 and 0) S
Continuation of WB 809.

WB 815—PRINCIPLES OF WILDLIFE BIOLOGY—3 cr. (2 and 3) S '69
and alternate years.

Theories and principles applicable to wildlife biology. Emphasis will be
placed on upland game species. **Prerequisite:** Permission of instructor.

WB 816—APPLIED WILDLIFE BIOLOGY—3 cr. (2 and 3) F '71 and alter-
nate years.

Techniques and practices involved in the management of wildlife spe-
cies with special reference to upland game. **Prerequisite:** Permission of
instructor.

WB 863—SPECIAL PROBLEMS IN WILDLIFE BIOLOGY—1 to 6 cr.

WB 891—RESEARCH—Credit to be arranged.
College of Architecture

H. E. McClure, Dean

The College of Architecture offers professional education of quality for the preparation of architects, city and regional planners, building contractors, and environmental designers trained to meet the challenges of our complex technological and urbanized world. Graduate programs leading to the degrees Master of Architecture, Master of City and Regional Planning, and Master of Fine Arts are available.

A. ARCHITECTURE

Admission to the graduate program in architecture is available on a competitive basis to qualified students for the fifth year level who have received a pre-professional degree with a major in architecture from an accredited school of architecture, and for the sixth year level who have received the first professional degree (B.Arch. or equivalent) and on the basis of the following criteria:

(1) Satisfactory undergraduate record, and evidence of quality in the last 60 semester hours of work.

(2) Personal interview with the Dean and examination of student portfolio.

(3) Evidence of professional motivation and creativity necessary for graduate concentration in design, building technology, public health facilities, or architectural history.

(4) Four letters of recommendation from:
   (a) dean of undergraduate school
   (b) an undergraduate teacher
   (c) an employer
   (d) a personal reference

(5) Satisfactory scores in the Graduate Record Examination are required before the student can be fully accepted.
as a candidate. Unusually qualified students may be accepted as provisional graduate students provided they complete the Graduate Record Examination during their first term of residence.

B. CITY AND REGIONAL PLANNING

Qualified students with undergraduate degrees in architecture, civil engineering, economics, political science, law, sociology, or other relevant fields may be admitted to the professional graduate program in City and Regional Planning. Selection is on a competitive basis after careful consideration of the following criteria:

(1) Evidence of aptitude and motivation for creative problem solving so necessary for a career in planning.

(2) Satisfactory undergraduate record indicating progressive development and strength in the student’s area of special concentration.

(3) Four letters of recommendation from:
   (a) dean of undergraduate school
   (b) a key teacher in the student’s undergraduate major
   (c) an employer
   (d) a personal character reference

(4) Satisfactory scores in the Graduate Record Examination must be indicated before the candidate may be accepted to the graduate curriculum without reservation.

C. VISUAL STUDIES

The graduate program in visual studies leading to the Master of Fine Arts degree admits a limited number of talented and creative professional candidates on a competitive basis from undergraduate fine arts programs in a visual arts area (B.F.A.) or with liberal arts or science degrees and an undergraduate major in architecture or fine arts. Especially well qualified
persons may be accepted from other degree backgrounds. The following criteria will be considered:

(1) Satisfactory undergraduate record.

(2) A review of creative work accomplished by the candidate in one or more of the following:

- painting
- sculpture
- printmaking
- graphics
- drawing
- photography
- multimedia

(3) Four letters of recommendation from:
   (a) two from former major professors
   (b) one from a producing artist
   (c) one personal character reference

(4) An interview with the Dean of Architecture and Head of the Department of Visual Studies.

ARCHITECTURE

H. E. McClure, Dean

Arch 611—DIRECTED RESEARCH IN ART HISTORY—3 cr.

Arch 612—DIRECTED RESEARCH IN ART HISTORY—3 cr.

Arch 815—HISTORY SEMINAR I—3 cr.

   Seminar in the history of architecture covering detailed studies of some particular aspect or period. **Prerequisite:** Permission of the instructor.

Arch 816—HISTORY SEMINAR II—3 cr.

   Seminar in the history of architecture covering detailed studies of some particular aspect or period. **Prerequisite:** Permission of the instructor.

Arch 853—GRADUATE DESIGN—8 cr.

   City Planning design and the development of complex building structures.

Arch 854—GRADUATE DESIGN—8 cr.

   Architectural and planning research and the design of complex buildings and urban groupings. **Prerequisite:** Arch 853.
Arch 855—THESIS RESEARCH—2 cr.
Systematic pre-thesis research and study by each student, working independently with tutorial assistance, to develop a graduate thesis program. **Prerequisite:** Arch 854.

Arch 857—GRADUATE DESIGN—10 cr.
Urban design problems, a portion of which will be undertaken as group effort and in individual problems. **Prerequisite:** Arch 854.

Arch 858—ARCHITECTURAL THESIS—17 cr.
Each student will select an individual thesis problem of appropriate scope, conducting his own comprehensive research. Under approved circumstances, the thesis may be a team effort. The solution will be presented in oral, written and visual form. **Prerequisite:** Arch 854.

Arch 861—ECONOMIC SEMINAR—3 cr.
Studies in urban and building economics.

Arch 872—ARCHITECTURAL THESIS—9 cr.
Each student will select an individual thesis problem of appropriate scope, conducting his own comprehensive research. Under approved circumstances, the thesis may be a team effort. The solution will be presented in oral, written and visual form. **Prerequisite:** Arch 854, Arch 855 and a Bachelor of Architecture Degree.

Arch 875—MECHANICAL PLANT—2 cr.
A study of the water supply, plumbing, heating and ventilating systems of present-day buildings.

Arch 876—MECHANICAL PLANT—2 cr.
A study of air-conditioning, electrical systems, lighting, mechanical transportation and acoustics as applied to contemporary buildings. **Prerequisite:** Arch 875.

Arch 881—ARCHITECTURAL OFFICE PRACTICE—2 cr.
General consideration of architectural office procedure. Study of the professional relationship of the architect to client and contractor, including problems in ethics, law, and business.

Arch 882—ARCHITECTURAL OFFICE PRACTICE—2 cr.
A continuation of Arch 881. **Prerequisite:** Arch 881.

Arch 890—DIRECTED STUDIES—1-5 cr.
Comprehensive studies and research of special topics not covered in other courses. Emphasis will be placed on field studies, research activities, and current developments in architecture and planning. **Prerequisite:** Permission of faculty advisor.
Arch 891—ARCHITECTURAL STRUCTURAL SEMINAR—2 cr.
   The application of structural theory to the development of building systems.

Arch 892—ARCHITECTURAL STRUCTURAL SEMINAR—2 cr.
   Analysis of architectural structures with special emphasis on shells and space frames. **Prerequisite:** Arch 891.

Arch 893—ARCHITECTURAL STRUCTURAL SEMINAR—2 cr.
   The analysis of advanced structural problems as related to concurrent graduate design problems. **Prerequisite:** Arch 892.

**CITY AND REGIONAL PLANNING**

H. E. McClure, Dean

CRP 611—INTRODUCTION TO CITY AND REGIONAL PLANNING—3 cr.
CRP 612—CITY AND REGIONAL PLANNING THEORY—3 cr.
CRP 621—URBAN SOCIAL STRUCTURE—3 cr.
CRP 641—HISTORY OF PLANNING—3 cr.
CRP 653—INTRODUCTION TO PLANNING STUDIO—5 cr.
CRP 654—PLANNING STUDIO II—5 cr.
CRP 672—PLANNING ADMINISTRATION AND PRACTICE—3 cr.
CRP 673—GOVERNMENT AND PLANNING LAW—3 cr.
CRP 683—SEMINAR ON PLANNING COMMUNICATION—3 cr.
CRP 822—URBAN SYSTEMS—3 cr.
   An analysis of the past and present urban, social, economic, and political system and their future applications.
CRP 831—ECONOMICS OF LAND USE PLANNING—3 cr.
   A study of cost factors relating to the development and redevelopment of land.
CRP 863—PLANNING STUDIO III—5 cr.
   Design of residential configuration with detailed consideration of vertical and horizontal street alignment; cut and fill, calculation of sewer sizes and cost; design and cost estimates for sidewalks, storm sewers, and street pavement; design of lot layout, commercial and public installations, etc.
CRP 864—PLANNING THESIS—9 cr.
   The student, working individually, will carefully program a planning
problem of appropriate scope and conduct his own comprehensive re-
search. He will make a complete oral, written, and, where appropriate,
a visual presentation of his thesis.

CRP 881—SEMINAR IN QUANTITATIVE METHODS I—3 cr.
An examination of the portentials and limitations of data, statistical
methods, operations research, electronic data processing and other methods
used in City and Regional Planning. Techniques and methods of inter-
pretation will be introduced through lectures, visiting speakers, student re-
ports and field trips.

CRP 882—SEMINAR IN QUANTITATIVE METHODS II—3 cr.
A continuation of CRP 881.

CRP 884—PUBLIC FACILITY PLANNING—3 cr.
An examination of the problems inherent in the planning and design
of public facilities such as community water and sanitation systems.

CRP 893 & 894—CITY AND REGIONAL PLANNING INTERNSHIP—6 cr.
Three months professional employment under competent supervision
in an approved planning office or agency. During the internship the stu-
dent will submit monthly reports covering his experience. Prerequisite:
Two semesters of City and Regional Planning or its equivalent.

VISUAL STUDIES
R. H. Hunter, Department Head

Vis 850—VISUAL ARTS STUDIO—3 cr. (0 and 9)
Concentrated and advanced work in drawing or painting or printmaking
of sculpture or photography or graphics or cinematography or multi
media. Prerequisite: 10 cr. in Vis 300 and 400 series or permission of
instructor.

Vis 851—VISUAL ARTS STUDIO—3 cr. (0 and 9)
Continuation of Vis 850. Prerequisite: Vis 850.

Vis 870—VISUAL ARTS STUDIO—6 cr. (1 and 15)
Advanced theory, directed research in art criticism, applied work in
painting or sculpture or photography or multi media. MFA majors only.

Vis 871—VISUAL ARTS STUDIO—6 cr. (1 and 15)
Continuation of Vis 870. Prerequisite: Vis 870.

Vis 880—VISUAL ARTS STUDIO—15 cr. (3 and 36)
Continuation of Vis 871. Prerequisite: Vis 871.

Vis 881—VISUAL ARTS THESIS—15 cr. (3 and 36)
Prerequisite: Vis 880.
The College of Education offers a professional program leading to the degrees Master of Education, Master of Agricultural Education, and Master of Industrial Education.

The graduate program is designed to provide a combination of professional and major field content to prepare students to intellectually and efficiently perform the duties required in the areas of concentration, encourage students to continue to develop in their professional fields, and enable them to meet the standards recommended by agencies in specific programs.

Individuals involved in elementary and secondary education (including industrial and agricultural education), educational media, higher education, agricultural extension, and other agricultural business and industry are being served.

**PROGRAM OF STUDY**

A minimum of thirty semester hours, at least fifteen of which are numbered 700 or above,* are required for all programs. In addition to such supplementary or supporting courses as may be required, by individual departments, course work and other requirements for degrees in the College of Education are as follows:

**Master of Agricultural Education**

Candidates are required to complete:

1. Twenty-one semester hours in the student’s major field including a course in statistics and a course in research methods.

2. A minimum of nine semester hours in an area of concentration outside the major field.

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*Applies to courses taken after August 15, 1970. Courses taken prior to that date must be numbered 800 or above to satisfy this requirement.
Master of Education

A major in Secondary Education is offered to high school or junior college teachers in the subject areas of English, history and government, mathematics, biological and the physical sciences. Candidates are required to complete:

1. At least six and not more than twelve hours in education.

2. A minimum of eighteen hours in the area of specialization.

A major in Personnel Services is offered to teachers who have a valid teacher's certificate on the level in which the specialization is sought. Those interested in the junior college or post-high school technical institute where a certificate is not usually required must have appropriate experience and/or training. The areas of specialization include Guidance Counselor (Elementary School), Guidance Counselor (Secondary School), Vocational Counselor, or Junior College Counselor. Candidates are required to complete:

1. A minimum of twenty-one hours in the area of specialization.

2. Three to six hours in field training at the level of specialization.

3. Three to six hours in statistics, research techniques or in a field related to the area of specialization.

A major in educational Administration and Supervision is offered to reading specialists, consultants and/or supervisors. The thirty semester hours are prescribed by the Department of Elementary and Secondary Education.

A major in educational Administration and Supervision is offered to experienced teachers who wish to prepare as elementary school administrators, elementary school supervisors, secondary school administrators, or secondary school supervisors. Courses may be selected from four areas as prescribed by the Department of Elementary and Secondary Education.

Master of Industrial Education

Candidates are required to complete:

1. Eighteen hours in subjects which contribute to the student's technical, administrative and/or supervisory competence.
2. Six hours in research methods including a research problem.
3. Six hours must be taken outside the major department.

AGRICULTURAL EDUCATION

E. T. Carpenter, Department Head

The Master of Agricultural Education degree is offered.

The Master of Agricultural Education is designed for persons desiring to increase their competence in providing professional educational services in agriculture. The program is quite flexible permitting specialization in areas of particular interest. Recipients of the degree often return to their former positions as agriculture teachers in high schools, vocational schools, technical education centers and junior colleges. They are also in demand for administrative, supervisory and specialized positions in these institutions. Agricultural extension workers and many others who have educational responsibilities in the agribusiness complex will also find this program to be a valuable step in their professional development.

Ag Ed 601—METHODS IN AGRICULTURAL EDUCATION—3 cr. (2 and 3)
Ag Ed 663—ADVANCED CONSERVATION EDUCATION—3 cr. (3 and 0)
Ag Ed 665—PROGRAM PLANNING IN AGRICULTURAL EDUCATION—3 cr. (3 and 0)
Ag Ed 667—ADULT EDUCATION IN AGRICULTURE—3 cr. (2 and 3)
Ag Ed 803—EVALUATION IN AGRICULTURAL EDUCATION—3 cr. (2 and 3)

Application of principles in evaluation to agricultural education. Major emphasis on development and use of instruments for appraising educational outcomes. Prerequisite: Experience in agricultural education.

Ag Ed 804—SPECIAL PROBLEMS—3 cr. (2 and 3)

Planning, conducting and reporting a special problem in agricultural education appropriate to the need of the student.

Ag Ed 805—ADMINISTRATION AND SUPERVISION IN AGRICULTURAL EDUCATION—3 cr. (3 and 0)

Emphasis given to developing a philosophy of education including the application of concepts of administration in supervising programs of agricultural education. Prerequisite: Experience in agricultural education.

Ag Ed 815—ADVANCED METHODS OF TEACHING FARM MECHANICS—3 cr. (2 and 3)

Organization of teaching units, methods of determining the content of the course, securing and equipping the shop, teaching farm mechanics and
other shop problems involved in teaching farm people are considered in this course.

Ag Ed 820—TEACHING YOUNG FARMERS—3 cr. (3 and 0)

Principles and practices appropriate to the solution of problems in developing and conducting instructional programs for young farmers.

Ag Ed 825—SUPERVISION OF STUDENT TEACHING—3 cr. (3 and 0)

Major emphasis is placed upon the following: (1) developing a philosophy of teacher education; (2) analyzing the present teacher training program in South Carolina, to discover problem situations to be used as a basis for teacher-education programs; (3) determining the relative emphasis for each teacher to place upon the solution of the problems in the teacher-education program; (4) projecting plans for an apprentice training program; and (5) supervising apprentice training. Prerequisite: Experience in agricultural education and permission of instructor.

Ag Ed 869—SEMINAR—1-3 cr. (1-3 and 0)

Ag Ed 891—INTRODUCTION TO RESEARCH IN EDUCATION—Credit to be arranged.

EDUCATION

M. A. King, Department Head

J. L. Idol, English Adviser

R. S. Lambert, History and Government Adviser

J. L. Flatt, Mathematics Adviser

J. H. Hobson, Science Adviser

The Department of Elementary and Secondary Education offers the Master of Education degree with subject specialties in English, history and government, mathematics, the natural sciences, or personnel services, reading and school administration and supervision.

Students seeking admission to the M. Ed. program should have:

a. A valid teacher's certificate; or

b. At least twelve hours in professional education.

Ed 601—THE COMMUNITY COLLEGE—3 cr. (3 and 0)

Ed 605—PRINCIPLES OF GUIDANCE—3 cr. (3 and 0)

Ed 606—HISTORY AND PHILOSOPHY OF EDUCATION—3 cr. (3 and 0)
Ed 631—SPECIAL INSTITUTE COURSE: EARLY CHILDHOOD EDUCATION—3 cr. (3 and 0)

Ed 632—SPECIAL INSTITUTE COURSE: ELEMENTARY SCHOOL—3 cr. (3 and 0)

Ed 633—SPECIAL INSTITUTE COURSE: SECONDARY SCHOOL—3 cr. (3 and 0)

Ed 634—SPECIAL INSTITUTE COURSE: CURRENT PROBLEMS IN EDUCATION—3 cr. (3 and 0)

Ed 635—SPECIAL INSTITUTE COURSE: CURRICULUM—3 cr. (3 and 0)

Ed 636—SPECIAL INSTITUTE COURSE: SUPERVISION AND ADMINISTRATION—3 cr. (3 and 0)

Ed 660—CURRICULUM DEVELOPMENT IN THE ELEMENTARY SCHOOL—3 cr. (3 and 0)

Ed 662—READING DIAGNOSIS AND REMEDIATION—3 cr. (2 and 3)

Ed 665—SECONDARY SCHOOL CURRICULUM—3 cr. (3 and 0)

Ed 671—THE EXCEPTIONAL CHILD—3 cr. (3 and 0) F

Ed 672—PSYCHOLOGY OF MENTAL RETARDATION—3 cr. (3 and 0) F

Ed 673—TEACHING THE MENTALLY RETARDED—3 cr. (3 and 0) F

Ed 687—METHODS AND MATERIALS IN SPEECH—3 cr. (3 and 0)

Ed 694—SCHOOL AND COMMUNITY RELATIONSHIPS—3 cr. (3 and 0)

Ed 697—AUDIO VISUAL AIDS IN EDUCATION—3 cr. (3 and 0)

Ed 698—TEACHING SECONDARY SCHOOL READING—3 cr. (3 and 0)

Ed 801—SEMINAR IN HUMAN GROWTH AND DEVELOPMENT—3 cr. (3 and 0) S

Critical analysis of theory and research in human development. Prerequisite: Six semester hours of psychology and/or Educational Psychology.

Ed 802—HUMAN DEVELOPMENT: PSYCHOLOGY OF LEARNING—3 cr. (3 and 0)

Analysis of the major theories of the learning processes applied to human education. Each student must conduct an experiment in learning theory. Prerequisite: Six semester hours of psychology and/or educational psychology.

Ed 803—ADVANCED METHODS OF TEACHING IN THE SECONDARY SCHOOL—3 cr. (3 and 0)

The principles and practices involved in promoting effective learning in secondary schools.
Ed 804—ADVANCED METHODS OF TEACHING IN THE ELEMENTARY SCHOOL—3 cr. (3 and 0)
Principles and practices involved in promoting effective learning in the elementary school; analysis and evaluation of educational media.

Ed 808—EDUCATIONAL TESTS AND MEASUREMENT—3 cr. (3 and 0) S
Construction, use, and interpretation of tests, subjective and standardized. Familiarizing with measurement applications.

Ed 809—ANALYSIS OF THE INDIVIDUAL—3 cr. (3 and 0)
Experience in gathering, interpreting and utilizing data as it relates to the individual. Especially significant to Counselors.

Ed 810—TECHNIQUES OF COUNSELING—3 cr. (3 and 0)
A study and use of counseling techniques (such as interviewing, testing, use of cumulative files, etc.). Prerequisite: Ed 605

**Ed 811—SCHOOL FINANCE—3 cr. (3 and 0)
A study of school finance relative to programs, revenues, and experience.

Ed 813—EDUCATIONAL AND VOCATIONAL INFORMATIONAL SERVICE AND PLACEMENT—3 cr. (3 and 0)
Gathering, interpreting and utilizing educational, social, and occupational information. Techniques used in placement, survey, and follow-up.

Ed 814—FIELD EXPERIENCES IN ELEMENTARY SCHOOL GUIDANCE—3 cr. (2 and 3)
Practicum designed to give experience in developing, evaluating, and reporting on a project appropriate to the particular field of interest. Open only to those seeking certification on the elementary school level. Permission of the instructor is required.

Ed 815—FIELD EXPERIENCES IN SECONDARY SCHOOL GUIDANCE—3 cr. (2 and 3)
Practicum designed to give experience in developing, evaluating, and reporting on a project appropriate to the particular field of interest. Open only to those seeking certification on the secondary school level. Permission of instructor is required.

Ed 816—FIELD EXPERIENCES IN PERSONNEL SERVICES IN HIGHER EDUCATION—3 cr. (2 and 3)
Practicum designed to give experience in developing, evaluating, and reporting on a project appropriate to the particular field of interest. Open only to those entering the field of Higher Education. Permission of instructor is required.
Ed 817—CLINICAL STUDIES IN COUNSELING AND GUIDANCE—
1 to 3 cr.
Intensive case studies of those with psychological and educational difficulties. May be taken more than one semester.

Ed 818—FIELD PROBLEMS IN SCHOOL ADMINISTRATION AND SUPERVISION—3 cr (2 and 3)
Application of research techniques and practices in the solution of field problems in school administration and supervision.

Ed 830—TECHNIQUES OF SUPERVISION—THE PUBLIC SCHOOLS—
3 cr. (3 and 0)
Designed for teachers, supervisors, and administrators who are interested in improving, coordinating and evaluation instruction. Modern trends of supervisory practices are emphasized.

Ed 831—EVALUATION OF SECONDARY SCHOOL INSTRUCTION—3 cr. (3 and 0)
A study of the techniques of determining the effectiveness of classroom instruction, with emphasis on curriculum.

Ed 832—EVALUATION OF INSTRUCTION IN THE ELEMENTARY SCHOOL—3 cr. (3 and 0)
A study of the devices for determining the effectiveness of instructional techniques and programs in terms of predetermined objectives.

Ed 840—RESEARCH UTILIZATION—3 cr. (3 and 0)
A course designed to acquaint users of research—administrators and practitioners in education—with the developing systems of research information, eg., the ERIC system. Techniques for bringing research information to bear on educational problems will be emphasized.

Ed 851—ORGANIZATION AND ADMINISTRATION OF THE ELEMENTARY SCHOOL—3 cr. (3 and 0)
Leadership roles, self-images, and administrative behavior; organizational principles, patterns and trends in the elementary schools; planning, developing, and assessing the elementary programs; building and grounds management; office and business management; student activities; staff selection and development.

Ed 852—ORGANIZATION AND ADMINISTRATION OF THE SECONDARY SCHOOL—3 cr. (3 and 0)
Leadership roles, self-images, and administrative behavior; organizational principles, patterns and trends in the secondary schools; planning, developing and assessing the secondary school program; building and ground management; office management; student activities; scheduling staff selection and development.
Ed 861—ORGANIZATION AND SUPERVISION OF READING—3 cr.  
(3 and 0) F  
Detailed study of supervisory problems concerned with the planning of reading programs, analysis of methods and materials of teaching, and evaluation of reading programs.

Ed 862—CLINICAL RESEARCH IN READING—3 cr. (3 and 0)  
Intensive analysis of reading research and literature; original investigation in such problems as development of reading skills and attitudes, clinical procedures and techniques.

Ed 863—PRACTICUM IN READING—3 cr. (2 and 2)  
Supervised practicum emphasizing diagnostic and remedial work with readers in the public schools. Permission of instructor is required.

Ed 871—INTERPERSONAL AND GROUP RELATIONSHIPS—3 cr.  
(3 and 0)  
Study of human relations, staff interaction, informal and small group processes, supervisor-teacher counseling, conducting group meetings, staff participation in decision-making, creating a climate conducive to change and success, human motivation.

Ed 881—INDIVIDUAL TESTING I—3 cr. (3 and 0)  
Interpretation of the Wechsler Scales with supervised practice in their administration. Prerequisites: Ed 801, 802, 808, 809 and permission of the instructor.

Ed 882—INDIVIDUAL TESTING II—3 cr. (3 and 0)  
Interpretation of the Stanford-Binet scales with supervised practice in their administration. Prerequisites: Ed 801, 802, 808, 809 and permission or instructor.

Ed 890—INTRODUCTION TO RESEARCH IN EDUCATION— 3 cr.  
(3 and 0)  
A study of historical, descriptive, and experimental research methodology; tools of research; use of reference materials; interpretation and analysis of data; techniques of writing research reports; evaluation of source materials.

The following courses are applicable only to the Master of Education degree in Natural Sciences.
Biol 650—BIOLOGY FOR HIGH SCHOOL TEACHERS—3 cr. (3 and 0)

Biol 800—PRINCIPLES OF BIOLOGY—3 cr. (2 and 3)  
Expressly designed for high school teachers. Lectures, demonstrations, and practical laboratory exercises are presented on an advanced level. Particular attention is given to the Vertebrata and the higher plant Phyla.
Ch 650—REVIEW OF GENERAL CHEMISTRY I—3 cr. (3 and 0)

Ch 800T—PHYSICAL SCIENCE FOR THE HIGH SCHOOL TEACHER—
3 cr. (3 and 0)

Ch 850—REVIEW OF GENERAL CHEMISTRY II—3 cr. (2 and 3)

Geol 800—EARTH SCIENCE I—3 cr. (2 and 3)
A study of the physics and chemistry of the earth and earth processes. The petrochemical cycle forms the nucleus about which the course is built. Theoretical considerations of the association of minerals and rocks which compose the earth’s crust, their origins and transformations are emphasized, along with geological processes by which changes are produced on or in the earth. Common minerals and rocks are studied in the laboratory, and geomorphic features are interpreted in terms of geological processes from topographic maps and during field trips.

Geol 850—EARTH SCIENCE II—3 cr. (2 and 3)
A study of the earth, its origin and subsequent developments. The evolution of continents and ocean basins as well as the beginnings and development of life on earth in all its forms are considered. Laboratory instruction in the recognition of plants and animals which have left their record as fossils in the rocks of the earth’s crust is planned. Emphasis in the laboratory is also placed upon geologic structures and the interpretation of geologic maps, and these principles demonstrated through numerous field excursions.

Phys 605—PHYSICS FOR HIGH SCHOOL TEACHERS I—4 cr. (3 and 1)

Phys 606—PHYSICS FOR HIGH SCHOOL TEACHERS II—4 cr. (3 and 1)

Phys 803—MODERN PHYSICS FOR HIGH SCHOOL TEACHERS—3 cr. (3 and 0)

Courses applicable to the Master of Education degree in English, history, and mathematics are found under the respective departmental headings.

INDUSTRIAL EDUCATION

A. F. Newton, Department Head

InEd 605—COURSE ORGANIZATION AND EVALUATION—3 cr. (3 and 0)

InEd 608—TRAINING PROGRAMS IN INDUSTRY—3 cr. (3 and 0)

InEd 616—DESIGN AND OPERATION OF INDUSTRIAL EDUCATION LABORATORIES—3 cr (2 and 3) FS

InEd 622—HISTORY AND PHILOSOPHY OF INDUSTRIAL AND VOCATIONAL EDUCATION—3 cr. (3 and 0)
InEd 625—TEACHING INDUSTRIAL SUBJECTS—2 cr. (3 and 0) FS
InEd 632—ADVANCED WOODWORKING—2 cr. (1 and 3) SS
InEd 635—ADVANCED WELDING—2 cr. (1 and 3) SS
InEd 636—ADVANCED MATERIAL FORMING—2 cr. (1 and 3) SS
InEd 638—ADVANCED MACHINING—2 cr. (1 and 3) SS
InEd 640—ADVANCED TECHNIQUES OF THE GRAPHIC ARTS—3 cr. (1 and 6)
InEd 641—COMPREHENSIVE GENERAL SHOP PRACTICES—2 cr. (2 and 0) F, SS
InEd 644—GRAPHIC ARTS PRODUCTION CONTROL—3 cr. (2 and 3)
InEd 652—ADVANCED PROJECTS—1-6 cr.
InEd 696—PUBLIC RELATIONS—3 cr. (3 and 0)
InEd 815—SEMINAR—1 cr. (1 and 0) SS
  A joint study and discussion by graduate students and members of the faculty of new technological and professional advances.
InEd 820—RECENT PROCESS DEVELOPMENTS—3 cr. (3 and 0) S, SS
  Consideration of new developments in production processes including ultrasonic and electrical discharge machining, high energy rate forming, precision casting methods, and recent joining techniques.
InEd 840—SCHOOL SHOP DESIGN—3 cr. (3 and 0) SS
  This course is designed to cover all aspects of unit shops, general shops, and comprehensive shops for schools giving vocational industrial subjects and industrial arts courses.
InEd 845—CURRICULUM DEVELOPMENT IN INDUSTRIAL EDUCATION—3 cr. (3 and 0) F, SS
  Major consideration is given to curriculum construction, departmental coordination of subject matter with other school subjects, curriculum modification, and staff organization in curriculum development. Emphasis is given to selection and organization of course materials.
InEd 860—CURRICULUM PLANNING AND DEVELOPMENT IN INDUSTRIAL ARTS—3 cr. (3 and 0) SS
  Philosophical, psychological, and sociological foundations of Industrial Arts education provides the basis on which curriculum planning and development techniques are acquired. An extensive study is made of contemporary and emerging curriculum patterns in Industrial Arts education.
InEd 861—ADMINISTRATION AND SUPERVISION OF VOCATIONAL EDUCATION—3 cr. (3 and 0) SS
A study of the principles and practices of administering and supervising various types of schools and classes under the Federal vocational acts and state regulations.

InEd 865—AMERICAN INDUSTRIES—3 cr. (3 and 0) SS
Major emphasis given to developing an understanding of the concepts and principles of American industry and technology. Fifteen plant visitations will supplement study of industrial organization, economics, management, production, and products. The study of American industry provides a basis for identifying Industrial Arts subject content.

InEd 891—RESEARCH—Credit to be arranged

InEd 895—SPECIAL PROBLEMS I—3 cr. (3 and 0) SS
Directed study of special problems in the field of Industrial Education. Subject matter will vary with interests, experiences, and needs of the student.

InEd 896—SPECIAL PROBLEMS II—3 cr. (3 and 0)
Continuation of InEd 895.
College of Engineering

L. G. Rich, Dean

In addition to the Master of Science and Doctor of Philosophy the College of Engineering offers the Master of Engineering program with work at an advanced level in courses which are professionally oriented.

Admission to this program is open to those applicants who, by virtue of their academic and professional records, have clearly demonstrated that they have the motivation and desire to benefit from an additional year of professional study. An applicant must have a Bachelor's degree from an ECPD accredited undergraduate curriculum and must be accepted by the Head of the Department in which he plans to do his major work.

The requirement for graduation from this program is the satisfactory completion of a minimum of thirty (30) semester hours of approved courses, fifteen (15) semester hours of which must be selected from courses in the student's major area of study. For those programs considered to be interdisciplinary, the approved courses will be identified by the chairman of the program involved as constituting an acceptable major. At least fifteen (15) semester hours must be taken in courses numbered 700 or above.*

The degree awarded upon successful completion of the program is the Master of Engineering degree.

Courses are offered leading to the degree of Master of Engineering in the following fields: Agricultural Engineering, Ceramic Engineering, Civil Engineering, Electrical and Computer Engineering, Environmental Systems Engineering, Mechanical Engineering, and Water Resources Engineering.

AGRICULTURAL ENGINEERING

A. W. Snell, Department Head

The Department of Agricultural Engineering offers the Master of Science, Master of Engineering and Doctor of Philosophy degrees.

The graduate programs in Agricultural Engineering are designed to prepare the individual for leadership, creative accomplishment and continued learning in his profession, and to qualify the student to conduct independent scientific research.

The physical control and modification of natural resources and living systems are required in present and future endeavors for the benefit of *Applies to courses taken after August 15, 1970. Courses taken prior to that date must be numbered 800 or above to satisfy this requirement.
mankind. The analysis of systems for control and modification requires a broad but deep scientific base. In addition to thorough preparation in the physical sciences and mathematics, the Agricultural Engineer must have a basic understanding of the biological sciences.

The M.S. and Ph.D. programs of study are planned for each individual student to augment his previous engineering or science background with adequate breadth in engineering and specialization in a specific area of Agricultural Engineering. Course work, in addition to Agricultural Engineering, consists of mathematics, physics, chemistry, statistics, biological science, and selected engineering sciences.

AgE 616—AGRICULTURAL MACHINERY—3 cr. (2 and 3) S
AgE 622—SOIL AND WATER CONSERVATION ENGINEERING—4 cr.
   (3 and 3) S
AgE 631—AGRICULTURAL STRUCTURAL DESIGN—3 cr. (2 and 3) F
AgE 642—AGRICULTURAL PROCESS ENGINEERING—3 cr. (2 and 3) S
AgE 652—FARM POWER—3 cr. (2 and 3) S
AgE 660—FARM AND HOME UTILITIES—3 cr. (2 and 3) S
AgE 665—ENGINEERING PROPERTIES OF BIOLOGICAL MATERIALS—3 cr. (2 and 3) S
AgE 801—SPECIAL PROBLEMS IN AGRICULTURAL ENGINEERING—3 cr. (2 and 3) S

Each student will select a subject pertaining to his particular interest or major field of study in Agricultural Engineering. Library and/or laboratory research will be conducted and a technical report will be written. The subject may be selected from one of the following: (a) Power and Machinery, (b) Soil and Water Resources, (c) Farm Structures, (d) Electric Power and Processing, (e) Food Engineering, (f) Forest Engineering, or (g) Solid Waste.

AgE 806—INSTRUMENTATION IN AGRICULTURAL AND BIOLOGICAL RESEARCH—3 cr. (2 and 3)

A course designed to acquaint the graduate student in agriculture and the biological sciences with fundamental mathematical and physical principles involved in measuring and recording physical phenomena studied in agricultural research. Methods and instruments used in measuring temperature, humidity, fluid pressure and flow, force, velocity, acceleration, mechanical strain and displacement, color and chemical composition are studied. Transducers and sensing elements, amplifiers, and recording instruments are related to each other through the appropriate electrical circuitry. Not open to engineering students. Prerequisite: general physics.

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AgE 811—TILLAGE AND SOIL DYNAMICS—3 cr. (3 and 0)

Soil physical and dynamic properties are related to the actions of tillage tools, tractive vehicles and plant growth and development. Some major topics dealt with are soil strength parameters, seedling environment and emergence mechanics of tillage implements, soil compaction causes and effects, tractive efforts of wheel and track-type vehicles and off-the-road locomotion. **Prerequisite:** AgE 616 or equivalent.

AgE 822—WATER MOVEMENT IN SOILS—3 cr. (3 and 0) F

A study of theory and principles of water movement in soils. Principal topics include theory and application of flow of water through soil in unsaturated and saturated states, flow nets and seepage forces, and the fundamentals of engineering design with respect to ground water problems and soil moisture relationships. **Prerequisite:** Math 306 or equivalent.

AgE 865—HEAT AND MOISTURE TRANSFER IN BIOLOGICAL MATERIALS—3 cr. (3 and 0) S

A study of heat and moisture diffusion in biological materials. Criteria for selecting the proper operational mathematics to solve certain boundary value problems are presented. The integral transforms of Laplace, Fourier, and Hankel are applied to various geometric configurations. The influence of heat of respiration and moisture of transpiration production are considered. **Prerequisites:** Math 653 or 657, or permission of instructor.

AgE 873—RADIOLOGICAL HEALTH—3 cr. (2 and 3)

Sources of ionizing radiation and radioisotopes in man’s environment will be illustrated, and methods of protection from these sources will be discussed. The engineering aspects of detection, shielding, and disposal of radioactive materials will be studied. **Prerequisite:** Permission of instructor.

AgE 874—RADIOLOGICAL HEALTH ENGINEERING—3 cr. (2 and 3)

This is a continuation of Radiological Health with more detailed study of radiation protection from air, water, food, and solids through engineering procedures. This course is offered primarily for engineering students. **Prerequisite:** AgE 873 or the equivalent.

AgE 882—SYSTEMS ENGINEERING—3 cr. (2 and 3) F

Systems analysis methods applied to the engineering of agricultural operations. Topics include: activity network analysis, the Critical Path Method, PERT, linear programming, simulation, queuing theory, and linear system analysis. Application of analog and digital computation in the analysis of complex systems is stressed.

AgE 891—RESEARCH—Credit to be arranged.

AgE 991—DOCTORAL RESEARCH—Credit to be arranged.
BIOENGINEERING

S. F. Hulbert, Program Coordinator

Courses are offered leading to the Master of Science and Doctor of Philosophy degrees.

The program in bioengineering is structured such that emphasis can be placed in either of two options; 1. studies relating to the fermentation field and the technology associated with artificial environments, or 2. systems, primarily man.

In the first program referred to above, the application of engineering technology to the fermentation processes employed in the production of pharmaceuticals and industrial chemicals is studied. In addition, the technology associated with the design and maintenance of artificial environments for man has become an important part of the program. The establishment and control of such environments require the application of engineering principles to biological systems producing the physiological necessities of man. The educational preparation of the student entering this option must include, in addition to a strong background in the unit operations in process engineering, a firm foundation of principles of chemistry and microbiology. Effective participation in the technology of artificial environments also requires a knowledge of environmental hygiene.

The second program in Bioengineering is concerned with the application of the technology of engineering science to problems in medical research. Mathematical modeling and computer simulation are used to study physiological systems. Biological signal processing, data handling and the design of specialized instrumentation are topics covered. Specific examples drawn from these areas include electrical and mechanical properties of bone, fluid dynamics as applied to cardio-vascular systems, electrical information processing in neuro-muscular systems and man-machine communication. There is a strong emphasis in artificial organ design and evaluation.

Normally students enrolling in the second option will have a strong background in mathematics, computers, and instrumentation. Course work in physiology, anatomy and physical chemistry is frequently part of the requirement for studies in this area.

In general, the bioengineering program is open to students possessing degrees in engineering and to those with degrees in science who have credits for certain prescribed engineering courses.

Candidates for a degree in this field are allowed considerable flexibility in planning their program.

EE 810—ANALYTICAL DESIGN OF LINEAR FEEDBACK CONTROL—3 cr. (3 and 0)
EE 815—RANDOM DATA MEASUREMENTS—3 cr. (3 and 0)
EE 827—INSTRUMENTATION AND MEASUREMENTS—3 cr. (3 and 0)
EE 870—BIOSYSTEMS ANALYSIS—3 cr. (3 and 0)
ME 860—DYNAMIC PROGRAMMING—3 cr. (3 and 0)
Zool 658—CELL PHYSIOLOGY—3 cr. (2 and 3)
Zool 660—GENERAL PHYSIOLOGY—3 cr. (2 and 3)
Zool 661—GENERAL ANATOMY—3 cr. (3 and 0)
Zool 801—ANIMAL HISTOLOGY—3 cr. (2 and 3)
Bioeng 601—COMPUTERS FOR BIOSCIENTISTS—1 cr. (1 and 0)
Bioeng 800—SEMINAR IN BIOMEDICAL ENGINEERING RESEARCH—1 cr. (1 and 0)
Bioeng 801—BIOMATERIALS—3 cr. (3 and 0)
  A study of primary and secondary factors determining the performance of
  artificial organs in terms of materials used and design properties for
  each specific site of implantation. Topics, such as the following, are treat-
  ed: metallurgy of stainless steel, cobalt-chromium alloys, dental amalgams,
  chemistry of medical polymers, physical properties of reinforced
  structures, ceramic-metallic bonding and corrosion in biological media.
Bioeng 810—BIOCHEMICAL ENGINEERING—3 cr. (3 and 0)
  Principles of biochemical reaction systems and their applications in the
  chemical process industries. Enzyme systems, their sources, essential
  characteristics, and employment in commercial chemical production (fer-
  mentation). Certain related topics (i.e., biological waste disposal, protein
  technology, etc.) introduced for illustration. Prerequisite: Ch 423 or an
  equivalent course.
Bioeng 812—BIOELECTROCHEMISTRY—3 cr. (3 and 0)
  The theory and application of the electrochemistry to biological prob-
  lems. Development of the fundamental laws of electrode kinetics and its
  relation with corrosion of prosthetic materials. Electrochemical effects
  in tissue. Application of electrochemistry to bioengineering. Prerequisite:
  Undergraduate Physical Chemistry.
Bioeng 846—ELEMENTS OF BIOENGINEERING I—3 cr. (3 and 0)
  Instrumentation for biological systems; signal conditioning, telemetry,
  impedance measurements, noise. Biological materials and mechanics;
physiology of cells and tissue, physical properties of tissue, mathematical models of muscular action. Nervous system; physiology of central nervous system, information coding, analogs of nerves, EEG, EKG, nerve conduction velocity.

Bioeng 847—ELEMENTS OF BIOENGINEERING II—3 cr. (3 and 0)
Cardiovascular system; physiology of blood, the heart, vascular bed, and organ blood flow. Hemodynamics, properties of blood as a fluid, fluid flow equations, turbulence, pulse propagation. Electrocardiography, pacemakers, blood pressure and flow instrumentation. Respiration; dynamics of breathing, gas exchange, and regulation. Digestive system and temperature regulation.

Bioeng 850—SPECIAL TOPICS IN BIOMEDICAL ENGINEERING—
3 cr. (3 and 0)
Directed study of advanced topics in Biomedical Engineering intended to develop in depth areas of particular student interest. (Credit may be earned for more than one semester.) Prerequisite: Permission of instructor.

Bioeng 860—ECOLOGICAL MODELS—3 cr. (2 and 3)
Systems analysis applied to ecology. Construction of models which predict ecological consequences of abuses to the environment. Frequency response analysis, energy models, information flow, and transfer functions for population interactions. Prerequisites: Bioengineering 601, a course in ecology or directed outside reading.

Bioeng 870—BIOINSTRUMENTATION—3 cr. (2 and 2)
Concepts and techniques of instrumentation in the area of bioengineering with particular emphasis on the effects of instrumentation on the biological system under investigation. Transducers and couplers, data conversion, conditioning and transmission. Experimental problems involved in acute and chronic procedures, with static dynamic subjects.

Bioeng 980—INTERNSHIP—1-5 cr. (0 to 5, 0 to 40)
Observation and assignment in a medical college or dental college, hospital, veterinary clinic, dental clinic, health service, or industrial department. Credits to be arranged. (For Ph.D. students only.) Prerequisite: Four semesters of graduate work in Bioengineering.

Bioeng 891—RESEARCH—Credit to be arranged.
(May be taken more than one semester.)

Bioeng 991—DOCTORAL RESEARCH—Credit to be arranged.
CERAMIC ENGINEERING
G. C. Robinson, Department Head

Courses are offered leading to the degrees Master of Science and Master of Engineering.

CrE 602—SOLID STATE CERAMICS—3 cr. (3 and 0)
CrE 603—GLASSES—3 cr. (3 and 0)
CrE 604—CERAMIC COATINGS—3 cr. (3 and 0)
CrE 610—ANALYTICAL PROCESSES—3 cr. (3 and 0)
CrE 612—RAW MATERIAL PREPARATION—3 cr. (3 and 0)
CrE 616—ELECTRONIC CERAMICS—3 cr. (3 and 0)
CrE 618—PROCESS CONTROL—3 cr. (3 and 0)
CrE 619—SCIENCE OF ENGINEERING MATERIALS—3 cr. (3 and 0)
CrE 620—SCIENCE OF ENGINEERING MATERIALS—3 cr. (3 and 0)
CrE 807—SPECIALIZED CERAMICS—3 cr. (3 and 0)

An advanced study of one of the divisions of ceramics. The student may select either structural products, refractories, whitewares, abrasives, enamels, glass, cements, or raw materials processing.

CrE 809—HIGH-TEMPERATURE MATERIALS—3 cr. (3 and 0)
A study of properties of oxides, carbides, nitrides, borides and silicides; the obtainment and measurement of high-temperatures; the measurement of properties at high temperatures.

CrE 810—CERAMIC ENGINEERING THERMODYNAMICS—3 cr.
(3 and 0)
The application of thermodynamics with special reference to physical and chemical changes in ceramic systems.

CrE 811—CERAMIC ENGINEERING KINETICS—3 cr. (3 and 0)
Theory and measurement of the rates and mechanisms of reactions in ceramic processes.

CrE 812—CURRENT TOPICS IN CERAMIC ENGINEERING—1 cr.
(1 and 0)
A study of the current literature in selected areas of ceramic science and engineering.

CrE 813—NUCLEAR CERAMICS—3 cr. (3 and 0)
A study of the properties, selection, and uses of ceramic materials in nuclear reactors.
CrE 814—CERAMIC PHYSICAL PROCESSING—3 cr. (3 and 0)
A study of the role of physical processing in determining the structure and composition of products.

CrE 815—COLLOIDAL AND SURFACE SCIENCE—3 cr. (3 and 0)
The theory and application of colloidal and surface chemistry to ceramic materials and processes.

CrE 816—CONSTITUTION AND STRUCTURE OF GLASSES—3 cr.
(3 and 0)
A study of modern concepts of glass structure and properties.

CrE 821—ANALYTICAL PROCEDURES AND EQUIPMENT I—3 cr.
(2 and 3)
Theory and application of powder x-ray diffractometry, emission spectroscopy, electron microscopy, and optical microscopy to ceramic problems.

CrE 822—ANALYTICAL PROCEDURES AND EQUIPMENT II—3 cr.
(2 and 3)
A continuation of CrE 821.

CrE 823—THERMAL PROPERTIES OF CERAMIC MATERIALS—3 cr.
(3 and 0)
A study of heat capacity, thermal conductivity, thermal expansion, and thermal shock resistance from a microscopic and macroscopic standpoint.

CrE 824—MECHANICAL PROPERTIES OF CERAMIC MATERIALS—
3 cr. (3 and 0)
Stress-strain-time relations in elasticity, plasticity, and rupture showing effects of high and low temperature and structures.

CrE 825—MAGNETIC AND ELECTRICAL CERAMIC MATERIAL—3 cr.
(3 and 0)
Application of magnetic and electrical theory to ceramic insulators, semiconductors, and ferroelectric and ferromagnetic products.

CrE 826—CERAMIC COATINGS—3 cr. (3 and 0)
A study of glassy and crystalline coatings emphasizing fundamentals of application, adhesion theories, and development of required properties.

CrE 828—SOLID STATE CERAMIC SCIENCE—3 cr. (3 and 0)
A study of bonding and structure of crystalline materials as related to mechanical, thermal, and chemical properties of solids.

CrE 891—RESEARCH—Credit to be arranged.
The Department of Chemical Engineering offers the Master of Science and the Doctor of Philosophy degrees.

Graduate students will be accepted with backgrounds in chemistry, physics, or branches of engineering other than chemical engineering. Special program will be laid out for non-chemical engineering graduates. Minors for doctoral students may be taken in chemistry, physics, mathematics, life science, or other branches of engineering. Teaching in undergraduate courses is considered to be an integral part of doctoral study in chemical engineering and is required of all doctoral students.

ChE 601—TRANSPORT PHENOMENA—3 cr. (3 and 0)
ChE 607—UNIT OPERATIONS LABORATORY II—2 cr. (0 and 6)
ChE 615—INTRODUCTION TO NUCLEAR ENGINEERING I—3 cr (3 and 0)
ChE 616—INTRODUCTION TO NUCLEAR ENGINEERING II—3 cr. (3 and 0)
ChE 630—CHEMICAL ENGINEERING THERMODYNAMICS II—3 cr. (3 and 0)
ChE 650—CHEMICAL ENGINEERING KINETICS—3 cr. (3 and 0)
ChE 652—MOLECULAR AND TURBULENT TRANSPORT—3 cr. (3 and 0)
ChE 802—PROCESS DYNAMICS AND CONTROL—3 cr. (3 and 0)

The utilization of engineering principles in the dynamic analysis and design of chemical processes, processing equipment and plants. The greatest emphasis will be placed on systems dynamics with some consideration of closed loop control and optimization. Prerequisites: ChE 307 and 453 and Math 306 or permission of instructor.

ChE 803—HEAT, MASS, AND MOMENTUM TRANSFER—3 cr. (3 and 0)

An advanced treatment of the fundamental mechanisms of molecular and turbulent transport of heat, mass and momentum.

ChE 804—CHEMICAL ENGINEERING THERMODYNAMICS—3 cr. (3 and 0)

Advanced topics in Chemical Engineering Thermodynamics including equilibria of physical and chemical systems, generalized properties of hydrocarbons and the application of thermodynamic methods in the design of equipment.
ChE 805—CHEMICAL ENGINEERING KINETICS—3 cr. (3 and 0)
An advanced treatment of the kinetics of chemical reactions, particularly in the design and operation of chemical reactors.

ChE 806—CHEMICAL ENGINEERING CALCULATIONS I—3 cr. (3 and 0)
Formulation and solution of basic chemical engineering problems using statistical and post-calculus techniques.

ChE 807—CHEMICAL ENGINEERING CALCULATIONS II—3 cr. (3 and 0)
A continuation of ChE 806. Emphasis is given to the formulation and solution of more complex problems in the area of steady and unsteady transport.

ChE 808—CHEMICAL ENGINEERING DESIGN AND ANALYSIS—3 cr. (1 and 6)
Design and analysis of chemical process equipment through the solution of comprehensive problems involving unit operations, kinetics, thermodynamics, strength of materials, and chemistry.

ChE 809—WASTE TREATMENT—3 cr. (3 and 0)
Basic biochemical principles underlying bio-oxidation and their applications in activated sludge and trickling filter processes: basic theory of oxygen transfer and its application to aeration equipment; and the design of typical industrial waste treatment processes.

ChE 810—BIOCHEMICAL ENGINEERING—3 cr. (3 and 0)
Principles of biochemical reaction systems and their applications in the chemical process industries. Enzyme systems, their sources, essential characteristics, and employment in commercial chemical production (Fermentation). Certain related topics (i.e., biological waste disposal, protein technology, etc.) introduced for illustration.

ChE 821—HEAT TRANSPORT—3 cr. (3 and 0)
Advanced topics in heat transport by conduction, convection, and radiation.

ChE 822—MASS TRANSFER AND DIFFERENTIAL CONTACT OPERATIONS—3 cr. (3 and 0)
Topics include diffusion theory in binary and multicomponent gas and liquid systems, the HTU concept, and design considerations in absorption and extraction.

ChE 823—MASS TRANSFER AND STAGEWISE CONTACT OPERATIONS—3 cr. (3 and 0)
Stagewise contact operations with major emphasis on distillation. Topics include vapor-liquid equilibria, integral and differential distillation, binary
and multicomponent rectification, analytical methods, batch rectification, and azeotropic and extractive distillation.

ChE 830—CHEMICAL TECHNOLOGY—3 cr. (3 and 0)
A study of those unit processes and operations that are of direct interest to the organic, inorganic, or electrochemical industries. Special emphasis is placed on the manner in which chemical engineering principles are used in solving the problems of these industries.

ChE 840—GRADUATE LABORATORY—Credit to be arranged.
Graduate level laboratory experiments in kinetics, unit operations and thermodynamics. Emphasis will be placed on independent work. The student will be required to plan the experiments to achieve a given objective, perform the experimental work and prepare a technical report on the work.

ChE 845, 846, 847—SELECTED TOPICS IN CHEMICAL ENGINEERING—3 cr. (3 and 0)
A comprehensive study of any topic in the field of chemical engineering, not covered in the other courses. Special emphasis will be placed on studies of the current literature and the results of recent and current research. The topics covered will be expected to vary from year to year to keep pace with developments in the field. May be repeated for credit.

ChE 852—AIR POLLUTION CONTROL PROCESSES—3 cr. (3 and 0)
A course devoted to operational and design variables in equipment for removal of gas, liquid and solid phase pollutants from air. Basic theory of small particle dynamics. Performance and design are discussed.

ChE 853—INDUSTRIAL AIR HYGIENE—3 cr. (3 and 0)
Deals with the control of air contaminants in confined industrial areas. Application of maximum allowable concentrations in the design of air handling and cleaning systems in enclosed work areas. A survey of heat, noise, and other industrial hazards.

ChE 854—ENVIRONMENTAL INSTRUMENTATION AND MEASUREMENTS—3 cr. (2 and 3)
The theory and practice of measurement of environmental control parameters are studied. The applications of survey instrumentation and microanalytical procedures in environmental and biochemical engineering are emphasized.

ChE 891—RESEARCH—Credit to be arranged.

ChE 902—PROCESS DYNAMICS AND CONTROL—3 cr. (3 and 0)
An extension of ChE 802; includes a detailed analysis of the recent chemical engineering literature in the areas of process dynamics and control. The analysis of non-linear systems along with complex control schemes will be considered. Prerequisite: ChE 802.
ChE 903—TRANSPORT PHENOMENA—3 cr. (3 and 0)
A consideration of problems in transport phenomena from the current literature. Prerequisite: ChE 803.

ChE 904—CHEMICAL ENGINEERING THERMODYNAMICS—3 cr. (3 and 0)
A continuation of ChE 804. Includes non-ideal behavior of mixtures, statistical thermodynamics and irreversible process. Prerequisite: ChE 804.

ChE 905—CHEMICAL ENGINEERING KINETICS—3 cr. (3 and 0)
A continuation of ChE 805. Prerequisite: ChE 805.

ChE 945, 946, 947—SELECTED TOPICS IN CHEMICAL ENGINEERING—3 cr. (3 and 0)
Study of any advanced topic in chemical engineering. Intended primarily for more comprehensive study of topics first covered in ChE 845-847.

ChE 954—ENVIRONMENTAL SYSTEMS DESIGN—3 cr. (3 and 0)
The design and evaluation of life support systems are considered. A study of energy and chemical requirements, the application of regenerative processes, and current developments. Prerequisites: ChE 854.

ChE 991—DOCTORAL RESEARCH—Credit to be arranged.

The catalog descriptions for the following interdepartmental fluid mechanics courses are given on pages 112 to 114:

FM 801—FOUNDATION OF FLUID MECHANICS—3 cr. (3 and 0) F
FM 811—EXPERIMENTAL FLUID MECHANICS—3 cr. (2 and 3) F
FM 812—THEORY OF INCOMPRESSIBLE IDEAL FLOW—3 cr. (3 and 0) S
FM 814—TURBULENT BOUNDARY LAYER—3 cr. (3 and 0) S
FM 815—NUMERICAL METHODS IN FLUID MECHANICS—3 cr. (3 and 0) F
FM 816—FLOW IN OPEN CHANNELS—3 cr. (3 and 0) S
FM 817—NON-NEWTONIAN FLOW—3 cr. (3 and 0) S
FM 841—SEMINAR—1 cr. (1 and 0) S, F
FM 901—APPLIED HYDRODYNAMICS—3 cr. (3 and 0)
FM 921—TWO-PHASE FLOW—3 cr. (3 and 0)
FM 931—FREE SURFACE FLOW—3 cr. (3 and 0)
FM 951—BIO-FLUID MECHANICS—3 cr. (3 and 0)

CIVIL ENGINEERING

H. W. Busching, Department Head

The Department of Civil Engineering offers the Master of Engineering, Master of Science, and Doctor of Philosophy degrees.

Graduate students in Civil Engineering can pursue programs in several areas of specialization — Traffic and Transportation, Materials and Soil Mechanics, Structures, Construction and Systems. Opportunities also exist for study and research in several interdisciplinary programs. Each student's educational and research objectives may be explicitly arranged to best reflect his personal motives and professional goals.

CE 610—TRAFFIC ENGINEERING OPERATIONS—3 cr. (3 and 0 S
CE 612—URBAN TRANSPORTATION PLANNING—3 cr. (3 and 0) F
CE 615—TRAFFIC ENGINEERING SEMINAR—1 cr. (0 and 2) F
CE 617—AIRPHOTO INTERPRETATION I—3 cr. (2 and 3) F
CE 619—GENERAL PHOTOGRAMMETRY—3 cr. (2 and 3) S
CE 620—MECHANICAL PROPERTIES OF MATERIALS—3 cr. (3 and 0)
CE 630—SOIL MECHANICS—3 cr. (2 and 2)
CE 631—APPLIED SOIL MECHANICS—3 cr. (2 and 3)
CE 634—CONSTRUCTION COSTS AND ESTIMATES—3 cr. (2 and 3)
CE 635—ENGINEERING PROJECT ANALYSIS—3 cr. (2 and 3)
CE 653—ADVANCED STRUCTURAL ANALYSIS—3 cr. (3 and 0)
CE 662—PORT AND HARBOR ENGINEERING—3 cr. (3 and 0)
CE 690—SPECIAL PROJECTS—I—3 cr. (1-3 and 0)
CE 699—SIMULATION TECHNIQUES—I—1 cr. (0 and 3)
CE 801—STRUCTURAL ENGINEERING I—3 cr. (3 and 0)

Analysis and design of tall buildings subjected to wind stresses; analysis of space frames; analysis and design of continuous trusses; secondary stresses in trusses; introduction to matrix methods of analysis; introduction to the design of arches. Prerequisite: CE 453 or equivalent.
CE 802—PRESTRESSED CONCRETE ANALYSIS AND DESIGN—3 cr.
(3 and 0)
Design and analysis of prestressed concrete beams, columns and floor slabs. Composite design of steel and concrete. CE 402.

CE 803—REINFORCED CONCRETE STRUCTURAL SYSTEMS—3 cr.
(3 and 0)
Relates behavior of reinforced concrete beams, columns, and frames to design practice. Discusses the effect of past and present research in the formulation of reinforced concrete design codes. Prerequisite: CE 402.

CE 804—THEORY AND DESIGN OF THIN PLATES—3 cr. (3 and 0)
Elastic analysis and design of circular, rectangular, and continuous plates by both classical and numerical methods. Prerequisites: A knowledge of Fourier series, and partial differential equations.

CE 805—PLASTIC DESIGN OF STEEL STRUCTURES—3 cr. (3 and 0)
The inelastic behavior of metal frameworks; concept of the plastic hinge and collapse configurations; requirements for stability; connections; minimum weight and cost design. Prerequisites: CE 302, CE 453.

CE 806—DESIGN OF STEEL MEMBERS—3 cr. (3 and 0)
Relates behavior of steel members to design practice. Review of experimental investigations of and design practice for primary buckling, twist buckling, local buckling, web buckling and interaction. Prerequisite: CE 302.

CE 807—NUMERICAL AND APPROXIMATE METHODS OF STRUCTURAL ANALYSIS—3 cr. (3 and 0)
Application of finite difference equations, iterative procedures and relaxation methods to the solution of structural problems. Introduction to the matrix formulation of structural problems. Application of matrix methods to the vibration of structures, and analysis and stability of statically loaded beams, frames, space frames and stiffened shell structures. Prerequisite: CE 453.

CE 808—FINITE ELEMENT METHODS IN STRUCTURAL ANALYSIS—3 cr. (3 and 0)
The basic formulation of finite element structural analysis; types of elements, application to linear elastic analysis; elastic instability; dynamic response; and inelastic analysis. Prerequisites: CE 801 or permission of instructor.

CE 811—HIGHWAY GEOMETRIC DESIGN—3 cr. (2 and 3) F
Geometric design of roadways, at-grade intersections, and interchanges in accordance with the conditions imposed by driver ability, vehicle performance, safety and economics. Prerequisite: CE 310.
CE 812—AIRPHOTO INTERPRETATION II—3 cr. (2 and 3) S
Principles of air photo interpretation as applied to transportation planning. Cultural, industrial, and recreational land use features are identified and analysed in order to predict the future needs of the transportation system. Transportation projects utilizing airport interpretation.

CE 813—HIGHWAY AND AIRPORT PAVEMENT DESIGN—3 cr.
(3 and 0)
Structural design of rigid and flexible pavements; design of bases and subbases; theory of stresses and application of plate bearing, triaxial, and California Bearing Ratio design methods to flexible pavements; Westergaard analysis for rigid pavements; pavement evaluation methods. Prerequisite: CE 330.

CE 814—TRAFFIC FLOW THEORY—3 cr. (3 and 0)
Qualitative and quantitative description of traffic flow, study of the parameters used to characterize traffic flow, procedures for adjusting traffic flow parameters to optimize flow, solution of traffic flow problems by methods of analogy and queuing theory, and discussion of digital simulation of vehicular motion and traffic flow. Prerequisite: CE 310.

CE 815—HIGHWAY SAFETY ENGINEERING—3 cr. (3 and 0)
An examination of the methodology for conducting highway traffic accident studies; accident characteristics as related to the vehicle driver, roadway, and vehicle; statistical applications to accident data and studies; and consideration of current trends and problems in highway safety. Prerequisite: CE 310.

CE 816—HIGHWAY PLANNING—3 cr. (3 and 0)
Advanced treatment of various aspects of highway planning including planning surveys, needs studies, impact studies, sufficiency ratings, highway finance, highway administration and extensive treatment of economic evaluation of alternative highway projects by benefit-cost ratio, annual cost, rate of return and investment return procedures.

CE 818—AIRPORT PLANNING AND DESIGN—3 cr. (3 and 0)
A comprehensive coverage of important aspects of the planning and design of airports and other air transportation facilities, an introduction to the characteristics of air transport, and a study of the future role of air transport in the overall transport program.

CE 819—TRANSPORTATION RESEARCH—2 to 4 cr.
Independent investigation of problems in transportation engineering.

CE 820—CEMENT AND CONCRETE—3 cr. (2 and 3) S
Chemistry and properties of cements; properties of plastic and hardened concrete; mix design methods. Prerequisite: CE 320.
CE 821—BITUMINOUS PAVING MATERIALS—3 cr. (2 and 3)
Manufacture of asphalt cements, road oils, asphalt emulsions, cutback asphalts and tars; theory, design and evaluation of asphalt-aggregate mixes. Prerequisite: CE 320.

CE 822—AGGREGATES AS CONSTRUCTION MATERIALS—3 cr.
(2 and 3)
Identification and suitability of aggregates for embankment, drainage, and roadbed structures, concrete mixes, and bituminous mixtures. Prerequisite: CE 320.

CE 823—INELASTIC BEHAVIOR OF ENGINEERING MATERIALS—3 cr.
(3 and 0)
Formulation of constitutive equations of mechanical behavior, strength theories, use of rheological models, static and dynamic viscoelasticity, introduction to fracture mechanics, applications in civil engineering. Prerequisite: EM 304.

CE 825—DISTRIBUTION AND PROPERTIES OF SOILS—3 cr. (3 and 0)
Distribution and engineering properties of soils and aggregates in North America on a physiographic basis, identification of the common problems associated with various natural construction materials and their solutions, and performance of structures as related to natural construction materials available in different areas. Prerequisite: CE 330.

CE 831—FOUNDATION ENGINEERING—3 cr. (2 and 3)
Requirements for satisfactory foundations, theory and design of shallow foundations, pressure distribution beneath rigid and flexible shallow foundations, bearing capacity and settlement of deep foundations, foundation failures. Laboratory includes site investigation field tests, and determination of design parameters. Prerequisite: CE 330.

CE 832—ADVANCED SOIL MECHANICS—3 cr. (3 and 3)
Stresses in soils, plastic equilibrium of soil masses, failure conditions, earth pressures, analysis of flexible retaining walls and bulkheads, solution of problem by elastic theory. Prerequisite: CE 330.

CE 833—PHYSICAL AND PHYSIO-CHEMICAL PROPERTIES OF SOILS—3 cr. (2 and 3)
Formation of soils, soil minerals, soil structure, permeability, swelling pressures, pore pressure theory as related to shear strength and consolidation; soil stabilization, shear strength tests, properties of compacted soils. Prerequisite: CE 330.

CE 835—DESIGN OF EARTH STRUCTURES—3 cr. (3 and 0)
Design and construction of earth and rock fill dams, appurtenances and embankment details, highway embankments, methods of soil stabilization,
compaction, and compaction control, drainage systems for seepage and pressure control. **Prerequisite:** CE 330.

CE 889 and 890—SPECIAL PROBLEMS I AND II—1-3 cr. F, S

Research design problems may be assigned from the fields of structures, construction, soil mechanics, transportation, or materials engineering. Subject matter will vary with interests and experience of student and instructor.

CE 891—RESEARCH—Credit to be arranged.

CE 901—THEORY AND DESIGN OF SHELLS—3 cr. (3 and 0)

Elastic analysis and design of shell structures such as cylindrical shells, folded plates, domes, roof structures with double curvature. **Prerequisites:** A knowledge of Fourier series, and partial differential equations.

CE 902—STRUCTURAL VIBRATION—3 cr. (3 and 0)

Analysis and design of structures subjected to dynamic loading. Response will be investigated for both lumped and distributed parameter systems of one or many degrees of freedom. Approximate design methods, earthquake analysis and design, and blast-resistant design. **Prerequisite:** Permission of the instructor.

CE 991—DOCTORAL RESEARCH—Credit to be arranged. F, S

**ELECTRICAL AND COMPUTER ENGINEERING**

Lyle C. Wilcox, Department Head

The Department of Electrical and Computer Engineering offers the Master of Engineering, Master of Science, and Doctor of Philosophy degrees.

Graduate students in Electrical and Computer Engineering can direct their program towards several areas of specialization. The traditional fields of networks, controls, communications, electronics, power systems, and computers are available. Also, the student can elect to work in one of the multi-disciplinary fields such as bio-medical engineering, systems or operations research.

EE 603—ENERGY CONVERSION—3 cr. (3 and 0) F
EE 606—INTRODUCTION TO INTEGRATED CIRCUITS—3 cr. (3 and 0) F
EE 610—SYSTEMS III—3 cr. (3 and 0) F, S
EE 611—ELECTRICAL SYSTEMS WORKSHOP III—2 cr. (0 and 4) F, S
EE 612—DIGITAL CONTROL SYSTEMS—3 cr. (3 and 0) S
EE 619—ELECTRICAL MACHINERY LABORATORY—1 cr. (0 and 2) F
EE 620—POWER SYSTEM ANALYSIS—3 cr. (3 and 0) S
EE 621—ELECTRICAL MACHINERY—3 cr. (3 and 0) F
EE 622—ELECTRONICS III—2 cr. (2 and 0) F, S
EE 628—COMMUNICATIONS THEORY—3 cr. (3 and 0) F
EE 629—FUNDAMENTALS OF DIGITAL COMPUTER DESIGN—
3 cr. (3 and 0) F
EE 630—COMMUNICATIONS THEORY IV—3 cr. (3 and 0) S
EE 631—DIGITAL ELECTRONICS—3 cr. (3 and 0)
EE 632—INSTRUMENTATION—3 cr. (3 and 0) S
EE 633—DIGITAL ELECTRONICS LABORATORY—1 cr. (0 and 2) S
EE 634—POWER ELECTRONICS—3 cr. (3 and 0) F
EE 635—COMMUNICATIONS CIRCUITS—3 cr. (3 and 0) S
EE 636—RADIATION AND WAVE PROPAGATION—3 cr. (3 and 0) F
EE 637—OPTICS OF COHERENT AND NONCOHERENT ELECTROMAGNETIC RADIATION—3 cr. (3 and 0) S
EE 650—SYSTEMS IV—3 cr. (3 and 0) F, S
EE 651—SYSTEMS DESIGN WORKSHOP IV—2 cr. (0 and 4) F, S
EE 660—COMPUTER-AIDED ANALYSIS AND DESIGN—3 cr. (3 and 0) F
EE 661—ANALOG/HYBRID COMPUTATION AND SIMULATION—
3 cr. (3 and 0) S

EE 801—ANALYSIS OF LINEAR SYSTEMS I—3 cr. (3 and 0) F
An introduction to the foundations of linear system analysis. The application of matrix algebra, linear graph theory, and operational mathematics to the formulation and solution of system equations in the time domain and in the frequency domain.

EE 802—ANALYSIS OF LINEAR SYSTEMS II—3 cr. (3 and 0) S
An extension of the topics of EE 801. The study of multi-terminal representations and equivalence concepts for linear systems. Emphasis is placed on computer formulation and solution techniques applicable to large-scale physical systems such as electric power networks. Prerequisite: EE 801.

EE 803—SEMINAR—1 cr. (1 and 0) F, S
Student presentations and group discussions dealing with current research activities.
EE 804—NETWORK SYNTHESIS I—3 cr. (3 and 0) F

EE 805—NETWORK SYNTHESIS II—3 cr. (3 and 0) S
Continuation of EE 804. Realization of two-port transfer function with an emphasis on LC and RC networks. The approximation problem. Extensions to active network synthesis. **Prerequisite:** EE 804.

EE 806—NONLINEAR NETWORKS AND SYSTEMS—3 cr. (3 and 0) S
Organized treatment of nonlinear problems arising in system analyses. Description and characterization of the properties of nonlinear components. Formulation and solution of system equations with emphasis on computer-oriented solution techniques. Stability in nonlinear systems.

EE 807—POWER SYSTEM STABILITY—3 cr. (3 and 0) S
Problems related to the interconnection of power systems. Division of load, maximum feasible lengths of interconnecting lines, synchronization and related topics.

EE 808—ENERGY CONVERSION—3 cr. (3 and 0) F
A discussion of electrical-mechanical, direct thermal-electrical and nuclear thermal conversion. Topics covered include dynamic characteristics of machines, vacuum converters, MHD, full cells, nuclear reactor theory, design and control.

EE 809—ADVANCED COMPUTER CONTROL SYSTEMS—3 cr. (3 and 0) S
Computer control systems are examined in detail from theoretical and practical viewpoints. Analog, direct digital and digital logic controllers are presented. Digital instrumentation, conversion equipment and actuators are considered. On-line data logging and system monitoring as well as the advanced areas of static and dynamic optimization and control are presented. Digital and hybrid computer simulation studies augment the theoretical presentations.

EE 810—MODERN CONTROL THEORY I—3 cr. (3 and 0) F
A detailed treatment of time domain (state space) analysis and design methods. Lyapunov's methods, discrete-time systems. Introduction to nonlinear problems. Computers frequently used to solve practical problems.

EE 811—MODERN CONTROL THEORY II—3 cr. (3 and 0) S
Concept of observability. Optimum control theory; the calculus of variations, principle of optimality. Hamilton-Jacob's equation and Pontryagin's principle. The computations of optimal control with gradient methods and dynamic programming.

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EE 812—SAMPLED DATA SYSTEMS—3 cr. (3 and 0) F

Analysis and design of control systems in which sampling elements occur. Sampling theory and data reconstruction are considered. The use of the classical z-transform analysis techniques augment modern control theory methods. Stability, compensation, and performance are considered.

EE 814—NONLINEAR AUTOMATIC CONTROLS—3 cr. (3 and 0) S

A study of control systems in which nonlinear elements occur. In some cases these are used deliberately to achieve results not obtainable by other methods. Statistical design principle and sampled data systems are studied. Both graphical and analytical procedures are used; these include the describing function, the method of harmonic balance, the phase plane. The phase plane is used in giving insight to Lyapunov’s second method of stability analysis.

EE 815—RANDOM DATA MEASUREMENTS AND ANALYSIS—3 cr. (3 and 0) S

Principles involved in the measurement and analysis of random data. Response characteristics of physical systems. Data sampling techniques. Analog and digital measurement techniques. Analysis of non-stationary data.

EE 819—DETECTION AND ESTIMATION THEORY—3 cr. (3 and 0) F

An introduction to the theory of statistical testing of hypotheses as applied to the detection and estimation of communication signal parameters. Detection of signals with random amplitude, phase and arrival time in noise. Detection of single and multiple observation. Estimates and their properties, signal resolution. Prerequisites: EE 820 and EE 815.

EE 820—COMMUNICATIONS I—3 cr. (3 and 0) F

A study of modern communications systems with emphasis on modulation and methods of taking into account the effects of noise on various systems. Prerequisite: EE 428 or equivalent.

EE 821—COMMUNICATIONS II—3 cr. (3 and 0) S

Continuation of EE 820.

EE 822—INFORMATION THEORY—3 cr. (3 and 0) F

A study of the statistical problems encountered in information handling. Relates probability, information, and coding theory. Presents a unified treatment of set theory, sample space, random variables, information measure and capacity as can be applied to communications.

EE 823—INTEGRATED CIRCUITS I—3 cr. (3 and 0) F

Characteristics and semiconductor devices are discussed in the context of their use in integrated circuits. Monolithic and hybrid construction are described and related to electrical performance. Circuits are categorized by technology and design guidelines developed.
EE 824—INTEGRATED CIRCUITS II—3 cr. (3 and 0) S
Continuation of EE 823 with emphasis on circuit layout and technological limitations to design. Complex function circuits and LSI structures are discussed. Prerequisite: EE 823.

EE 825—SOLID-STATE ELECTRONICS—3 cr. (3 and 0) S
The electron in solids is studied by the modern physics approach. This includes elementary quantum mechanics, statistics, plasmas, and band theory. These principles are then applied to modern amplifiers; e.g., the traveling-wave tube, tunnel diode, masers, and parametric amplifiers.

EE 826—LARGE SCALE INTEGRATION—3 cr. (3 and 0) S
LSI concepts are increasingly influencing electronic system design. This course examines in depth the technological and economic factors affecting the use of these components. Prerequisite: EE 824.

EE 827—INSTRUMENTATION AND MEASUREMENTS—3 cr. (3 and 0) F
Instrumentation capable of measuring physical parameters, including spectrophotometry, spectroscopy, mass spectrometry, gas chromatography, NMR and EPR, will be considered. Electronic components such as detectors, pulse height analyzers, and data processing and telemetry equipment will also be covered.

EE 830—ELECTROMAGNETICS I—3 cr. (3 and 0) F
Vector analysis, electrostatics, electrostatic fields in material bodies, solution of boundary-value problems, stationary currents, static magnetic fields, magnetic field in material bodies, quasi-stationary magnetic fields. Prerequisite: Approval of department.

EE 831—ELECTROMAGNETICS II—3 cr. (3 and 0) S
Time dependent fields, plane waves, guided transmission systems, resonators, radiation, antennas, and interaction of charged particles with fields. Prerequisite: EE 830.

EE 832—ANTENNA THEORY I—3 cr. (3 and 0) F
Point sources, the antenna as an aperture, thin linear antennas, loop antennas, helical antennas, the current distribution and impedance of the cylindrical antenna, coupled antennas, and the electromagnetic fields of antennas. Prerequisite: EE 831.

EE 833—ANTENNA THEORY II—3 cr. (3 and 0) S
Continuation of EE 832 with emphasis on microwave antennas, slot antennas, slot antenna arrays, horn antennas, and antenna pattern theory. Prerequisite: EE 832.

EE 834—MICROWAVE ELECTRONICS—3 cr. (3 and 0) S
Interaction of charged particles with electromagnetic fields, fundamental principles of microwave devices, including klystrons, magnetrons
traveling wave tubes and particle-accelerators. Semiconductor devices as microwave frequencies. **Prerequisite:** EE 831.

EE 836—OPTICAL ELECTROMAGNETICS AND QUANTUM ELECTRONICS—3 cr. (3 and 0) F  
An advanced study of the theory and modern technology of physical optics including methods used to generate, guide, and detect coherent waves in the millimeter, infrared, and visual portions of the electromagnetic spectrum.

EE 850—COMPUTATION AND SIMULATION—3 cr. (3 and 0) F  
Covers the general area of computer modeling as related to engineering problems. Emphasis is placed on matching problems and computers to obtain the most effective solution.

EE 851—THEORY AND DESIGN OF DIGITAL-ANALOG MACHINES—3 cr. (3 and 0) S  
Theory and design of general purpose, special purpose, hybrid and sequential machines. Particular emphasis is placed on practical applications.

EE 852—DIGITAL COMPUTERS AND INFORMATION PROCESSES—3 cr. (3 and 0) F  
A survey of techniques and problems involved in computer and information processing technology. Algorithmic approach to problem solving, software concepts, and machine organization are considered. **Prerequisite:** A student is expected to have a prior knowledge of programming.

EE 855—ARTIFICIAL INTELLIGENCE—3 cr. (3 and 0) F  
A study of the problem of creating intelligent behavior in machines with emphasis on computer-oriented approaches. Topics covered include models of cognitive processes, goal-seeking behavior, self-organizing systems, learning algorithms, game-playing machines, pattern recognition, and heuristic programming. Practical applications such as machine aids to human problem-solving and computer control of external manipulators are considered. Current developments in the field are reviewed.

EE 856—PATTERN RECOGNITION—3 cr. (3 and 0) S  
An investigation of several approaches to the general pattern recognition problem with practical computer-oriented applications. Topics treated include feature extraction, classification algorithms, discriminant functions, learning schemes, statistical methods, information theoretic approaches, and applications. Current developments in the field are reviewed.

EE 857—CODING THEORY—3 cr. (3 and 0) S  
A study of the principles of algebraic coding and its application to the transmission of information over noisy communications channels. Topics covered include an introduction to abstract algebra, code performance
bounds, code representations, linear codes of the Hamming and Bose-
Chandnuri types and burst-error correcting codes. Also considered are
problems of implementation and decoding. **Prerequisite:** EE 822.

EE 858—AUTOMATA THEORY—3 cr. (3 and 0) S

A study of the structure and capabilities of sequential machines. Topics
covered include: machine identification, regular expressions, linear ma-
chines, and stochastic machines.

EE 860—ENGINEERING APPLICATIONS OF OPTIMIZATION—3 cr.
(3 and 0) F

Optimization without constraints. Maximizing under constraining con-
ditions. Linear programming, separable programming and quadratic pro-
gramming. Use of analog and hybrid computers in optimization studies.
Optimal control using state-space formulations and dynamic programming.

EE 861—FOUNDATIONS AND METHODOLOGY OF SYSTEMS
ENGINEERING—3 cr. (3 and 0) F

Definition of Systems Engineering, fundamental concepts of Systems
Engineering. (Subsystems, environments for systems, microscopic aspects
of systems.) Problem definitions (technical and economic environment).
Theory of value and needs. Decision making.

EE 863—ADVANCED PHYSICAL SYSTEM ANALYSIS I—3 cr
(3 and 0) S

Complex problem formulation using component terminal equations and
linear graph theory. Instrumentation and measurement processes for
multi-terminal subsystems. Nonlinear systems and the state model formu-
lation. Solutions to mixed systems of algebraic and differential equa-
tions. Same course as ME 863.

EE 864—ADVANCED PHYSICAL SYSTEMS ANALYSIS II—3 cr. F

Digital and analog computer solutions to linear and nonlinear systems,
continuous and discrete. Systems with discrete and continuous sub-
systems. Optimizing processes; separable programming, and dynamic
programming. Adaptive systems. Same course as ME 864.

EE 870—BIOSYSTEMS ANALYSIS—3 cr. (3 and 0) F

A discussion of the classical and recent mathematical models of biologi-
ical systems, particularly as they relate to modern systems theory. Bio-
medical instrumentation, data collection and data processing are covered.
Emphasis is on applications to humans.

EE 890—SELECTED TOPICS IN ELECTRICAL ENGINEERING—
Variable (3 and 0) F, S

A comprehensive study of any topic in the field of electrical engineering
not covered in the other courses. Special emphasis will be placed on
studies of the current literature and results of recent and current re-
search. The topics covered will be expected to change from year to year in keeping with developments in the field. Can be repeated for additional credit.

EE 891—RESEARCH—Credit to be arranged.
EE 991—DOCTORAL RESEARCH—Credit to be arranged.

ENGINEERING MECHANICS
R. W. Moorman, Department Head

The Department of Engineering Mechanics offers the Master of Science and Doctor of Philosophy degrees.

Enrollment in these programs is open to students possessing baccalaureate or master's degrees in any branch of engineering and to those with degrees in physics or applied mathematics who have credit for certain prescribed courses in engineering.

The three general areas of concentration are mechanics of solids, dynamics and fluid mechanics. Some limitations are imposed on the selection of courses to reflect the particular concentration. The normal minor area of study is mathematics. However, suitable complementary minor programs may also be arranged in physics, materials engineering, civil engineering, and mechanical engineering.

EM 621—HYDROLOGY AND HYDRAULICS—2 cr. (2 and 0)
EM 625—ADVANCED MECHANICS OF MATERIALS—3 cr. (3 and 0)
EM 650—MECHANICAL VIBRATIONS—3 cr. (3 and 0)
EM 670—EXPERIMENTAL STRESS ANALYSIS I—3 cr. (2 and 3)
EM 802—EXPERIMENTAL STRESS ANALYSIS II—3 cr. (2 and 3)

Experimental analysis of stress fields using photoelasticity as the principal method. Basic theory of photoelasticity, and transmission polariscope and the reflective polariscope are discussed with applications utilizing two and three dimensional models and photoelastic coatings. Emphasis is on the techniques of simulating stress fields with model and the proper interpretation of fringe patterns. Prerequisites: EM 304 and permission of instructor.

EM 821—CONTINUUM MECHANICS—3 cr. (3 and 0)

A comprehensive, unified treatment of the mathematical theories of elastic solids. Introduction to tensor analysis; stress and strain tensors; invariants; deformations and flow; conservation of mass; momentum theorems; constitutive equations; equations of elastic solids. Prerequisites: Math 208, or 306, and permission of instructor.
EM 823—DIMENSIONAL ANALYSIS AND DYNAMIC SIMILARITY—3 cr. (3 and 0)

Systematic study of the algebraic theory of dimensional analysis and the theory of models. Applications include problems in the following areas: mechanics of materials, fluid mechanics, heat transfer and electromagnetic theory. Special attention is given the method of deriving model laws from the differential equations governing a particular phenomena. Prerequisite: Permission of instructor.

EM 827—TOPICS IN ANALYTICAL MECHANICS—3 cr. (3 and 0)

An introduction to topics of fundamental importance in the formulation of the classical theories of solid mechanics, fluid mechanics, and dynamics. Prerequisites: Math 208 or 306 and permission of instructor.

EM 829—ENERGY METHODS AND VARIATIONAL PRINCIPLES—3 cr. (3 and 0)

Theory of variational energy principles including the principle of virtual work, first law of thermodynamics, principle of complementary energy, Castigliano and unit-dummy load methods, principle of stationary potential energy. Hamilton's principle and the equations of Hamilton and Lagrange. Application of these principles to dynamics of rigid bodies, analyses of linear and non-linear elastic frames, general elasticity theory, theories of plates and shells, and the theories of buckling and vibrations. Prerequisites: EM 831 and permission of instructor.

EM 831—THEORY OF ELASTICITY I—3 cr. (3 and 0)

The theory of stress and the general theory of deformation for continuous media. The linear stress-strain relations for an elastic region including the particular case of a homogeneous, isotropic material. Basic equations are developed in both scalar and tensor form. Specific topics are considered: e.g., the Airy stress function, torsion and bending of prismatic bars, and thermal stresses. Prerequisites: EM 304, Math 208 or 306.

EM 832—THEORY OF ELASTICITY II—3 cr. (3 and 0)

Continuation of EM 831. Three-dimensional problems associated with the infinite elastic medium, the elastic half-space, contact stresses and the deformation of a symmetrically loaded elastic sphere and circular cylinder. Prerequisite: EM 831.

EM 834—THEORY OF ELASTIC STABILITY—3 cr. (3 and 0)

Theoretical bases for the analysis of the static and dynamic stability of conservative and non-conservative systems are developed. Emphasis is placed on the application of the classical stability criteria to various important structural elements such as columns, beam-columns, rings, arches, thin plates, and shells. Special attention is given to the methods of adjacent equilibrium, initial imperfection, and total potential energy. Prerequisite: EM 831 or permission of instructor.

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EM 845—INTERMEDIATE DYNAMICS—3 cr. (3 and 0)
Kinematics and dynamics of particles and rigid bodies. Lagrange and
Hamilton's formulations of mechanics. Two-body central force problem.
Rendezvous of two bodies in a central force field. Rotation of rigid
bodies about a fixed point in space. Vector analysis and matrix methods
are introduced as aids in the mathematical analysis. Prerequisites:
EM 202 or permission of instructor.

EM 881—SPECIAL PROBLEMS—3 cr.
Experience is provided in the development and solution of an assigned
comprehensive problem in the student's major area of interest. A report
of findings is required.

EM 889, 890—SEMINAR—0 or 1 cr. (1 and 0)
(May be taken more than one semester.)

EM 891—RESEARCH—Credit to be arranged.

EM 932—THEORY OF PLASTICITY—3 cr. (3 and 0)
Development of the fundamental equations of the theory of plasticity.
Yield criteria, yield surfaces, plastic stress-strain relations, considera-
tion of perfectly plastic and strain-hardening materials and methods and solu-
tions for a number of specific problems. Prerequisite: EM 831.

EM 980, 981, 982, 983—SPECIAL TOPICS IN MECHANICS—3 cr. (3 and 0)
Directed study of advanced topics in both solid and fluid mechanics. In-
tended to develop in depth the candidate's area of particular interest.

EM 991—DOCTORAL RESEARCH—Credit to be arranged.

The catalog descriptions for the following interdepartmental fluid me-
chanics courses are given on pages 112 to 114:

FM 801—FOUNDATION OF FLUID MECHANICS—3 cr. (3 and 0)
FM 811—EXPERIMENTAL FLUID MECHANICS—3 cr. (2 and 3)
FM 812—THEORY OF INCOMPRESSIBLE IDEAL FLOW—3 cr. (3 and 0)
FM 814—TURBULENT BOUNDARY LAYER—3 cr. (3 and 0)
FM 815—NUMERICAL METHODS IN FLUID MECHANICS—3 cr.
(3 and 0)
FM 816—FLOW IN OPEN CHANNELS—3 cr. (3 and 0)
FM 817—NON-NEWTONIAN FLOW—3 cr. (3 and 0)
FM 841—SEMINAR—1 cr. (1 and 0)
FM 901—APPLIED HYDRODYNAMICS—3 cr. (3 and 0)
The Master of Science, Master of Engineering, and Doctor of Philosophy degrees are offered.

Environmental Systems Engineering is an interdisciplinary field concerned with the engineering aspects of the understanding, prediction, and control of man's environment. The objective of the College of Engineering in this area is to help provide the increasing number of qualified personnel required to cope with the problems of environmental pollution in today's complex society. Stress is placed on applying basic principles of the sciences to research and design in engineering and on the application of operations research, system analysis, and quantitative economics to operation and management problems. The unit operations-unit process approach is emphasized in both academic work and research.

The M.S., M.Engr., and Ph.D. programs of study are planned to augment the student's previous engineering or science background with specialization in the technological or operations and management areas of water quality control or air quality control. In addition to students with a B.S. degree in any branch of engineering, students from chemistry, physics, and biology with a strong mathematical background may be admitted to the program with appropriate prerequisites.

The curriculum for the M.S. and M.Engr. degrees is designed to meet the needs of individual students. One calendar year is normally required to complete the requirements for the M.S. and M.Engr. degrees. A formal thesis is optional with the committee which directs the program of each student. No foreign language is required for the Master's degree.

The program of study for the Ph.D. degree is flexible and depends upon the background and objectives of the candidate. The Ph.D. candidate will select at least one minor from other engineering disciplines or the sciences. The major field of study will be interdisciplinary in nature, consisting of existing courses in engineering and the basic sciences with research being guided by ESE faculty.
ESE 644—ENVIRONMENTAL ENGINEERING CHEMISTRY LAB. I—2 cr. (0 and 6) F

ESE 842—UNIT PROCESSES OF ENVIRONMENTAL ENGINEERING—3 cr. (3 and 0) S

A consideration of the theory, design, and operation and control of those unit processes employed in environmental engineering. These topics which are discussed include gas transfer, theory of biological oxidations, kinetics and dynamics of biological processes, activated sludge and trickling filter processes, anaerobic and photosynthetic biological processes, heat transfer, and wet combustion.

ESE 843—UNIT OPERATIONS OF ENVIRONMENTAL ENGINEERING—3 cr. (3 and 0) F

An intensive study of the fundamental principles and rational design considerations of those unit operations that relate to the physicochemical treatment of waters and wastewaters. Topics that are discussed include reactor kinetics, fluid transport, water characteristics, and water quality standards, coagulation and flocculation, sedimentation, filtration, adsorption, ion exchange, membrane separations, ionic equilibria, disinfection, and advanced waste treatment methods.

ESE 846—POLLUTION OF THE AQUATIC ENVIRONMENT—3 cr (2 and 3) S

A study of the effects of pollution resulting from domestic and industrial wastes upon the physical, chemical, and biological characteristics of natural waters.

ESE 848—ENVIRONMENTAL ENGINEERING CHEMISTRY—2 cr. (2 and 0) S

Applications of the principles of organic and biochemistry to the problems of environmental control, waste treatment, and bioengineering. Pre-requisite: ESE 643 or permission of instructor.

ESE 849—ENVIRONMENTAL ENGINEERING CHEMISTRY LAB II—2 cr. (1 and 3) S (alternate years)

Theory and application of instrumental methods of analysis as applied to measurements for environmental control. Spectroscopy and spectrophotometric techniques, electrochemical analyses, chromatographic methods of analysis, and light scattering and electrophoretic measurements are discussed in detail and demonstrated in the laboratory.

ESE 851—UNIT OPERATIONS AND PROCESSES LAB—2 cr. (1 and 3) S

Laboratory exercises in selected unit operations and processes. Typical topics are solid-liquid separations, adsorption, coagulation, ion exchange, filtration, combustion, membrane separations, activated sludge, and anaerobic digestion. Considerable emphasis is placed on the relation between theory and experimental results.

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ESE 852—WATER AND WASTEWATER TREATMENT SYSTEMS—3 cr. (3 and 0) SS

Integration of the unit operations and processes involved in water and wastewater treatment into systems. Emphasis will be placed on functional design and operation through consideration of process economics and application of operations research and systems engineering techniques. Pre-requisites: ESE 842 and 843.

ESE 854—WATER AND WASTE TRANSPORT SYSTEMS—3 cr. (3 and 0) (alternate years)

Theory and design of both continuous and discrete transport systems for fluids and solids. Consideration is given to water distribution and wastewater collection systems as well as transport mechanisms in streams. Also considered are solid waste transport systems. Emphasis will be on modeling and computer solution and the application of modern systems engineering and operations research techniques.

ESE 861—ENVIRONMENTAL SYSTEMS ENGINEERING SEMINAR—1 cr. F, S

A discussion of current advances and research developments in various areas of environmental engineering. Off-campus speakers, students, and faculty will participate.

ESE 862—ENVIRONMENTAL QUALITY CASE STUDY—1 cr. (0 and 3) F

An in-depth analysis and investigation of a significant current or recent situation affecting or involving some facet of environmental quality. The study will be conducted by a team of students and will result in a comprehensive position paper which integrates the pertinent social, political and economic considerations in the case with the technical aspects.

ESE 874—RADIOLOGICAL HEALTH ENGINEERING—3 cr. (2 and 3)

This is a continuation of Radiological Health with a more detailed study of radiation protection from air, water, food, and solids through engineering procedures. This course is offered primarily for engineering students Prerequisite: ESE 873 or the equivalent.

ESE 881—SPECIAL PROBLEMS—1-4 cr. F, S, SS

Problems are selected in the field of environmental engineering to meet the interests and experience of student and instructor.

ESE 883—SELECTED TOPICS IN ENVIRONMENTAL ENGINEERING—3 cr. (3 and 0)

A comprehensive study of any topic in the field of environmental engineering that is not covered in other courses. Emphasis will be placed on recent developments in environmental engineering. The topics covered are expected to vary from year to year to keep pace with current developments.
ESE 884—SELECTED TOPICS II—3 cr. (3 and 0) S
A comprehensive study of any topic in the field of Environmental Engineering that is not covered in other courses. Emphasis will be placed on current developments in Environmental Engineering. The topics covered are expected to vary from year to year to keep pace with current developments.

ESE 891—RESEARCH—1-6 cr.
May be taken more than one semester. (CE 891)

ESE 991—DOCTORAL RESEARCH—1-18 cr.
May be taken more than one semester. (CE 991)

FLUID MECHANICS SEQUENCE

The courses listed are offered by the faculties of the Departments of Chemical Engineering, Engineering Mechanics, and Mechanical Engineering for students majoring in those departments who desire an area of concentration in fluid mechanics. This integrated sequence provides the opportunity for in-depth penetration of this study area as well as breadth of application to such diverse fields of technology as: propulsion systems, water distribution systems, chemical systems, biological systems, and air and water pollution.

The 800 series courses will be offered on fixed schedule, odd number offered in fall and even number in spring. The 900 series are offered as needed.

FM 801—FOUNDATION OF FLUID MECHANICS—3 cr. (3 and 0) F
The basic equations for multi-dimensional flow fields are derived. Analytical techniques for solving laminar inviscid flows are introduced and discussed. Theories of similitude are introduced. Prerequisite: Graduate standing and permission of instructor.

FM 811—EXPERIMENTAL FLUID MECHANICS—3 cr. (2 and 3) F
Techniques and fundamental principles in measuring fluid properties, velocity, pressure, temperature and methods of flow visualization are presented in theory sessions. Details of the instrumentations are introduced in lab sessions. Prerequisite: FM 801.

FM 812—THEORY OF INCOMPRESSIBLE IDEAL FLOW—3 cr.
(3 and 0) S
Analytical treatment of the flow of an inviscid fluid. Topics to be covered include: superposition of flows, distributing singularities, conformal mapping and non-steady flow problems. Prerequisite: FM 801.
FM 814—TURBULENT BOUNDARY LAYER—3 cr. (3 and 0) S

Semi-empirical theories on Reynolds stress terms are introduced. Analytical methods of solving turbulent boundary layer momentum and energy equations are discussed for flows with pressure gradient and/or heat transfer. Theories pertinent to experimental techniques used for turbulent boundary layer study are presented. **Prerequisite:** FM 801.

FM 815—NUMERICAL METHODS IN FLUID MECHANICS—3 cr.

(3 and 0) F

Examine stability and convergence and develop numerical solution techniques. Applications from the literature will be reviewed which will range from hydrodynamic shocks to flow in ocean or lakes, depending on the interest of the class. Finite element techniques, solution of efficiency, generalized coordinate systems, and coordinate extensions will also be discussed. **Prerequisite:** FM 801.

FM 816—FLOW IN OPEN CHANNELS—3 cr. (3 and 0) S

Consideration of free surface flow problems including applications of digital computer, concepts of boundary layer theory, uniform and varied flow, the hydraulic jump, design criteria for prismatic channels and transitions, and some applications of unsteady flow. **Prerequisite:** Graduate standing and permission of instructor.

FM 817—NON-NEWTONIAN FLOW—3 cr. (3 and 0) S

Covers rheology, experimental classification, and viscometry of Non-Newtonian fluids such as polymer melts and solutions. Also design procedures for flow, mixing and heat transfer of Non-Newtonian fluids are considered. **Prerequisite:** Graduate standing and permission of instructor.

FM 841—SEMINAR—1 cr. (1 and 0) S, F

Required for all graduate students with major interest in fluid mechanics.

FM 901—APPLIED HYDRODYNAMICS—3 cr. (3 and 0)

The theories of classical hydrodynamics are applied to multiple body problems. Particular emphasis will be given to internal flows and hydrofoils. **Prerequisites:** FM 812, 815.

FM 921—TWO-PHASE FLOW—3 cr. (3 and 0)

The basic techniques of analyzing one-dimensional two-phase flows will be developed. Their applicability to a wide variety of practical problems will be demonstrated. Particular attention will be given to the current literature on the “Suspensions of Particles in Fluids.” **Prerequisites:** FM 801, FM 814 or consent of instructor.

FM 931—FREE SURFACE FLOW—3 cr. (3 and 0)

Study of classical hydrodynamics theories applied to deep and shallow wave problems. Special emphasis will be given to flows in estuaries. **Prerequisite:** FM 816.

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FM 951—BIO-FLUID MECHANICS—3 cr. (3 and 0)

Pulsating flow in artificial systems and steady flow in capillary distributed systems are studied. **Prerequisite:** FM 801.

**MATERIALS ENGINEERING**

S. F. Hulbert, Coordinator

Courses are offered leading to the Master of Science and Doctor of Philosophy Degrees

Students who possess a baccalaureate degree in engineering or science may be accepted for graduate study in the Materials Engineering program. Materials Engineering is an interdisciplinary program, where, by considering the general principles which govern the relationships between the structure and properties of materials, an understanding of the nature of materials is developed which leads to the solution of materials problems. To accomplish this understanding, the student studies chemistry, physics, mathematics, and the materials fields of thermodynamics, kinetics, mechanical properties, electronic properties, and crystallography in order to understand and be able to predict the properties of metals, ceramics, and polymers. Further study in specific areas of interest to the student is accomplished by taking courses in specialized materials fields and by performing a thorough investigation, resulting in an M.S. thesis or Ph.D. dissertation, in an area of materials research.

MatE 608—PRINCIPLES OF POLYMER SCIENCE I—3 cr. (3 and 0)
MatE 609—PRINCIPLES OF POLYMER SCIENCE II—3 cr. (3 and 0)
MatE 620—MECHANICAL PROPERTIES OF MATERIALS—3 cr. (3 and 0)
MatE 650—METALLIC CORROSION—3 cr. (2 and 3)
MatE 800—SEMINAR IN MATERIALS RESEARCH—1 cr. (1 and 0)

Presentation and discussion of special topics and original research in materials engineering. Required of all materials engineering graduate students each semester in residence. (Credit may be earned for more than one semester.)

MatE 802—RESEARCH TECHNIQUES IN PHYSICAL METALLURGY—3 cr. (2 and 3)

A study of advanced x-ray diffraction, field ion microscopy, electron microscopy, neutron diffraction, torsional pendulum, advanced optical microscopic methods, radioactive tracer techniques, methods employed to study metal structure, and interpretation of experimental data in terms of metallic structure.
MatE 805—PHYSICAL METALLURGY I—3 cr. (3 and 0)
A study of the structure and properties of the metallic state, the relation between structural characteristics of the metallic state, and the properties of metals. Topics covered will include: quantum states, free electron theory, wave mechanics, Fermi-Dirac distribution, zone theory, band theory, types of cohesion, metallic bonding, conductors, semi-conductors and insulators, paramagnetism, diamagnetism, ferromagnetism, antiferromagnetism, point defect, dislocations, anelasticity, solid state transformations, martensitic transformations, structure sensitive and insensitive properties, liquid to solid transformations.

MatE 806—PHYSICAL METALLURGY II—3 cr. (3 and 0)
A continuation of MatE 805

MatE 807—PHYSICAL PROPERTIES OF POLYMERS—3 cr (3 and 0)
Application of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, ultracentrifuge sedimentation, flow birefringence, polarimetry, spectroscopy, x-ray and electron diffraction, infrared adsorption, nuclear magnetic resonance, electron microscopy and other techniques to the characterization of polymers. The treatment of experimental data to obtain information on average molecular weight, molecular weight distribution, chemical heterogeneity and molecular configurations. Theory of rubberness. Rheology of concentrated solutions and polymer melts. Prerequisite: Permission of instructor.

MatE 808—MECHANICAL PROPERTIES OF POLYMERS—3 cr. (3 and 0)
Study of mechanical behavior of polymers related to molecules and aggregate structure. Viscoelastic responses of amorphous, crystalline and elastomeric materials in stress-strain tests, creep, stress relaxation and dynamic tests. Thermal properties, phase transition, electrical properties, surface properties, impact tests, and effect of fabrication and previous history on mechanical behavior. Prerequisite: Permission of instructor.

MatE 810—DIFFUSION IN SOLIDS—3 cr. (3 and 0)

MatE 811—KINETICS OF HETEROGENEOUS REACTIONS—3 cr. (3 and 0)
Theoretical and phenomenological aspects of heterogeneous solid-gas, solid-liquid, and solid-solid reactions. Factors influencing stability of phases as a function of composition, temperature, pressure, etc. Nucleation in solids. Rate of growth of one phase into another. Typical morphologies and their origin. Selected examples of different types of solid-solid reactions as typified by the formation of austenite and its decomposition. Recovery, recrystallization, and grain growth.
MatE 812—METALLURGICAL THERMODYNAMICS—3 cr. (3 and 0)
   The application of thermodynamic principles to reactions of metallic
materials with one another and with their surroundings. Development of
the thermodynamic properties of materials and the practical consequences
thereof. Special emphasis on graphical description of equilibria and the
reactions of metallic systems not at equilibrium.

MatE 814—SURFACE CHEMISTRY OF SOLIDS—3 cr. (3 and 0)
   Thermodynamic, kinetic, and chemical factors underlying surface and
interfacial phenomena. Intermolecular forces, orientation at interfaces
and the origins of surface tension. Capillarity and the effects of surface
curvature on bulk phase properties. Thermodynamics of adsorption at
interfaces; the Gibbs adsorption isotherm. Electrical phenomena at inter-
faces: origins of surface potential, structure of the diffuse double double
layer, eletrokinetic phenomena. Surface-active agents, contact angles,
spreading, and wetting phenomena.

MatE 815—APPLICATIONS OF HETEROGENEOUS EQUILIBRIA—3 cr.
   (3 and 0)
   Systematic development and geometric character of equilibrium dia-
grams with special emphasis on condensed phases. Considerations involve
the equilibrium and natural solidification of materials including synthe-
sis and analysis of microstructure.

MatE 820—DEFORMATION MECHANISMS IN SOLIDS—3 cr. (3 and 0)
   An introduction to the dislocation theory of solids. Mechanisms of
plastic deformation in single crystals and polycrystalline aggregates of
metals as well as non-metals will be studied. A study of ductile and
brittle fractures will be followed by an analysis of fatigue, creep and
stress corrosion cracking in metals. Prerequisite: MatE 304 or equivalent.

MatE 821—STRENGTHENING MECHANISMS IN SOLIDS—3 cr. (3 and 0)
   An introductory review of significant strengthening mechanisms will be
followed by a detailed study of the mechanisms leading to strengthening
by solid solution formation, strain hardening, martensitic transformations
and age and dispersion hardening. Developments in strengthening of
ionic solids, surface effects and fiber composites will also be studied.
Prerequisite: MatE 820.

MatE 831—QUANTUM THEORY OF METALS I—3 cr. (3 and 0)
   Systematic development and exploration of the wave mechanics of elec-
trons in metals. Discussion of many electron systems, metallic cohesion,
and Brillouin zones with an introduction to Fermi surfaces. Prerequisite:
Permission of instructor.

MatE 835—X-RAY METALLOGRAPHY—3 cr. (2 and 3)
   The practical utilization, through analysis, of diffraction phenomena as
based on the reciprocal lattice concept and with special emphasis upon
x-ray diffraction phenomena. Includes introduction to x-ray physics, crystallography, camera and diffractometer techniques, texture analysis, ordering, stress analysis, phase diagram synthesis and crystal defect effects. Laboratory emphasis is on equipment, pattern analysis, and problem solving techniques. **Prerequisites:** Phys 222 and Math 309, or their equivalents.

MatE 841—SINTERING AND RELATED PHENOMENA—3 cr. (3 and 0)

Manufacture of Metal Powders—physical and chemical principles involved, the theory and practice of pressing, sintering and pressureless sintering of powders; powder rolling, extrusion, hot-pressing, explosive forming; grain growth during sintering and its influence on mechanical properties; control of porosity and effect of porosity on mechanical properties; study of cermets, magnets and electrical equipment produced by powder metallurgy.

MatE 850—SPECIAL TOPICS IN MATERIALS ENGINEERING—3 cr. (3 and 0)

Directed study of advanced topics in Material Engineering intended to develop in depth areas of particular students interest. (Credit may be earned for more than one semester.) **Prerequisite:** Permission of instructor.

MatE 851—OXIDATION OF METALS AND ALLOYS—3 cr. (3 and 0)

Enumeration and description of the physical processes involved in the high-temperature oxidation of metals and alloys. Consideration of adsorption and solution of gases, nucleation and growth of oxides, defects in ionic lattices, diffusion in ionic solids, and their interplay in both classical and non-classical analyses of oxidation processes. **Prerequisite:** Permission of instructor.

MatE 891—RESEARCH

Credit to be arranged. (May be taken more than one semester.)

MatE 991—DOCTORAL RESEARCH

Credit to be arranged. (May be taken more than one semester.)

**MECHANICAL ENGINEERING**

J. C. Hester, Department Head

The Department of Mechanical Engineering offers the Master of Engineering, Master of Science, and Doctor of Philosophy degrees.

Students will be accepted into the graduate program with backgrounds in physics, applied mathematics, or branches of engineering other than mechanical engineering. For the Master's degrees, thesis and non-thesis
options are available. Programs of study may be followed which have
majors in mechanical design, thermal sciences, and automatic control.

ME 601—PRINCIPLES OF MECHANICAL ENGINEERING DESIGN—
3 cr. (3 and 0) FS

ME 602—MECHANICAL ENGINEERING ANALYSIS AND DESIGN—
3 cr. (1 and 6)

ME 604—PHYSICAL SYSTEMS ANALYSIS—3 cr. (3 and 0)

ME 606—PHYSICAL SYSTEM ANALYSIS AND DESIGN—3 cr. (3 and 0)

ME 608—COMPUTER-AIDED DESIGN—3 cr. (3 and 0)

ME 611—GAS POWER—3 cr. (3 and 0)

ME 622—PRINCIPLES OF TURBOMACHINERY—3 cr. (2 and 3)

ME 624—ENGINEERING ANALYSIS—3 cr. (3 and 0)

ME 680—METHODS OF OPERATION RESEARCH I—3 cr. (3 and 0)

ME 681—METHODS OF OPERATION RESEARCH II—3 cr. (3 and 0)

ME 684—ENGINEERING ECONOMIC ANALYSIS—3 cr. (3 and 0)

ME 801—THERMAL ENVIRONMENTAL ENGINEERING—3 cr. (3 and 0)

A study of the effects of the thermal environment upon people, processes,
and materials including a detailed analysis of the fundamental theories of
refrigeration, psychrometrics, heat and mass transfer processes with moist
air, periodic heat transfer in buildings, solar radiation, and cryogenics.

ME 810—ADVANCED THERMODYNAMICS—3 cr. (3 and 0)

A critical review of the first and second laws, entropy, and general
thermodynamic relations. The relations of entropy to probability and
communication theory. Non-steady flow processes. Selected topics. Pre-
requisite: One year of thermodynamics.

ME 811—GAS DYNAMICS II—3 cr. (3 and 0)

Concepts from thermodynamics, one-dimensional gas dynamics, one-
dimensional wave motion, normal and oblique shocks. Flow in ducts and
wind tunnels. Two-dimensional equation of motion. Small perturbation
theory. Prerequisites: ME 321 and ME 809.

ME 813—ADVANCED GAS DYNAMICS III—3 cr. (3 and 0)

Rayleigh-Janzen method; Prandtl-Glauert method; Hodograph method
and Karman Tsien approximation. Exact solutions in irrotational flow.
The method of characteristics of supersonic flows and shock tubes. Pre-
requisite: ME 811.
ME 815—KINETIC THEORY OF GASES—3 cr. (3 and 0)

ME 816—ENERGY CONVERSION—3 cr. (3 and 0)
A study of energy conversion by non-mechanical means. Thermionics, thermoelectric effects, fuel cells and magnetohydrodynamics will be covered. Prerequisite: Permission of instructor.

ME 824—PROPULSION SYSTEMS—3 cr. (3 and 0)
A study of thermochemical reaction processes employing both the microscopic and macroscopic method of analysis. Detail study of the chemical reaction process and the associated effect of chemical dissociation in the field of thermal jets and rockets. Prerequisite: ME 810.

ME 830—HEAT TRANSFER III—3 cr. (3 and 0)
Physical properties; derivation of general conduction equation; solutions for steady state and transient one-, two-, and three-dimensional cases. Radiation phenomena; solutions for multibody systems, including gases, liquids and solids. Prerequisites: ME 304 or equivalent, Math 208.

ME 831—HEAT AND MASS TRANSFER IV—3 cr. (3 and 0)
Derivation of continuity, momentum and energy equations for boundary layer flow: solutions for confined and external flow regimes, with and without phase change. Derivation of mass transfer relations; solutions for mass transfer in laminar and turbulent flow. Prerequisites: ME 304 or equivalent, Math 208.

ME 840—KINEMATICS II—3 cr. (3 and 0)

ME 842—ADVANCED MECHANICAL ENGINEERING DESIGN I—3 cr. (3 and 0)
Optimization techniques, decision theory, probabilistic approaches to design, and the principles of mechanical sciences applied to the analysis and design of machines, devices and engineering systems. Prerequisite: ME 401 or permission of instructor.

ME 843—ADVANCED MECH. ENGR. DESIGN II—3 cr. (3 and 0)
Continuation of ME 842. Prerequisite: ME 842.

ME 844—DYNAMICS OF ELASTIC MECHANICAL SYSTEMS—3 cr (3 and 0)
Dynamics of elastic mechanisms. Vibration analysis of elastic systems and components, including acoustical phenomena. Dynamic stress analy-
sis, shock and fatigue of system components. Synthesis and design of elastic systems. Analog simulation and digital computer solutions of problems in dynamic analysis.

ME 860—DYNAMIC PROGRAMMING—3 cr. (3 and 0)

The theory and methodology of dynamic programming. Topics included are calculus of variations, Bellman's Principle of Optimality, multistage optimization, countercurrent flow, and adaptive control. **Prerequisite:** Permission of instructor.

ME 861—NONLINEAR PROGRAMMING—3 cr. (3 and 0)

The theory and methodology of nonlinear programming including classical optimization techniques, separable programming stochastic programming, quadratic programming, integer programming, and gradient methods. **Prerequisite:** Permission of instructor.

ME 862—ANALYTICAL METHODS OF SYSTEMS ANALYSIS—3 cr. (3 and 0)

Application of selected mathematical topics from Operations Research and Systems Engineering such as linear algebra, graph, theory, topology, calculus of finite differences and operational calculus. **Prerequisite:** Permission of instructor.

ME 863—ADVANCED PHYSICAL SYSTEMS ANALYSIS I—3 cr. (3 and 0)


ME 864—ADVANCED PHYSICAL SYSTEMS ANALYSIS II—3 cr. (3 and 0)


ME 865—MODERN CONTROL THEORY I—3 cr. (3 and 0)

A detailed treatment of time domain (state space) analysis and design methods. Lyapunov's methods, discrete-time systems. Introduction to nonlinear problems. Computers frequently used to solve practical problems. Same course as EE 810.

ME 866—NONLINEAR AUTOMATIC CONTROLS—3 cr. (3 and 0)

A study of control systems in which nonlinear elements occur. In some cases these are used deliberately to achieve results not obtainable by other methods. Statistical design principles and sampled data systems are studied. Both graphical and analytical procedures are used; these include
the describing function, the method of harmonic balance, and the phase plane. The phase plane is used in giving insight to Lyapunov's second method of stability analysis. Same course as EE 814.

ME 867—CONTROL SYSTEM COMPONENTS—3 cr. (3 and 0)
A study of the control systems components from the standpoint of performance specification and for mathematical models and laboratory evaluation of components and systems by transient and frequency response methods. **Prerequisite:** ME 404 or equivalent.

ME 868—CONTROL OF AEROSPACE SYSTEMS—3 cr. (3 and 0)
Derivation of mathematical models of aerospace vehicles and systems. Vector equations based in inertial and body-axis reference frames. Euler equations. Guidance and control techniques and their application to the design of closed-loop control for aerospace systems. **Prerequisite:** ME 404 or EE 410 or equivalent.

ME 880—METHODS OF OPERATIONS RESEARCH—3 cr. (3 and 0)
Application and theory of selected topics from Operations Research such as linear programming, network analysis, game theory and simulation. **Prerequisites:** ME 299 and Math 313 or equivalent.

ME 881—ADVANCED METHODS OF OPERATIONS RESEARCH II—3 cr. (3 and 0)
A continuation of ME 880. Topics included are nonlinear programming, dynamic programming, queuing theory, and stochastic processes. **Prerequisite:** ME 880.

ME 882—RELIABILITY ENGINEERING—3 cr. (3 and 0)
The statistical study of reliability of life testing. The reliability of series, parallel, and non-serial systems are analyzed. **Prerequisites:** Math 402 or equivalent and permission of instructor.

ME 883—OPERATIONS SYSTEM SIMULATION I—3 cr. (3 and 0)
An introduction to feedback type simulation models and their use in analyzing business, governmental, and military programs. The concept of Industrial Dynamics is stressed along with the simulation language FORDYN. **Prerequisite:** Permission of instructor.

ME 884—OPERATIONS SYSTEM SIMULATION II—3 cr. (3 and 0)
Continuation of ME 883 with emphasis on Monte Carlo type simulation models. The simulation languages GPSS and GASP are used. **Prerequisite:** Permission of instructor.

ME 885—DESIGN AND ANALYSIS OF SIMULATION MODELS—3 cr. (3 and 0)
A theoretical study of the design and validation of simulation models of the operations research type. Included is an advanced analysis of the
The statistical properties of input data of these models. **Prerequisites:** ME 884 and ExST 805 or equivalent.

**ME 886—OPERATIONS RESEARCH IN PRODUCTION CONTROL—3 cr.**  
(3 and 0)

The latest techniques in scientific inventory management, scheduling, and forecasting are presented. Operations research, statistics, and computer methods are used along with case studies.

**ME 887—OPERATIONS RESEARCH AND PRODUCTION CONTROL II—3 cr. (3 and 0) S**

A continuation of ME 886. **Prerequisite:** ME 886.

**ME 888—APPLIED QUEUEING THEORY AND MARKOV PROCESSES—3 cr. (3 and 0)**

Analysis of single and multiple channel queues using mathematical queueing theory. Also, an introduction to Markov programming including rewards and value and policy iteration techniques. **Prerequisites:** Math 402 and ME 481.

**ME 891—RESEARCH—Credit to be arranged.**

**ME 893—SELECTED TOPICS IN MECHANICAL ENGINEERING—1-6 cr.**  
(1-6 and 0)

A comprehensive study of any topic in the field of Mechanical Engineering not covered in other courses. May be repeated for credit.

**ME 914—MAGNETOHYDRODYNAMICS—3 cr. (3 and 0) S**

Review of electrodynamics, conduction of electricity in gases. Equation of motion of magnetohydrodynamics. Solutions for special cases and various approximations. Magnetohydrodynamo waves and shocks. Application to propulsion. **Prerequisite:** Phys 541 or EE 521.

**ME 915—ENERGY CONVERSION—3 cr. (3 and 0)**

A study of energy conversion by non-mechanical means. Thermionics, thermoelectric effects, fuel cells and magnetohydrodynamics will be covered. **Prerequisite:** Permission of instructor.

**ME 930—CONDUCTION HEAT TRANSFER—3 cr. (3 and 0) S**

Physical properties; steady conduction in one and two-dimensional systems; periodic and transient systems; heat conduction with change in phase; moving heat sources. **Prerequisite:** ME 407.

**ME 931—CONVECTION HEAT TRANSFER—3 cr. (3 and 0) F**

Analytical solutions for laminar and turbulent boundary layers; similarity relations for heat convection; heat convection including change of phase. **Prerequisite:** ME 407.
ME 932—RADIATION HEAT TRANSFER—3 cr. (3 and 0) S
Radiation properties; analysis of radiation heat transfer; applications.
Prerequisite: ME 407.

ME 940—APPLIED PLASTICITY—3 cr. (3 and 0)
Theory of plasticity applied to the mechanics of metal-forming, theoretical and descriptive accounts of tube-shrinking, deep-drawing, extrusion, hot and cold rolling, forging and cutting.

ME 941—THEORY OF LUBRICATION AND WEAR—3 cr. (3 and 0)
Applications of the principles of fluid mechanics heat transfer and material behavior to problems associated with bearings, lubrication and rotor dynamics. Friction, wear, hydrostatic and hydrodynamic lubrication, boundary lubrication, thermal effects on bearings, theory of turbulent lubrication and other topics of current interest are presented.

ME 991—DOCTORAL RESEARCH—Credit to be arranged.

The catalog descriptions for the following interdepartmental fluid mechanics courses are given on pages 112 to 114:

FM 801—FOUNDATION OF FLUID MECHANICS—3 cr. (3 and 0) F

FM 811—EXPERIMENTAL FLUID MECHANICS—3 cr. (2 and 3) F

FM 812—THEORY OF INCOMPRESSIBLE IDEAL FLOW—3 cr.
(3 and 0) S

FM 814—TURBULENT BOUNDARY LAYER—3 cr. (3 and 0) S

FM 815—NUMERICAL METHODS IN FLUID MECHANICS—3 cr.
(3 and 0) F

FM 816—FLOW IN OPEN CHANNELS—3 cr. (3 and 0) S

FM 817—NON-NEWTONIAN FLOW—3 cr. (3 and 0) S

FM 841—SEMINAR—1 cr. (1 and 0) S, F

FM 901—APPLIED HYDRODYNAMICS—3 cr. (3 and 0)

FM 921—TWO-PHASE FLOW—3 cr. (3 and 0)

FM 931—FREE SURFACE FLOW—3 cr. (3 and 0)

FM 951—BIO-FLUID MECHANICS—3 cr. (3 and 0)
The Master of Science, Master of Engineering and Doctor of Philosophy degrees are offered.

Water Resources Engineering is an interdisciplinary graduate program encompassing several departments and colleges within the University. The areas of emphasis within the program are water resources planning and management, surface water systems, ocean and coastal resources, water-soil transport systems, and water resources surveillance systems. The program is designed to provide training to meet the modern water resources challenges encountered in careers with industry, government agencies, and consulting firms.

The Ph.D., M.S., and M.Engr. curricula in Water Resources Engineering are designed to enhance and build upon the student's previous engineering or science background. The program is directed by a core faculty containing representatives from most of the departments in the Engineering College as well as several supporting departments in other colleges within the University. The major and minor work can be selected from the offerings of a wide variety of departments in addition to the Water Resources Engineering course listing. Both thesis and non-thesis options are available for the Master of Science degree.

WRE 660—PHYSICAL OCEANOGRAPHY—3 cr. (3 and 0)

WRE 661—OCEANOGRAPHICAL ENGINEERING—3 cr. (3 and 0)

WRE 811—CLIMATOLOGY—3 cr. (3 and 0)

Study of the physical factors that affect climate and the development of the general circulation patterns of the world. The climates of the world are discussed and related to the activities of man. Prerequisite: Permission of instructor.

WRE 812—METEOROLOGY—3 cr. (3 and 0)

A course designed to provide the student with a physical description of the atmosphere and its interactions with the earth. Topics include condensation and precipitation processes, energy exchange, wind systems, and weather development.

WRE 822—WATER MOVEMENT IN SOILS—3 cr. (3 and 0)

A study of the theory and principles of water movement in soils. Principal topics include theory and application of flow of water through soil in unsaturated and saturated states, flow nets and seepage forces, and the fundamentals of engineering design with respect to ground water problems and soil moisture relationships. Prerequisite: Math 306 or equivalent.
WRE 861—HYDROLOGY—3 cr. (3 and 0)

The principles concerning the occurrence of natural water and engineering practices in dealing with it in the design of facilities for water supply, flood control, power development and other purposes. Prerequisite: Permission of instructor.

WRE 862—ADVANCED HYDROLOGY—3 cr. (3 and 0)

Special work to strengthen the student's background in modern methods. Emphasis is laid on evaporation, infiltration and the synthetic hydrograph. Prerequisite: WRE 861.

WRE 864—GROUND-WATER HYDROLOGY—3 cr. (3 and 0)

A study of the occurrence and movement of water beneath the earth's surface, with emphasis on development and management of ground-water as part of the total resource. Prerequisite: Permission of instructor.

WRE 865—HYDROLOGY I—3 cr. (3 and 0)

Study of the hydrologic cycle as a hydrologic system. Most of this course deals with deterministic hydrology. All aspects of physical hydrology are treated with emphasis on a balanced approach to ground water hydrology and surface water hydrology. Other topics include meteorology, infiltration, soil moisture, and evapotranspiration. Probability analysis and partial system synthesis by unit hydrograph techniques are also studied. Prerequisite: Permission of instructor.

WRE 866—HYDROLOGY II—3 cr. (3 and 0)

A continuation of WRE 865. A portion of the semester deals with deterministic hydrology with emphasis on parametric hydrology including system synthesis and correlation analysis. Statistical hydrology, including time series analysis and stochastic hydrology, makes up the second part of the course. Prerequisite: WRE 865 or permission of instructor.

WRE 870—STREAM AND ESTUARINE ANALYSIS—3 cr. (3 and 0)

An integrated survey of the principal physical, chemical, and biological processes and relationships which exist in streams and estuaries. Emphasis is placed upon the estuarine environment, with free-flowing streams considered as a special case, and the several mechanisms which describe the transport of conservative and non-conservative materials through the estuarine system. The estuary is considered as a resource, and techniques for its management are presented. Prerequisite: EM 320 or permission of instructor.

WRE 875—RIVER BASIN PLANNING—3 cr. (3 and 0)

A comprehensive study of river basin planning which considers historical development, current practice, as well as new approaches and tech-
niques. Emphasis is on the formulation of objectives and constraints, resolution of conflicting demands, institutional aspects, and plan implementation. Water quality and water quantity, and their interactions, are included in the planning process. **Prerequisite:** Permission of instructor.

WRE 876—WATER RESOURCES SYSTEMS—2 cr. (2 and 0)

A broad consideration of the water resources system area. Particular emphasis is given to the application of modern systems engineering and operations research techniques and their use in the design, operation, and management of water quality and water quantity systems. Among the types of systems considered are reservoirs and regional pollution control systems. **Prerequisites:** EE 330 and ME 480 or permission of instructor.

WRE 881—SPECIAL PROBLEMS IN WATER RESOURCES ENGINEERING—1-4 cr. (1-4 and 0)

Individual directed study in some phase of water resources engineering. Emphasis may be on water quality, water quantity, the social-economic-political aspects or a blend thereof. The special problem topic is designed to utilize knowledge gained in formal course work and to further prepare the student for his particular professional goals.

WRE 883—SELECTED TOPICS IN WATER RESOURCES ENGINEERING—1-3 cr. (1-3 and 0)

An in-depth study of any topic in the broad field of water resources engineering which is not considered in existing courses. Emphasis is placed upon current developments in water resources. Topics covered will vary as necessary to keep pace with recent developments and to satisfy emerging needs in professional practice. (May be taken more than one semester.)

WRE 891—RESEARCH—Credit to be arranged.

WRE 991—DOCTORAL RESEARCH—Credit to be arranged.
College of Forest and Recreation Resources

W. H. D. McGregor, Dean

FORESTRY

R. M. Allen, Department Head

The Department of Forestry offers the Master of Science and Master of Forestry degrees.

The candidate for a Master of Science or Master of Forestry degree in Forestry should hold a Bachelor of Forestry degree from a forestry school, accredited by the Society of American Foresters. Without such a degree additional course work may be required of the candidate by his departmental advisers and graduate committee to insure adequate preparation in his specialty field. For the Master of Forestry degree a minimum of thirty-six semester hours of graduate course work must be completed with at least eighteen of the required hours from courses numbered 700* or above.

For 601—LOGGING AND MILLING—4 cr. (2 and 6) S
For 602—DENDROMETRY—3 cr. (2 and 3) S
For 604—FOREST ECONOMICS—3 cr. (3 and 0) S
For 606—WOOD AND WOOD FIBER IDENTIFICATION—1 cr. (0 and 3) S
For 607—ELEMENTS OF FORESTY—3 cr. (2 and 3) F, S
For 608—AERIAL PHOTOGRAPHS IN FORESTRY—3 cr. (2 and 3) F
For 610—SILVICULTURE—4 cr. (3 and 3) S
For 612—FOREST PROTECTION—2 cr. (2 and 0) S
For 614—MANAGEMENT PLANS—1 cr. (0 and 3) S
For 616—FOREST POLICY AND ADMINISTRATION—2 cr. (2 and 0) S
For 617—FOREST REGULATION—4 cr. (3 and 3) F
For 618—FOREST VALUATION—3 cr. (3 and 0) S
For 620—FOREST PRODUCTS—3 cr. (2 and 3) F

* Applies to courses taken prior to August 15, 1970. Courses taken after that date must be numbered 800 or above in order to satisfy this requirement.
For 621—WOOD PROPERTIES I—3 cr. (2 and 3)
For 622—WOOD PROPERTIES II—3 cr. (2 and 3)

For 801—DATA PROCESSING IN FORESTRY PROBLEMS—3 cr. (2 and 3) F
Illustration, analysis and discussion of specific approaches used in forestry problems for handling, arranging and analyzing large volumes of field data and for presentation in concise, meaningful form.

For 802—DENDROMETRY—3 cr. (2 and 3) S
A continuation of For 602 with special emphasis on specialized sampling techniques and statistical methods often required only in forestry, on the compilation of timber volume tables, and on forest survey problems. Prerequisites: ExSt 401, For 602 or permission of instructor.

For 803—PHOTO—INTERPRETATION—3 cr. (2 and 3) F
Current methodology in aerial photo interpretation techniques, flight plans, taking and processing aerial photographs, and using the aerial photographs in timber inventories and cruising. Prerequisites: ExSt 401, For 602 or permission of instructor.

For 804—FOREST ECONOMICS—3 cr. (2 and 3) S
Examination, discussion and application of economic principles to forestry problems in the use of land, labor and capital. A study of the use of theory to problems of resource allocation and efficiency in forest management. Prerequisites: For 604, 618, or permission of instructor.

For 805—COST STUDIES IN HARVESTING AND PROCESSING—3 cr. (2 and 3) F
An evaluation of selected cost studies in harvesting and processing problems. Major emphasis to be placed on the recognition, measurement, and analysis of the individual elements of cost which constitute total cost of an operation. Current problem data will be collected and analyzed and problem solutions will be presented in the form of written reports. Prerequisites: For 601, or permission of instructor.

For 806—MULTIPLE-USE MANAGEMENT—3 cr. (3 and 0) F
A study of the interplay of economics, public relations and political expediency and forest ecosystem in deciding the order of preference of various possible land uses, particularly with reference to privately owned forest land. Prerequisites: For 617, 618, or permission of instructor.

For 807—SPECIAL PROBLEMS IN FORESTRY— (Credit to be arranged) F, S, SS
Special problems in forestry research, unrelated to a thesis, but designed for training in research methods.

For 891—RESEARCH—(Credit to be arranged) F, S, SS
Courses are offered leading to the Master of Arts degree.

Students desiring to enroll in this curriculum will need at least twelve hours of undergraduate economics to include a course in intermediate price theory, mathematics to include some calculus, and a course in statistics. Where necessary the economic theory, mathematics and statistics courses may be taken at Clemson before or early in the program.

The graduate program will include one course in quantification and one in statistics as part of the major.

A reading knowledge of one modern foreign language is required for completion of the Master of Arts degree. Additional information about this requirement may be found elsewhere in this Bulletin.

Econ 603—DEVELOPMENT OF ECONOMIC THOUGHT—3 cr. (3 and 0) F, S
Econ 604—COMPARATIVE ECONOMIC SYSTEMS—3 cr. (3 and 0)
Econ 607—NATIONAL INCOME AND EMPLOYMENT ANALYSIS—3 cr. (3 and 0) F, S
Econ 610—ECONOMIC DEVELOPMENT—3 cr. (3 and 0)
Econ 612—INTERNATIONAL TRADE—3 cr. (3 and 0) S
Econ 613—INTERNATIONAL FINANCE—3 cr. (3 and 0)
Econ 616—DEVELOPMENT OF THE MODERN ECONOMY—3 cr. (3 and 0) F
Econ 619—ECONOMICS OF DEFENSE—3 cr. (3 and 0)
Econ 620—ECONOMICS OF TAXATION—3 cr. (3 and 0) F
Econ 621—URBAN ECONOMICS—3 cr. (3 and 0)
Econ 622—MONETARY THEORY AND POLICY—3 cr. (3 and 0)
Econ 624—INDUSTRIAL ORGANIZATION—3 cr. (3 and 0) F
Econ 800—ADVANCED ECONOMIC ANALYSIS—3 cr. (3 and 0)
Econ 802—ADVANCED ECONOMIC CONCEPTS AND APPLICATIONS I
—3 cr. (3 and 0)
A progressively more rigorous development of price theory under alternative product and resource market structures. **Prerequisite:** Permission of the Instructor.

Econ 803—ADVANCED ECONOMIC CONCEPTS AND APPLICATIONS II—3 cr. (3 and 0)
A continuation of Econ 802 consisting of selected topics, such as the demand for capital, industrial structures, labor markets, and monetary phenomena, developed through the intensive examination of current literature. **Prerequisite:** Econ 802.

Econ 811—SEMINAR IN LABOR ECONOMICS—3 cr. (3 and 0)
A study of wage and employment theory, labor markets, labor history and current problems in labor and man-power economics.

Econ 812—SEMINAR IN THE DEVELOPMENT OF ECONOMIC THOUGHT—3 cr. (3 and 0) F
Intensive study of selected topics concerning the historical development of economic ideas, doctrines, and theories. Students are expected to conduct original research in areas related to the topic of the seminar.

Econ 813—SEMINAR IN PUBLIC GOODS AND ECONOMIC WELFARE—3 cr. (3 and 0) F, even numbered years.
A study in pricing and distribution which emphasizes their effects upon economic welfare. Particular emphasis is given to those goods allocated by government purchase for joint consumption and to those distributed by rationing. Alternate plans for allocating public goods are discussed. **Prerequisite:** Econ 314 or equivalent.

Econ 820—SEMINAR IN THE ECONOMICS OF TAXATION—3 cr. (3 and 0)
A study of the effects of particular taxes on particular prices, outputs and economic activity. Students will select specific taxes and prepare papers dealing with theoretical discussions of the tax and empirical results that have come from the imposition of the tax in various forms.

Econ 821—ECONOMIC THEORY I—3 cr. (3 and 0) F
A study of the use of theory in the analysis of problems and behavior of industries, firms, and consumers under various market conditions.

Econ 822—ECONOMIC THEORY II—3 cr. (3 and 0) S
A study of macroeconomic theory involving static and dynamic models and their use in the analysis of economic problems and policies.

Econ 831—SEMINAR IN URBAN DEVELOPMENT ECONOMICS—3 cr. (3 and 0)
A review of current studies in the emerging area of urban economics with special focus on development. Background lectures will be given on
the historical, empirical, and theoretical aspects of urban development. Students will identify areas for individual research to be conducted, completed, and reported during the progress of the semester.

Econ 891—RESEARCH—Credit to be arranged.

Econ 900—SEMINAR IN ADVANCED ECONOMIC THEORY—3 cr. (3 and 0) F, odd numbered years.

A study of selected topics that have been and are being discussed in the scholarly journals.

ENGINEERING MANAGEMENT

C. H. Whitehurst, Jr., Chairman

Courses are offered leading to the Doctor of Philosophy degree.

The Department of Industrial Management offers the Ph.D. in engineering management in cooperation with the College of Engineering.

Although entering students are accepted from diverse undergraduate backgrounds, each is required as a prerequisite to full graduate standing to have completed or to schedule in his first semester, basic courses in economics, accounting, statistics and calculus. In addition, students must have completed or schedule during the first year of enrollment, one or more courses in engineering communication and design.

The purpose of this degree is to develop a high level "manager-scholar" capable of applying the most advanced concepts and methods of management science, administrative theory and research techniques to engineering and scientific projects and enterprises. The curriculum also provides an unexcelled background for those interested in pursuing a university teaching career in the fields of industrial and engineering management.

EMgt 910—SEMINAR IN PRODUCTION MANAGEMENT—2 cr. (2 and 0)

This seminar is devoted to a detailed study of new methodological developments, both analytical and philosophical, in the field of production management. The orientation is toward development of the theory of management science and the converting of management theory to practice while considering the behavioral and economic aspects of the problem. Prerequisite: Permission of instructor.

EMgt 911—SEMINAR IN DECISION THEORY—2 cr. (2 and 0) F

The individualistic approach of micro economic theory is utilized in an exploration of decision making, interaction and consensus of individuals as they function in groups. Recent theoretical, legal, and empirical litera-

Note: All candidates for the Ph.D. degree in engineering management are required to take responsibility for and instruct an undergraduate course in either management, economics, engineering or mathematics.

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ture which has been inspired by political markets is intensively critiqued. The manager's confrontation of the dynamics of consent—both within and in the firm's negotiations with public bodies—is emphasized.

EMgt 912—SEMINAR IN FINANCE—3 cr. (3 and 0) S

The seminar in finance involves original research in the collection, analysis, and reporting of financial data as supplemented by published material. Evaluation of individual student projects in particular and financial problems in general is achieved through discussion around a conference table. **Prerequisite:** Mgt 802 and permission of instructor.

EMgt 913—SYSTEMS-ANALYSIS—3 cr. (3 and 0)

The industrial firm is examined from the premise that the functional areas of management-marketing, research, production, and investment are highly interrelated and that this "system" can best be understood by examining the relationships between policies, firm structure and management decisions. Several simulation type models will be built to demonstrate a systems behavior through time as these components are varied.

EMgt 991—DOCTORAL RESEARCH—Credit to be arranged.

**MANAGEMENT**

_C. H. Whitehurst, Jr., Department Head_

Courses are offered leading to the Master of Science degree. The Department also administers the program leading to the Doctor of Philosophy Degree in Engineering Management.

Although entering graduate students are accepted from diverse undergraduate backgrounds, each is required as a prerequisite to full graduate standing to have completed, or to schedule in his first semester, basic courses in economics, accounting, statistics, and calculus.

All students enrolled in the management curriculum must take the core courses Mgt 800, 801, 802, 803 (or 805), 804, and Mgt 816 or Econ 811.

A thesis or non-thesis option is allowed. For the non-thesis program at least one formal paper or report of substantial content evidencing the student's ability to do original effective writing is required. It must be deemed satisfactory by the graduate faculty of the Department of Industrial Management.

Prior to the end of their second semester of graduate work all students must successfully complete the computer operation and programming course offered to faculty and graduate students by the Clemson University Computer Center or successfully complete a university level computer course and write several proven programs. In the latter option the student's major advisor will ultimately decide when the requirement is met.
The Department of Industrial Management periodically schedules a number of its regular graduate courses in the late afternoons and evenings. Thus, while no night degree program is offered as such, a route toward the Masters degree is available for the industrial manager/engineer who is employed on a full time basis.

Acct 605—ADVANCED FEDERAL TAXES—3 cr. (3 and 0)
Acct 610—EXECUTIVE BUDGETING AND CONTROL—3 cr. (3 and 0) FS
Acct 611—ADVANCED ACCOUNTING—3 cr. (3 and 0)
Acct 615—AUDITING—3 cr. (3 and 0)
Hosp Adm 610—HOSPITAL INTERNSHIP—3 cr. (0 and 9)
Hosp Adm 800—THE FUNCTION AND ORGANIZATION OF HOSPITALS AND HEALTH SERVICES ADMINISTRATION—3 cr. (3 and 0)

An overview of organization, function, place in the community and society of hospitals, individual health services and public health services. This course in conjunction with an administrative internship will prepare the student for major responsibilities in the area of health service administration.

IM 601—MARKETING ANALYSIS I—3 cr. (3 and 0) FS
IM 602—OPERATIONS PLANNING AND CONTROL—3 cr. (0 and 3) FS
IM 604—MANAGERIAL ECONOMICS—3 cr. (3 and 0) FS
IM 605—ECONOMICS OF TRANSPORTATION—3 cr. (3 and 0) F
IM 606—THEORY OF INDUSTRIAL LOCATION—3 cr. (3 and 0) S
IM 608—WORK SIMPLIFICATION AND STANDARDIZATION—3 cr. (2 and 3) FS
IM 612—MARKETING ANALYSIS II—3 cr. (3 and 0) S
IM 615—MANAGEMENT DECISION MAKING—3 cr. (3 and 0) F
IM 616—MANAGEMENT OF HUMAN RESOURCES—3 cr. (3 and 0) F
IM 617—MANUFACTURING LOGISTICS—3 cr. (3 and 0) F
IM 620—MANAGEMENT OF DEFENSE EXPENDITURES—3 cr. (3 and 0) F
MgtSc 611—INTRODUCTION TO ECONOMETRICS—3 cr. (3 and 0)
MgtSc 613—MANAGEMENT SCIENCE I—3 cr. (3 and 0) F
MgtSc 614—STATISTICAL ANALYSIS—3 cr. (3 and 0) F
Mgt 800—ADVANCED MANAGEMENT SIMULATION—1 cr. (0 and 3) FS

The student is introduced to management game literature, writes the computer program for a minimum of two case book simulations and is required (as a class project) to conceive and write the computer program for an original management game or alternatively to severely critique an already-published game. The purpose of this course is to insure that the student is thoroughly familiar with the technique and criticisms of management games as educational adjuncts.

Mgt 801—QUANTITATIVE ECONOMIC ANALYSIS—3 cr. (3 and 0)

A mathematical formulation of economic theory with respect to its applications in management decision making. Emphasis is placed on analytical ideas and the rigorous techniques of economic analysis. Prerequisite: IM 404 (704) or permission of instructor.

Mgt 802—FINANCE—3 cr. (3 and 0) F

The analysis of the financial condition of business firms as a means of recognizing current and long-term financial needs. Emphasis on selection of the most feasible actions necessary to secure the best possible financing under varied circumstances.

Mgt 803—OPERATIONS MANAGEMENT—3 cr. (3 and 0)

A rigorous study of the applications of modern statistical technique to give the student an understanding of the theory and application of such techniques as evolutionary operations, exponential smoothing, cumulative sums, adaptive controls, critical path methods, response surfaces and fractional factorial experiments. Prerequisites: Math 405 and IM 402 or equivalent.

Mgt 804—MANAGERIAL POLICY—3 cr. (3 and 0) F

A course in management policy making. The course emphasizes determining objectives and developing sound policies for achieving them. Managerial Policy builds upon and integrates the other graduate courses. The case method is used extensively. Written and oral presentations.

Mgt. 805—QUALITY CONTROL—3 cr. (3 and 0)

The organization and management of the quality function in industry are covered. Statistical techniques employed in industrial quality control are emphasized, including recent developments in this field. Prerequisite: Prior satisfaction of the Statistics requirement (by course or exam) of the Industrial Management Department.

Mgt Sc 806—REGIONAL SCIENCE METHODS—3 cr. (3 and 0) F

This course examines the major contributions to regional growth theory, regional development and planning. A number of topics are considered, including: location, theory, theory of spatial organization, the role of resources and migration in regional development, the definition of regions, the concept of planning regions, objectives and measures of regional de-
development, regional investment criteria, regional input-output analysis, regional linear programming model, and regional income and product accounts. Attention is focused on major policy questions as well as the analytical tools of regional science. **Prerequisite:** Permission of instructor.

**Mgt Sc 807—ECONOMETRIC METHODS I—3 cr. (3 and 0)**

The role and uses of statistical inference in the analysis of economic phenomena; the problem of spanning the gap from an economic model to its statistical counterpart; measurement problems and their solution arising from the statistical model and the nature of the data; limitations and interpretation of results of economic measurement from statistical techniques. Topics include the problems of specification, aggregation, identification, multicollinearity and autocorrelation. Attention is also given to expectations models and simultaneous stochastic equations. **Prerequisite:** Math 405 (705) 411 (711), or permission of instructor.

**Mgt Sc 808—ECONOMETRIC METHODS II—3 cr. (3 and 0) S**

A continuation of Mgt Sc 807 with emphasis on current economic models and estimation procedures.

**Mgt 811—ADVANCED MARKETING ANALYSIS—3 cr. (3 and 0) F**

A seminar in marketing in which the topic is approached from the viewpoint of highest level management. The decision-making process in this respect will be treated extensively. **Prerequisite:** IM 401 or permission of instructor.

**Mgt Sc 812—MANAGEMENT SCIENCE II—3 cr. (3 and 0)**

A continuation of Management Science I; both deterministic and probabilistic models will be considered, and topics include dynamic programming, integer programming, nonlinear programming, queueing theory, Markov processes, and simulation. Attention will also be given to investment analysis, and to business and industrial applications of mathematical programming. **Prerequisite:** MgtSc 413, or consent of instructor.

**Mgt 816—MANAGEMENT OF HUMAN RESOURCES II—3 cr. (3 and 0) S**

A more advanced consideration of the topics covered in Mgt 716. **Prerequisite:** IM 416 (Mgt 716) or permission of instructor.

**Mgt 891—THESIS RESEARCH—Credit to be arranged.**

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**TEXTILE CHEMISTRY**

**J. L. Lundberg, Head, Textile Department**

The Master of Science degree is offered. For Ph.D. requirements see Ph.D. in Chemistry with Major in Textile Chemistry.
Candidates with bachelors' degrees in textile chemistry, textile science, the physical or life science, engineering, or related disciplines will be accepted into this program provided that they have training in chemistry, physics and mathematics. The student's major area of study normally will be in polymer chemistry, fiber chemistry, the chemistry of dyeing and/or finishing of fibers and textiles, or the chemistry of composite systems. His minor area of study usually will be in chemistry, physics, engineering, life sciences, or mathematics. Each candidate for the Master of Science degree will conduct an original, independent, scientific investigation in his major area. He will report the results and conclusions from his research in his thesis.

**TC 615—INTRODUCTION TO POLYMER SCIENCE AND ENGINEERING**
—3 cr. (3 and 0)

**TC 616—CHEMICAL PREPARATION OF TEXTILES**—3 cr. (2 and 3)

**TC 657—DYEING AND FINISHING I**—3 cr. (3 and 0)

**TC 658—DYEING AND FINISHING II**—3 cr. (3 and 0)

**TC 666—TEXTILE UNIT OPERATIONS**—3 cr. (3 and 0)

**TC 675—CELLULOSE CHEMISTRY**—2 cr. (2 and 0)

**TC 811—POLYMER SCIENCE I**—3 cr. (3 and 0)

The chemistry, preparation, kinetics and polymerization, mechanisms of polymerizations and reactions, structures, properties, and fabrication of polymers, copolymers, terpolymers, etc., with emphasis on fiber forming polymers and polymer solution chemistry and methods for molecular characterization, are considered in depth.

**TC 812—POLYMER SCIENCE II**—3 cr. (3 and 0)

Sorption phenomena are treated by the generally applicable theory of molecular clustering. Light scattering from solutions and from fibers, molecular weight (MW) and MW distributions, transport properties, viscoelastic behavior, fiber drawing, and degradation of polymers are considered in depth emphasizing inter-relationships of properties with particular attention to fiber forming polymers.

**TC 821—CHEMISTRY OF NATURAL POLYMERS**—3 cr. (3 and 0)

The chemistry of natural polymers with emphasis on cellulose and fibrous proteins. Detailed study of monosaccharides serves as the basis for study of cellulose and related polysaccharides including degradation and substitution reactions. Globular and fibrous proteins are treated in terms of structure, conformation, and chemistry of constituent amino acids.
TC 831—PHYSICAL CHEMISTRY OF DYEING—3 cr. (3 and 0)
An advanced treatment of the fundamental properties of dye systems. The use of kinetic and thermodynamic data to correlate dye and fiber structure with proposed dyeing mechanisms, kinetics of diffusions in dyeing processes, theory of color and its use in dyeing operations. Prerequisite: TC 457.

TC 891—RESEARCH—Credit to be arranged.

TEXTILE SCIENCE

J. L. Lundberg, Head, Textile Department

The Master of Science degree is offered.

Candidates with bachelor's degrees in textile chemistry, textile science, the physical or life sciences, engineering, or related disciplines will be admitted to this program. A student's chosen major area of study usually will be in fiber science, polymer science, or textile technology. His minor area of study normally will be in the life or physical sciences, engineering, mathematics, or management. Each student will complete an original, independent, scientific or technical investigation and report his results and conclusions in his thesis.

Text 601—POLYMER AND FIBER MECHANICS—3 cr. (3 and 0)
Text 603—FIBER PROCESSING III—3 cr. (2 and 3)
Text 604—FIBER PROCESSING IV—3 cr. (2 and 3)
Text 611—FABRIC DEVELOPMENT III—3 cr. (2 and 3)
Text 612—FABRIC DEVELOPMENT IV—3 cr. (2 and 3)
Text 621—FIBER SCIENCE—3 cr. (2 and 3)
Text 622—PROPERTIES OF TEXTILE STRUCTURES—3 cr. (2 and 3)
Text 626—INSTRUMENTATION—3 cr. (3 and 0)
Text 640—COLOR SCIENCE—3 cr. (3 and 0)
Text 660—TEXTILE PROCESSES—3 cr. (3 and 0)
Text 821—FIBER PHYSICS I—3 cr. (3 and 0)

Concepts and theories of fiber structure. Methods of investigating natural and man-made fiber structure. Examination of various interpretations of fiber structure which are based upon the methods used to investigate structure. Analytical and empirical models of fiber structure.

Text 822—FIBER PHYSICS II—3 cr. (3 and 0)

A study of the relationships between and dependence upon microstructural and macrostructural phenomena in polymeric fibers, introduction to
anisotropic elasticity, tensile and shear behavior, fracture, dynamic properties, viscoelasticity and fatigue. **Prerequisite:** Text 821.

Text 830—TEXTILE PHYSICS—3 cr. (3 and 0)

The physical principles necessary to study of the properties of fibers, yarns, and fabrics are examined in some depth. Electromagnetic and mechanical properties of textile materials and instrumental methods for measuring properties are analyzed in some detail.

Text 835—TEXTILE STRUCTURES I—3 cr. (3 and 0)

A study in depth at the pioneering works relating fiber properties to yarn properties: yarn geometry, fiber arrangements in twisted yarns, extension and breakage of continuous filament yarns, and deformation of staple fiber yarns.

Text 836—TEXTILE STRUCTURES II—3 cr. (3 and 0)

A study in depth of the pioneering works relating fiber properties to yarn properties: analysis of cloth geometry and mechanics, conventional yarn bearing fabrics, tensile properties of woven structures, fabric shear and buckling, and the geometry and mechanics of knitted fabrics.

Text 837—COMPOSITE STRUCTURES—3 cr. (3 and 0)

Advanced study of the structures and properties of composite structures with particular emphasis on the fundamentals of synthetic sheet materials and analysis of the chemical and physical structure of laminated sheets, sponge, film, and molded sheet materials.

Text 840—SPECTROPHOTOMETRY—3 cr. (3 and 0)

Application of modern instruments and computers to color matching and control of color in the industrial environment.

Text 866—FIBER FORMATION—3 cr. (3 and 0)

The formation of fibers by wet, dry, and melt spinning are studied in depth with emphasis on rheology of solutions and melts, fiber structure, stretching and drawing processes, and the inter-relationships of polymer properties and processes that determine fiber properties.

Text 870—ADVANCES IN TEXTILE MANUFACTURING—3 cr. (3 and 0)

Comparisons among cotton, woolen, and worsted processing systems with respect to suitability to fiber characteristics, processing of fiber blends, modern yarn production, non-woven fabrics, and the latest developments in textile machinery.

Text 880—SELECTED TOPICS—3 cr. (3 and 0)

Comprehensive studies of selected topics not covered in other courses in Textile Chemistry or Textile Science.

Text 891—RESEARCH—Credit to be arranged.
The English Department offers the Master of Arts degrees.

A student desiring to pursue graduate study with a major in English should present at least twelve hours of undergraduate credit in English above the sophomore level, including a course each in the English language, Shakespeare, and American literature. A student seeking the Master of Education degree with emphasis in English must present at least six hours of undergraduate credit in English above the sophomore level. A student who does not meet these requirements may seek admission as a provisional graduate student. Variations from the MA requirements are these: a final written examination and no thesis.

In addition to the requirements of the Graduate School, candidates for the Master of Arts degree in English must satisfy the following departmental requirements:

1. A reading knowledge of an approved foreign language.
2. Demonstrated proficiency in composition.
4. Completion of Engl 801 (Obligatory for graduate assistants only).
5. A preliminary oral examination.

Engl 602—THE ENGLISH LANGUAGE—3 cr. (3 and 0) S
Engl 604—STRUCTURE OF MODERN ENGLISH—3 cr. (3 and 0) F, S
Engl 605—SHAKESPEARE—3 cr. (3 and 0) F, S
Engl 606—SHAKESPEARE—3 cr. (3 and 0) S
Engl 609—CHAUCER—3 cr. (3 and 0) F
Engl 613—CLASSICAL DRAMA—3 cr. (3 and 0) F
Engl 616—MODERN DRAMA—3 cr. (3 and 0) S
Engl 622—A SURVEY OF AMERICAN LITERATURE—3 cr. (3 and 0)
Engl 623—A SURVEY OF AMERICAN LITERATURE—3 cr. (3 and 0) F
Engl 624—A SURVEY OF AMERICAN LITERATURE—3 cr. (3 and 0) S
Engl 625—THE ROMANTIC REVIVAL—3 cr. (3 and 0) F
Engl 627—VICTORIAN POETRY—3 cr. (3 and 0) S
Engl 629—NINETEENTH CENTURY PROSE—3 cr. (3 and 0)
Engl 631—THE RESTORATION AND EIGHTEENTH CENTURY—3 cr.
(3 and 0) S
Engl 635—SOUTHERN LITERATURE—3 cr. (3 and 0) F
Engl 636—MILTON AND HIS AGE—3 cr. (3 and 0) S
Engl 637—THE EIGHTEENTH CENTURY ENGLISH NOVEL—3 cr.
(3 and 0) F
Engl 638—TWENTIETH CENTURY POETRY—3 cr. (3 and 0) F
Engl 639—TWENTIETH CENTURY FICTION—3 cr. (3 and 0) S
Engl 640—APPLIED LITERARY CRITICISM—3 cr. (3 and 0) S
Engl 641—A SURVEY OF WORLD LITERATURE—3 cr. (3 and 0) F
Engl 642—A SURVEY OF WORLD LITERATURE—3 cr. (3 and 0) S
Engl 643—SEVENTEENTH CENTURY POETRY AND PROSE—3 cr.
(3 and 0)
Engl 645—RENAISSANCE NON-DRAMATIC LITERATURE—3 cr.
(3 and 0)
Engl 646—TUDOR-STUART DRAMA—3 cr. (3 and 0)
Engl 647—THE AMERICAN NOVEL—3 cr. (3 and 0)
Engl 661—STUDIES IN ENGLISH LITERATURE TO 1700—3 cr. (3 and 0)
Engl 662—STUDIES IN ENGLISH LITERATURE SINCE 1700—3 cr.
(3 and 0)
Engl 801—THE TEACHING OF ENGLISH—3 cr. (3 and 0)
The teaching of grammar, composition, and literature. Required of all teaching assistants seeking an M.A. and all students seeking the M.Ed. Recommended for English teachers.
Engl 802—STUDIES IN MIDDLE ENGLISH LITERATURE—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from c. 1100-1500.
Engl 803—STUDIES IN RENAISSANCE ENGLISH LITERATURE—3 cr.
(3 and 0)
Topics embrace the principal works in verse and prose from c. 1500-1700.
Engl 804—STUDIES IN NEO-CLASSIC AND ROMANTIC—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from c. 1700-1832.

Engl 805—STUDIES IN VICTORIAN AND MODERN ENGLISH LITERATURE—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from c. 1832 to the present.

Engl 810—STUDIES IN COLONIAL AND REVOLUTIONARY AMERICAN LITERATURE—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from c. 1607-1830.

Engl 811—STUDIES IN ROMANTIC AND REALISTIC AMERICAN LITERATURE—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from 1830-1900.

Engl 812—STUDIES IN MODERN AMERICAN LITERATURE—3 cr. (3 and 0)
Topics embrace the principal works in verse and prose from c. 1900 to the present.

Engl 820—STUDIES IN THEORETICAL AND APPLIED LITERARY CRITICISM—3 cr. (3 and 0)
Topics embrace the principal statements of literary critics from the classical era to the present.

Engl 830—STUDIES IN LINGUISTICS—3 cr. (3 and 0)
Topics embrace the concepts of traditional and modern grammarians as well as the development of the English language.

Engl 840—STUDIES IN WORLD LITERATURE—3 cr. (3 and 0)
Topics embrace masterpieces of Oriental and Occidental writers and related works.

Engl 890—INTRODUCTION TO RESEARCH—1 cr. (1 and 0)
Introduction to literary history and research; the use of libraries and bibliographical tools; the exposition of scholarship. Required of all candidates for the master's degree.

Engl 891—RESEARCH—Credit to be arranged.

HISTORY AND POLITICAL SCIENCE
R. S. Lambert, Department Head

A student who wishes to pursue graduate study toward a Master of Arts degree in history must have earned an overall grade point ratio of 2.5 on
his undergraduate work, including a grade point ratio of 3.0 on a minimum of twenty-four semester hours of history, for admission to the program.

During his graduate study he will be expected to demonstrate a reading knowledge of either French or German and to be prepared to do research for his thesis in primary materials beyond those held by the Clemson Library.

Hist 610—HISTORY OF COLONIAL AMERICA—3 cr. (3 and 0) F
Hist 611—UNITED STATES, 1783-1850—3 cr. (3 and 0) S
Hist 612—UNITED STATES, 1850-1900—3 cr. (3 and 0) F
Hist 613—UNITED STATES SINCE 1900—3 cr. (3 and 0) S
Hist 673—MEDIEVAL HISTORY—3 cr. (3 and 0) (Formerly Hist 702)
Hist 675—THE RENAISSANCE—3 cr. (3 and 0) (Formerly Hist 704)
Hist 679—EUROPE, 1789-1850—3 cr. (3 and 0)
Hist 680—EUROPE, 1850-1914—3 cr. (3 and 0)
Hist 682—INTERNATIONAL RELATIONS SINCE 1914—3 cr. (3 and 0)
   (Formeraly Hist 708)
Hist 807—UNITED STATES DIPLOMATIC HISTORY SINCE 1877—3 cr.
   (3 and 0) S
   The course will emphasize the factors influencing American diplomacy since 1877, and students will be given some acquaintance with source materials and documents.
Hist 811—INTRODUCTION TO HISTORICAL RESEARCH—3 cr. (3 and 0)
Hist 812—UNITED STATES HISTORIOGRAPHY—3 cr. (3 and 0)
Hist 813—MEDIEVAL HISTORIOGRAPHY—3 cr. (3 and 0)
   An examination of the major historical works of Europe to 1500.
Hist 814—MODERN EUROPEAN HISTORIOGRAPHY—3 cr. (3 and 0)
   An examination of the major historical works of Europe since 1500.
Hist 824—SEMINAR IN THE AMERICAN SOUTH—3 cr. (3 and 0)
Hist 825—SEMINAR IN CIVIL WAR AND RECONSTRUCTION—3 cr.
   (3 and 0)
Hist 861—SEMINAR IN MEDIEVAL ENGLAND TO 1485—3 cr. (3 and 0)
   Political and institutional development with emphasis on government records. Prerequisites: Hist 308-309 or equivalents.

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Hist 862—SEMINAR IN MEDIEVAL ENGLAND TO 1485—3 cr. (3 and 0)
  Political and intellectual development with emphasis on chronicles and
  local records. Prerequisites: Hist 308-309 or equivalents.

Hist 863—SEMINAR IN TUDOR ENGLAND—3 cr. (3 and 0)
  Prerequisites: Hist 308-309 or equivalents.

Hist 864—SEMINAR IN STUART ENGLAND—3 cr. (3 and 0)
  Prerequisites: Hist 308-309 or equivalents.

Hist 865—SEMINAR IN MODERN ENGLAND SINCE 1715—3 cr. (3 and 0)
  The emphasis will be on domestic politics. Prerequisites: Hist 308-309 or
  equivalents.

Hist 866—SEMINAR IN MODERN ENGLAND SINCE 1715—3 cr. (3 and 0)
  The emphasis will be on imperial politics. Prerequisites: Hist 308-309 or
  equivalents.

Hist 891—RESEARCH—Credit to be arranged.

PolSc 632—AMERICAN CONSTITUTIONAL LAW—3 cr. (3 and 0) F

PolSc 662—INTERNATIONAL ORGANIZATIONS—3 cr. (3 and 0) S

PHILOSOPHY

R. S. Lambert, Department Head

Phil 825—SEMINAR IN PHILOSOPHY OF SCIENCE—3 cr. (3 and 0)
  A study of methods, principles, and problems of scientific explanation
  including such topics as meaning, verification, confirmation, distinctions
  drawn between various types of scientific laws, types of definitions,
  formal models, and probable inferences.

SOCIOLOGY

W. J. Lanham, Chairman, Rural Sociology

R. S. Lambert, Chairman, General Sociology

Advanced degrees are not awarded in Sociology. Courses are offered
to provide a minor for students majoring in other fields.

RS 659—THE COMMUNITY—3 cr. (3 and 0)

RS 661—RURAL LEADERSHIP—3 cr. (3 and 0)
RS 801—RURAL SOCIAL SYSTEMS—3 cr. (3 and 0)

Designed to provide the advanced student with a brief review of the basic working concepts of rural sociology and a knowledge of the basic institutions of rural life and to acquaint the student with the techniques used in applying scientific methods and theory toward understanding the social structure of rural life. **Prerequisite:** Permission of instructor.

Soc 611—HISTORY OF SOCIAL THOUGHT—3 cr. (3 and 0)

Soc 621—SOCIOLOGICAL THEORY—3 cr. (3 and 0)

Soc 631—COMPLEX ORGANIZATIONS—3 cr. (3 and 0)

Soc 641—SOCIAL STRATIFICATION—3 cr. (3 and 0)

Soc 651—SOCIOLOGY OF MEDICINE—3 cr. (3 and 0)
The Master of Science degree is offered in Biochemistry.

Enrollment in the biochemistry graduate program is open to students possessing baccalaureate degrees in agricultural and biological sciences, chemistry, and in engineering. Students selecting biochemistry will be expected to have had courses in analytical, organic and physical chemistry. Students who have not completed these courses may be admitted to the program, but will be required to correct any deficiencies by registering for the appropriate courses.

Undergraduate teaching is an integral part of graduate work in biochemistry and is required of all graduate students.

Bioch 606—PHYSIOLOGICAL CHEMISTRY—4 cr. (3 and 3) S
Bioch 623—PRINCIPLES OF BIOCHEMISTRY—3 cr. (3 and 0) F
Bioch 624—PRINCIPLES OF BIOCHEMISTRY—3 cr. (3 and 0) S
A continuation of Bioch 623.
Bioch 625—GENERAL BIOCHEMISTRY LABORATORY—1 cr. (0 and 3) F
Bioch 626—GENERAL BIOCHEMISTRY LABORATORY—1 cr. (0 and 3) S
Bioch 810—BIOCHEMICAL TECHNIQUES—3 cr. (1 and 6) F
A discussion of techniques relating to the analysis of biological materials. Practice in the use of gas and liquid chromatography, Warburg apparatus, amino acid analyzer, spectrophotometers, radioisotopes, and other instruments employed in biochemical work will be stressed. **Prerequisites:** Ch 313 and 315 or 317.

Bioch 815—LIPIDS—2 cr. (2 and 0) S
Chemistry of plant and animal lipids, to include formation, function, metabolism, chemical reactions, and physical properties. Methods of analysis are discussed. **Prerequisite:** Ch 723.
Bioch 817—CHEMISTRY AND METABOLISM OF HORMONES—2 cr. (2 and 0) F
The isolation, assay, and chemistry of the various hormones are discussed. The hormonal control of metabolism and body function as well as endocrinopathies of hormone imbalance are also studied. **Prerequisite:** Bioch 623.

Bioch 819—INTERMEDIARY METABOLISM—3 cr. (3 and 0) F
A descriptive consideration of the various chemical pathways of metabolism. **Prerequisite:** Bioch 623.

Bioch 820—NUCLEIC ACIDS—2 cr. (2 and 0) S
The isolation, composition, structure, metabolism, and function of nucleic acids and nucleoproteins. **Prerequisite:** Bioch 623.

Bioch 821—PROTEINS—2 cr. (2 and 0) F
The isolation, composition, structure, and colloidal properties of proteins. Methods of isolation, analysis, and characterization will be discussed. **Prerequisite:** Bioch 623.

Bioch 822—ENZYMES—3 cr. (3 and 0) F
An advanced course on the kinetics, mechanism of action, inhibition and general properties of enzymes. **Prerequisite:** Bioch 623.

Bioch 823—CARBOHYDRATES—2 cr. (2 and 0) S
The types, distribution, biological functions, reactions and energetics of the biosynthesis and degradation of carbohydrates. **Prerequisite:** Bioch 623.

Bioch 851—BIOCHEMISTRY SEMINAR—1 cr. (1 and 0) F
A review of current topics in biochemistry by graduate students in biochemistry and interested staff members.

Bioch 852—BIOCHEMISTRY SEMINAR—1 cr. (1 and 0) S
Continuation of Bioch 851.

Bioch 891—RESEARCH—Credit to be arranged.

BOTANY

C. J. Umphlett, Department Head

The Master of Science degree is offered in Botany.
The Doctor of Philosophy degree is offered in Plant Physiology on an interdepartmental basis.

Students who desire to pursue graduate work in botany or plant physiology should have sound undergraduate training in the biological and
physical sciences, especially botany and chemistry. This training may be received in an undergraduate curriculum in botany, biology, or chemistry, or in one of the agricultural plant sciences, such as agronomy, forestry, or horticulture.

Bot 652—PLANT PHYSIOLOGY—4 cr. (3 and 3) FS

Bot 656—TAXONOMY OF VASCULAR PLANTS—3 cr. (1 and 6) S

Bot 604—CYTOLOGY—3 cr. (3 and 0) F, odd numbered years.

Bot 606—PLANT ANATOMY—3 cr. (2 and 3) F, even numbered years.

Bot 651—MORPHOLOGY OF THE FUNGI—3 cr. (2 and 3) F, even numbered years.

Bot 659—PLANT ECOLOGY—3 cr. (2 and 3) S

Bot 655—PLANT MORPHOLOGY—4 cr. (2 and 6) S, odd numbered years.

Bot 657—PHYCOLOGY—3 cr. (2 and 3) S, odd numbered years.

Bot 802—MYCOLOGY—4 cr. (3 and 3) S, odd numbered years.

Designed chiefly for students majoring in plant pathology and closely allied fields. A detailed study is made of specific groups of fungi, especially those of economic importance in this region. Emphasis is placed on field collection, identification, morphology, and cytology through lectures, student reports, and laboratory work. **Prerequisite:** Bot 651.

Bot 805—SPECIAL PROBLEMS IN BOTANY—Credit to be arranged.

Original investigation of special problems in botany or plant physiology which are not related to a thesis but designed to provide experience and training in research. **Prerequisite:** Permission of instructor.

Bot 807—SEMINAR—1 cr. (1 and 0) F S

A review of areas of the botanical sciences not covered by formal courses, with special emphasis on the review of literature, and organization and presentation of material by students. (May be taken for credit only twice.)

Bot 811—INORGANIC PLANT METABOLISM—4 cr. (3 and 3) F, odd numbered years.

A consideration of plant, soil, water, nutrient relations, permeability, uptake and translocation, transpiration, and mineral nutrition. **Prerequisites:** Bot 652, organic chemistry, or permission of instructor.

Bot 812—ORGANIC PLANT METABOLISM—3 cr. (3 and 0) S, even numbered years.

A consideration of respiration and photosynthesis; synthesis, translocation, storage, transformation and degradation of organic materials, fats, carbohydrates, proteins, pigments and enzymes. **Prerequisites:** Bot 652, organic chemistry, or permission of instructor.
Bot 813—GROWTH AND DEVELOPMENT—3 cr. (3 and 0) F, even numbered years.

A consideration of vegetative and reproductive growth and development, from seed to maturity, flowering, fruiting and senescence. Also natural and synthetic growth regulators, and morphogenesis. Prerequisites: Bot 652, organic chemistry, or permission of instructor.

Bot 821—PLANT TAXONOMY I—4 cr. (2 and 6) F

Principles of plant classification and relationships and characteristics of the major groups of vascular plants. The collection and identification of the fall flora of the area. Prerequisites: Bot 101; Bot 356 or permission of instructor.

Bot 822—PLANT TAXONOMY II—4 cr. (2 and 6) S

A continuation of Bot 821 with emphasis on the collection and identification of the spring flora of the area. Prerequisites: Bot 101; Bot 821 or permission of instructor.

Bot 891—RESEARCH—Credit to be arranged.

CHEMICAL PHYSICS

H. G. Spencer, Chairman (Chemistry)
H. E. Vogel, Chairman (Physics)

Courses are offered leading to the Doctor of Philosophy degree.

Chemical physics is an interdisciplinary field utilizing particular courses in chemistry and physics. Where physical chemistry is concerned with the physical and thermodynamic properties of materials in bulk, chemical physics studies the involved spatial structures and properties of matter on the atomic and molecular scale. The theoretical and experimental techniques of physics and physical chemistry are used in chemical physics.

Students may conduct their research with faculty members in either the Department of Physics or the Department of Chemistry, and joint projects may be arranged.

Course work required of the student in this field is drawn principally from the offerings in chemistry, physics, and mathematics.

CHEMISTRY

H. G. Spencer, Department Head

Courses are offered leading to the Master of Science and Doctor of Philosophy degrees.
An entering graduate student should have a record of sound academic achievement in an undergraduate chemistry curriculum.

Although additional courses are desirable, courses in general, analytical, organic and physical chemistry, and basic courses in physics and calculus, generally provide the preparation necessary for the students to enroll in courses carrying graduate credit. While minor deficiencies may be removed during the course of graduate study, major deficiencies will require undergraduate course work during the first year of study.

Entering graduate students are given placement examinations in four fields of chemistry—analytical, inorganic, organic and physical. Results of these examinations and a review of the student's undergraduate record and graduate study objectives assist his adviser in selecting the appropriate courses for the beginning student.

Research areas available to the student include analytical, inorganic, organic, physical, textile and biochemistry.

In addition to the requirements of the Graduate School, students must satisfy the following departmental requirements:

**For the Master of Science degree.** A reading knowledge of German or Russian is required. This requirement should be met as early in the student's program as is possible. The course to be completed for the degree normally include advanced courses in several areas of chemistry. A thesis is required.

**For the Doctor of Philosophy degree.** For those students who have not had a course in atomic and molecular structure, Ch 635 is required.

Qualification to pursue the degree is accomplished by completing a core of four courses with at least a B-average during the first two years of graduate study. The required courses are taken from four areas of chemistry; one each from physical, organic and two other areas chosen from analytical, inorganic and biochemistry. In lieu of these courses, qualification may be accomplished by examination.

A reading knowledge of two languages selected from French, German or Russian is required.

A comprehensive examination of the cumulative type is required in the major field of specialization. The examination consists of a series of eight one-hour, written examinations given monthly beginning immediately after completing three semesters in residence. An oral presentation before the faculty in the major area of concentration follows the successful completion of the cumulative examinations.

**The Ph.D. in Chemistry with Major in Textile Chemistry.** The student in this program must meet the basic requirements of the chemistry de-
partment as set forth in the Graduate Bulletin. On exception is that the comprehensive examination is a single written examination prepared by the student's advisory committee, followed within two weeks by an oral examination before the committee.

The minor for textile chemistry majors would normally be organic or physical chemistry.

**Teaching** in undergraduate courses is an integral part of graduate work in chemistry and is required of all graduate students.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Ch 602</td>
<td>INORGANIC CHEMISTRY—3 cr. (3 and 0)</td>
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<tr>
<td>Ch 603</td>
<td>INORGANIC CHEMISTRY—3 cr. (3 and 0)</td>
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<tr>
<td>Ch 611</td>
<td>INSTRUMENTAL ANALYSIS—4 cr. (2 and 6)</td>
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<td>Ch 613</td>
<td>QUANTITATIVE ANALYSIS—3 cr. (3 and 0)</td>
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<td>Ch 615</td>
<td>QUANTITATIVE ANALYSIS LABORATORY—2 cr. (0 and 6)</td>
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<td>Ch 617</td>
<td>QUANTITATIVE ANALYSIS LABORATORY—1 cr. (0 and 3)</td>
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<tr>
<td>Ch 621</td>
<td>ADVANCED ORGANIC CHEMISTRY—3 cr. (3 and 0)</td>
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<tr>
<td>Ch 622</td>
<td>ADVANCED ORGANIC CHEMISTRY LABORATORY—2 cr. (0 and 6)</td>
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<td>Ch 628</td>
<td>ORGANIC SPECTROSCOPY—3 cr. (2 and 2)</td>
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<tr>
<td>Ch 631</td>
<td>PHYSICAL CHEMISTRY—3 cr. (3 and 0)</td>
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<tr>
<td>Ch 632</td>
<td>PHYSICAL CHEMISTRY—3 cr. (3 and 0)</td>
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<td>Ch 635</td>
<td>ATOMIC AND MOLECULAR STRUCTURES—3 cr. (3 and 0)</td>
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<td>Ch 636</td>
<td>PHYSICAL CHEMISTRY LABORATORY—1 cr. (0 and 3)</td>
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<tr>
<td>Ch 639</td>
<td>PHYSICAL CHEMISTRY LABORATORY—1 cr. (0 and 3)</td>
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<tr>
<td>Ch 640</td>
<td>PHYSICAL CHEMISTRY LABORATORY—1 cr. (0 and 3)</td>
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<tr>
<td>Ch 654</td>
<td>INORGANIC SYNTHESIS—2 cr. (0 and 6)</td>
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<tr>
<td>Ch 672</td>
<td>ORGANIC SYNTHESIS—4 cr. (2 and 6)</td>
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<tr>
<td>Ch 691</td>
<td>INTRODUCTION TO RADIOCHEMISTRY—3 cr. (2 and 3)</td>
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<tr>
<td>Ch 800T</td>
<td>PHYSICAL SCIENCE FOR THE HIGH SCHOOL TEACHER—3 cr. (3 and 0)</td>
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</tbody>
</table>

The basic principles of the physical sciences are investigated in such a way that the relationship to other sciences and other academic areas in general is clarified. Students in the course will have opportunity to be involved in laboratory demonstrations which might be useful in a physical
science course in high school. The enrollment is limited to science teachers with some experience in the classroom.

Ch 805—THEORETICAL INORGANIC CHEMISTRY—3 cr. (3 and 0)

The applications of modern theory to inorganic chemistry. Prerequisites: Ch 602 and Ch 635, or permission of instructor.

Ch 806—SPECIAL TOPICS IN INORGANIC CHEMISTRY—1-4 cr.

(1-4 and 0)

Topics such as crystals, non-aqueous solvents, chemical application of group theory, rare-earth elements and non-stoichiometric compounds will be treated according to the interests of the students. Credit varies. (May be taken more than one semester.)

Ch 807—CHEMISTRY OF THE TRANSITION ELEMENTS—3 cr. (3 and 0)

The chemistry of the transition elements with special emphasis on the coordination compounds formed by these elements. Prerequisite: Ch 602.

Ch 808—CHEMISTRY OF THE NON-METALLIC ELEMENTS—3 cr.

(3 and 0)

The inorganic chemistry of the non-metallic elements, especially boron, silicon, phosphorous, and sulfur. Prerequisite: Ch 602.

Ch 811—ANALYTICAL CHEMISTRY—3 cr. (3 and 0)

A survey of the art of analytical chemistry. Topics included are: sample selection, sample treatment, the practical aspects of instrumentation, and the analytical chemistry of seventy chemical elements and several organic functional groups. The emphasis is upon the understanding of complete, economically feasible, analytical procedures for the determination of the components of complex mixtures.

Ch 812—CHEMICAL SPECTROSCOPIC METHODS—3 cr. (2 and 3)

A study and practice of emission and absorption spectroscopy, chemical microscopy, and X-ray diffraction and fluorescence techniques in analytical chemistry. The emphasis is on the theory and operation of the instruments.

Ch 814—ELECTROANALYTICAL CHEMISTRY—3 cr. (2 and 3)

A study of modern electrochemistry as applied to analytical chemistry, including both theory and practical application.

Ch 821—ORGANIC CHEMISTRY I—3 cr. (3 and 0)

A detailed survey of representative organic reactions with an emphasis on their utility in organic synthesis. Prerequisite: Ch 621, or approval of the instructor.

Ch 822—ORGANIC CHEMISTRY II—3 cr. (3 and 0)

A study of theoretical concepts of organic chemistry. Prerequisite: Ch 621, or approval of the instructor.
Ch 823—ORGANIC REACTION MECHANISMS—3 cr. (3 and 0)

The mechanisms of organic chemical reactions, both aliphatic and aromatic.

Ch 824—FUNDAMENTAL PRINCIPLES OF POLYMER CHEMISTRY—3 cr. (3 and 0)

The organic chemistry of natural and synthetic macromolecules.

Ch 831—CHEMICAL THERMODYNAMICS—3 cr. (3 and 0)

Primarily a study of classical thermodynamics, with emphasis on theory and significance of energetics, and on systems of variable composition. Prerequisite: Ch 631 or its equivalent.

Ch 834—STATISTICAL THERMODYNAMICS—3 cr. (3 and 0)

A treatment of statistical thermodynamics. Prerequisite: Ch 831.

Ch 835—CHEMICAL KINETICS—3 cr. (3 and 0)

A study of rate processes and reaction mechanisms. Topics such as the following are treated: Order of reaction, theory of rate processes, relation of reaction rates to mechanism, homogeneous and heterogeneous catalysis, experimental methods, chain reactions, diffusion, and the effects of solvent, temperature and pressure on reaction rates and mechanisms. Lectures are supplemented by assigned problems, and a paper and oral examination of a topic of special interest to the individual student.

Ch 837—QUANTUM CHEMISTRY—3 cr. (3 and 0)

A study of the mathematical and conceptual formulation of the quantum theory of the electronic structure of atoms and molecules. Emphasis is placed on the eigenvalue solution of the one-dimensional Schroedinger equation and the applications of this method to chemical problems.

Ch 851—SEMINAR—0, 1, or 2 cr. (May be taken more than one semester.)

Ch 861—PRINCIPLES OF BIOCHEMISTRY—3 cr. (3 and 0) S

A rigorous, quantitative treatment of the properties of biological molecules using the modern techniques of organic, physical and analytical chemistry to study structural relationships and biological activity. Prerequisites: Satisfactory performance on placement examinations in organic and physical chemistry.

Ch 891—RESEARCH—Credit to be arranged. (May be taken more than one semester.)

Ch 920—ADVANCED TOPICS IN ORGANIC CHEMISTRY—1-4 cr. (1-4 and 0)

An advanced study of one or more topics in organic chemistry. Topics such as heterocyclic compounds; stereochemistry, natural products, organo-metallic chemistry, photochemistry, etc., will be treated according to the interest of the students. (May be taken more than one semester.)
Ch 930—ADVANCED TOPICS IN PHYSICAL CHEMISTRY—1-4 cr. (1-4 and 0)

An advanced study of one or more topics in physical chemistry. Topics such as special problems in molecular spectroscopy, molecular orbital treatments, applications of group theory to chemical structure, irreversible thermodynamics, special topics in statistical mechanics, etc., will be treated according to the interest of the students. (May be taken more than one semester.)

Ch 950—MICROANALYTICAL TECHNIQUES—3 cr. (1 and 6)

Designed to perfect the laboratory technique of the advanced graduate students. Procedures followed are those used to analyze organic compounds for elemental composition.

Ch 991—DOCTORAL RESEARCH—Credit to be arranged. (May be taken more than one semester.)

GEOLOGY

P. K. Birkhead, Chairman

Advanced degrees are not awarded in Geology. Courses are offered as a minor for students majoring in other areas.

Geol 602—STRUCTURAL GEOLOGY—3 cr. (2 and 2)

Geol 603—INVERTEBRATE PALEONTOLOGY—3 cr. (2 and 2)

Geol 604—ECONOMIC GEOLOGY—3 cr. (3 and 0)

Geol 605—GEOMORPHOLOGY—4 cr. (3 and 3)

Geol 606—MINERALOGY—3 cr. (2 and 3)

Geol 607—GLACIAL GEOLOGY—3 cr. (2 and 2)

Geol 608—GEOHYDROLOGY—3 cr. (3 and 0)

Geol 609—PETROLOGY—3 cr. (2 and 3)

Geol 610—OPTICAL MINERALOGY—3 cr. 1 and 4)

Geol 611—RESEARCH PROBLEMS—1-3 cr. (0 and 3-9)

Geol 613—STRATIGRAPHY AND SEDIMENTATION—3 cr. (3 and 0)

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Courses are offered leading to the Master of Science and Doctor of Philosophy degrees.

Students seeking the Master's degree may choose a thesis or non-thesis option. Work for the non-thesis Master's degree will consist of a minimum of thirty-one semester hours.

Students are admitted to candidacy for the Doctor of Philosophy degree upon the successful completion of a written qualifying examination on the subject matter of the major and minor fields.

Teaching in undergraduate courses is an integral part of graduate study in mathematics and is required of all graduate students.

Comp Sc 609—INTRODUCTION TO NUMERICAL ANALYSIS I—3 cr.
(3 and 0)

Comp Sc 610—INTRODUCTION TO NUMERICAL ANALYSIS II—3 cr.
(3 and 0)

Comp Sc 611—COMPUTER ORGANIZATION AND PROGRAMMING—
3 cr. (2 and 3)

Comp Sc 628—ALGORITHMIC LANGUAGES AND COMPILERS—3 cr.
(3 and 0)

Math 601—STATISTICAL THEORY AND METHODS I—3 cr. (3 and 0)

Math 602—THEORY OF PROBABILITY—3 cr. (3 and 0)

Math 603—STATISTICAL INFERENCE—3 cr. (3 and 0)

Math 604—INTRODUCTION TO STOCHASTIC PROCESSES—3 cr.
(3 and 0)

Math 605—STATISTICAL THEORY AND METHODS II—3 cr. (3 and 0)

Math 607—PARTIAL DIFFERENTIAL EQUATIONS—3 cr. (3 and 0)

Math 608—TOPICS IN GEOMETRY—3 cr. (3 and 0)

Math 609—STATISTICAL THEORY AND METHODS III—3 cr. (3 and 0)
Math 611—LINEAR ALGEBRA—3 cr. (3 and 0)

Math 612—INTRODUCTION TO MODERN ALGEBRA I—3 cr. (3 and 0)

Math 613—INTRODUCTION TO MODERN ALGEBRA II—3 cr. (3 and 0)

Math 615—INTRODUCTION TO TOPOLOGY—3 cr. (3 and 0)

Math 617—MATHEMATICAL PROGRAMS—3 cr. (3 and 0)

Math 619—APPLIED COMBINATORIAL ALGEBRA I—3 cr. (3 and 0)

Math 620—APPLIED COMBINATORIAL ALGEBRA II—3 cr. (3 and 0)

Math 625—INTERMEDIATE DIFFERENTIAL EQUATIONS—3 cr. (3 and 0)

Math 629—INTRODUCTION TO NUMERICAL ANALYSIS—3 cr. (3 and 0)

Math 635—COMPLEX VARIABLES—3 cr. (3 and 0)

Math 652—LINEAR PROGRAMMING—3 cr. (3 and 0)

Math 653—ADVANCED CALCULUS I—3 cr. (3 and 0)

Math 654—ADVANCED CALCULUS II—3 cr. (3 and 0)

Math 655—LAPLACE TRANSFORMS—3 cr. (3 and 0)

Math 657—APPLIED MATHEMATICS I—3 cr. (3 and 0)

Math 658—APPLIED MATHEMATICS II—3 cr. (3 and 0)

Math 663—MATHEMATICAL ANALYSIS I—3 cr. (3 and 0)

Math 664—MATHEMATICAL ANALYSIS II—3 cr. (3 and 0)

Math 671—APPLIED STATISTICAL DECISION THEORY—3 cr. (3 and 0)

Math 673—INTRODUCTION TO NONLINEAR OPTIMIZATION—3 cr. (3 and 0)

Math 801—GENERAL LINEAR HYPOTHESIS I—3 cr. (3 and 0)

Topics include: Least-square estimates, Gauss-Markoff theorem, confidence ellipsoids and confidence intervals for estimable functions, test of
hypothesis, one-two-and higher-way layouts, the analysis of variance for
other models. **Prerequisites:** Math 603 and 611.

Math 802—GENERAL LINEAR HYPOTHESIS II—3 cr. (3 and 0)
A continuation of Math 801.

Math 803—STOCHASTIC PROCESSES I—3 cr. (3 and 0)
Principal topics include: theory and analysis of time series, recurrent
events, Markov chains, random walks, renewal theory, application to com-
munication theory, and operation research. **Prerequisite:** Math 604.

Math 804—STOCHASTIC METHODS IN PROBABILITY AND STATIS-
TICS—3 cr. (3 and 0)
Conditional expectation, conditional variance, best predictor, introduc-
tion to multivariate analysis, introduction to stochastic processes, applica-
tion of mathematical and stochastic models. **Prerequisites:** Math 605 and
611.

Math 807—MATHEMATICAL STATISTICS I—3 cr. (3 and 0)
A discussion, without utilizing measure theory, of advanced topics in
mathematical statistics. Principal topics include methods of estimation,
properties of estimators, confidence level theory, Bayesian and fiducial in-
fERENCE, foundations of hypothesis testing, multivariate normal distribu-
tion, simultaneous interval estimation, nonparametric inference. **Prerequi-
sites:** Math 603, 611, 654.

Math 808—MATHEMATICAL STATISTICS II—3 cr. (3 and 0)
A continuation of Math 807.

Math 811—NONLINEAR PROGRAMMING—3 cr. (3 and 0)
A theoretical development of non-linear optimization with applications.
Main topics include: classical optimization, convex and concave functions,
separable programming, quadratic programming, and gradient methods.
**Prerequisites:** Math 452, 453.

Math 812—DYNAMIC PROGRAMMING—3 cr. (3 and 0)
The study of deterministic and stochastic multi-stage decision processes.
Topics include: Mitten sufficiency, existence and uniqueness theorems,
approximation in policy space, multi-stage games, Markovian decision
processes, surveillance theory, and the Pontryagin maximum principle.
**Prerequisites:** Math 652, 654.

Math 813—ADVANCED LINEAR PROGRAMMING—3 cr. (3 and 0)
Review of simplex and dual simplex algorithms, Gomory's integer pro-
gramming algorithm, parametric programming, transportation problem
via networks, Chebyshev approximation, convex programming, introduc-
tion to stochastic programming, fixed charge problems. **Prerequisite:**
Math 452.
Math 821—REAL ANALYSIS I—3 cr. (2 and 0)

Hausdorff and metric spaces, cardinal and ordinal numbers, rings and algebras of sets, exterior and interior measure, completion of measures, Borel and Lebesgue measures in Euclidean n-space, integration theory associated with a measure, types of convergence, derivatives. **Prerequisite:** Math 654.

Math 822—REAL ANALYSIS II—3 cr. (3 and 0)

A continuation of Math 821.

Math 823—COMPLEX ANALYSIS I—3 cr. (3 and 0)

Topological concepts, complex integration, local and global properties of analytic functions, Power series, representation theorems, calculus of residues. Designed for non-engineering majors. **Prerequisite:** Math 664.

Math 824—COMPLEX ANALYSIS II—3 cr. (3 and 0)

A continuation of Complex Analysis I with an introduction to topological analysis.

Math 825—ORDINARY DIFFERENTIAL EQUATIONS I—3 cr. (3 and 0)

Existence and uniqueness theorems, dependence on initial conditions and parameters, linear differential equations, self adjoint eigenvalue problems, oscillation and comparison theorems. **Prerequisites:** Math 654 and 611 or 664.

Math 826—ORDINARY DIFFERENTIAL EQUATIONS II—3 cr. (3 and 0)

Perturbations of systems having a periodic solution, stability, Poincare-Bendixson theory, use of fixed point theorems, almost periodic solutions and integral manifolds. **Prerequisite:** Math 825.

Math 831—FOURIER SERIES—3 cr. (3 and 0)

Fourier series with applications to the solution of boundary value problems in the partial differential equations of physics and engineering; and introduction to Bessel functions and Legendre polynomials, with applications. **Prerequisites:** Math 845 or 664.

Math 833—OPERATIONAL MATHEMATICS—3 cr. (3 and 0)

A study of the operational properties of the Laplace and other integral transforms. The applications are chiefly to problems in engineering and physics that involve differential equations, with emphasis on boundary value problems in partial differential equations. **Prerequisite:** Math 654.

Math 837—CALCULUS OF VARIATIONS—3 cr. (3 and 0)

The fundamental theory of the calculus of variation. Variable end points. The parametric problem. The isoperimetric problem. Fundamental sufficiency theorems. **Prerequisite:** Math 664 or 654.

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Math 839—INTEGRAL EQUATIONS—3 cr. (3 and 0)
Basic theory. Relationships to linear differential initial value problems.

Math 841—APPLIED MATHEMATICS I—3 cr. (3 and 0)

Math 842—APPLIED MATHEMATICS II—3 cr. (3 and 0)
A continuation of 841.

Math 851—ABSTRACT ALGEBRA I—3 cr. (3 and 0)
A review of the fundamental theory of Math 612-613, a study of finite groups including permutation groups, p-groups, the Sylow theorems and the structure of finite abelian groups. Groups with chain conditions, the Krull-Schmidt and Jordan-Holder theorems. Solvable, nilpotent and free groups. Galois theory, finite fields and the Wedderburn theorem.

Math 852—ABSTRACT ALGEBRA II—3 cr. (3 and 0)
A continuation of Math 851 including a study of the structure of rings and introductions to other algebraic systems.

Math 853—ADVANCED LINEAR ALGEBRA—3 cr. (3 and 0)
Properties of finite dimensional vector spaces: bases, dimensions, transformations, projections and orthogonality. Prerequisites: Math 611 and Math 612.

Math 854—THEORY OF GRAPHS I—3 cr. (3 and 0)
Connectedness, path problems, trees, matching theorems, directed graphs, fundamental numbers of the theory of graphs, groups and graphs. Prerequisite: consent of instructor.

Math 855—COMBINATORIAL ANALYSIS I—3 cr. (3 and 0)
Topics selected from combinations, permutations, permutations with restricted position, Polya’s theorem, principal of inclusion and exclusion, partitions, recurrence relations, generating functions, Mobius inversion, enumeration techniques, Ramsey numbers, finite projective and affine geometrics, Latin rectangles, orthogonal arrays, block designs, error detecting and error correcting codes. Prerequisite: Math 611.

Math 861—NUMERICAL ANALYSIS—3 cr. (3 and 0)
Math 863—DIGITAL ANALYSIS I—3 cr. (3 and 0)


Math 864—DIGITAL ANALYSIS II—3 cr. (3 and 0)

A continuation of Math 863.

Math 865—CALCULUS OF FINITE DIFFERENCES—3 cr. (3 and 0)

Difference operators, summation formulas, functions important in the calculus of finite differences, existence and uniqueness theorems of difference equations, orthogonal polynomials. **Prerequisite:** Math 654.

Math 871—GENERAL TOPOLOGY I—3 cr. (3 and 0)

Definitions and elementary properties of a topological space, subspaces, quotient and product spaces, Moore-Smith convergence, separation axioms and consequences, metrization theorems, introduction to homotopy theory. Uniformities and axiomatic boundedness. **Prerequisite:** Math 664.

Math 872—GENERAL TOPOLOGY II—3 cr. (3 and 0)

A continuation of Math 871.

Math 873—ALGEBRAIC TOPOLOGY I—3 cr. (3 and 0)

Homology and cohomology in complexes. Applications to fixed point theorems. Introduction to homotopy theory. Singular homology theory; The cohomology ring. Introduction to manifolds, fibre spaces, and sheaf theory. **Prerequisites:** Math 413, Math 871.

Math 874—ALGEBRAIC TOPOLOGY II—3 cr. (3 and 0)

A continuation of Math 873.

Math 875—CONVEXITY I—3 cr. (3 and 0)

Hyperplanes and separation theorems, characterizations of convex sets, local convexity, Helly-type theorems, convex functions.

Math 876—CONVEXITY II—3 cr. (3 and 0)

Continuation of Math 875—Survey of current literature and discussion of open questions.

Math 881—HISTORY OF MATHEMATICS—3 cr. (3 and 0)

A survey of the development of mathematics. Use of reference material supplements the text, and class discussion is expected. **Prerequisite:** Consent of instructor.
Math 883—THEORY OF NUMBERS—3 cr. (3 and 0)
A study of the properties of the integers with theorems on divisibility, congruences, numbers, theoretical functions, and continued fractions.

Math 885—PROJECTIVE GEOMETRY—3 cr. (3 and 0)
Introductory concepts relating to elements, axioms, primitive forms, and central projections; the principal of duality as applied to simple and complete figures; perspectivity and Desargues's theorem; harmonic sets; metric properties and double ratio; projectively related primitive forms; conics and cones; Pascale theorem and Brianchon's theorem; theory of the pole and the polar metric properties of conics; ruled surfaces; extended theory of projectivity; involution and metric considerations; complex elements; planar collineations. **Prerequisite:** Math 608 or consent of the instructor.

Math 891—RESEARCH—Credit to be arranged.

Math 901—PROBABILITY THEORY I—3 cr. (3 and 0)
Axomatic theory of probabilities. General concepts and tools of probability theory are developed to discuss sums of independent random variables and their limit properties. Principal topics: cartesian product of infinity many measurable spaces, Daniel-Kolmogoroff theorem, Borel-Cantelli's lemma, monotone class theorem, modes of convergence, characteristic functions, infinitely divisible distributions, central limit theorems, law of large number, ergodic theorems. **Prerequisites:** Math 602 and 822.

Math 902—PROBABILITY THEORY II—3 cr. (3 and 0)

Math 903—ADVANCED STOCHASTIC PROCESSES—3 cr. (3 and 0)
Markov Process, martingales, stationary processes, linear least squares, prediction-stationary (wide sense) processes. **Prerequisites:** Math 604 and 901.

Math 905—DECISION THEORY I—3 cr. (3 and 0)
Basic topics include: classes of decision functions, estimators, properties of estimators, methods of deriving estimators, testing of hypothesis, uniformly most powerful tests, methods of deriving tests. **Prerequisites:** Math 603 and 822.

Math 906—DECISION THEORY II—3 cr. (3 and 0)
A continuation of Math 905.

Math 907—MULTIVARIATE ANALYSIS—3 cr. (3 and 0)
Principal topics include: Multivariate normal distribution, Wishart distribution, Hotelling's $T^2$ distribution, estimation of parameters, test of
hypothesis on vector means and covariance matrices. **Prerequisite:** Math 802.

Math 920—INTRODUCTION TO HARMONIC ANALYSIS—3 cr. (3 and 0)
Topics include trigonometric functions and series, summability methods, convergence and summability of Fourier series, Fourier integrals, Fourier transforms, the Banach algebra \( L^1(\mathbb{R}) \) and ideals in \( L^1 \). **Prerequisites:** Math 822 and 824.

Math 921—ABSTRACT HARMONIC ANALYSIS I—3 cr. (3 and 0)
**Prerequisites:** Real and complex variables (Math 422 and 424), Algebra (Math 413), Topology (Math 415).

Math 922—ABSTRACT HARMONIC ANALYSIS II—3 cr. (3 and 0)
A continuation of Math 921.

Math 923—INTRODUCTION TO THE THEORY OF DISTRIBUTIONS I—
3 cr. (3 and 0)
Topics include: Linear topological spaces, generalized functions, support of distributions, distributions, convolutions of distributions, Fourier transforms of distributions, and Connection with Analytic Functions. **Prerequisites:** Real and Complex Variables (Math 822 and 824).

Math 924—INTRODUCTION TO THE THEORY OF DISTRIBUTIONS II—
3 cr. (3 and 0)
A continuation of Math 923.

Math 925—TOPICS IN NON LINEAR DIFFERENTIAL EQUATIONS—
3 cr. (3 and 0)
The subject matter to be chosen from current research problems of interest: e.g. fixed point methods for obtaining periodic and almost periodic solutions in dissipative and conservative systems, methods of averaging and the related study of integral manifolds, general theory of dynamical systems, etc.; and the applications of the above to such classical problems as the three body problem. **Prerequisite:** Math 826.

Math 927—FUNCTIONAL ANALYSIS I—3 cr. (3 and 0)
A study of Hilbert, normed, Banach and topological linear spaces; linear operators in these spaces; Hahn-Banach, uniform boundedness, and closed-graph theorems; applications to problems in analysis; spectral theory for linear operators. **Prerequisite:** Math 822.

Math 928—FUNCTIONAL ANALYSIS II—3 cr. (3 and 0)
A continuation of Math 927.

Math 929—FUNCTIONAL ANALYSIS III—3 cr. (3 and 0)
A continuation of Math 827-28; special topics, including survey of current literature and open questions in the field.

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Math 930—FUNCTIONAL ANALYSIS IV—3 cr. (3 and 0)
A continuation of Math 929.

Math 945—POTENTIAL THEORY I—3 cr. (3 and 0)
A survey of classical results in the theory of harmonic functions; Laplace and other elliptic equations, boundary value problems, Poisson's integral, logarithmic and Newtonian potentials, capacity. **Prerequisite:** Math 835.

Math 946—POTENTIAL THEORY II—3 cr. (3 and 0)
A survey of recent development in potential theory, Axiomatic theory of harmonic and super-harmonic functions; Choquet's theory of capacity; resolvent functions and semi-group techniques. **Prerequisite:** Math 945.

Math 951—GROUP THEORY—3 cr. (3 and 0)
A further study of groups including: extensions, linear groups, infinite abelian groups, word problems, group representations. **Prerequisite:** Math 851.

Math 952—RING THEORY I—3 cr. (3 and 0)
Injective and projective modules, exact sequences, Wedderburn-Artin theorem, various radicals, rings with minimum condition. **Prerequisites:** Math 851, 852.

Math 953—RING THEORY II—3 cr. (3 and 0)
A continuation of Math 952 emphasizing recent developments in ring theory.

Math 954—THEORY OF GRAPHS II—3 cr. (3 and 0)
A continuation of Math 854.

Math 955—COMBINATORIAL ANALYSIS II—3 cr. (3 and 0)
A continuation of Math 855.

Math 956—FIELD THEORY—3 cr. (3 and 0)
A further study of fields including: valuations, ideals, algebraic number fields, Dedekind fields, and additional topics in finite fields. **Prerequisites:** Math 851, 852.

Math 957—SEMIGROUP THEORY I—3 cr. (3 and 0)
An introduction to the algebraic theory of semigroups: elementary concepts, ideals and related concepts, minimal conditions, inverse semigroups, various representations, decompositions and extensions. **Prerequisite:** Math 851 or consent of instructor.

Math 958—SEMIGROUP THEORY II—3 cr. (3 and 0)
A continuation of Math 957.

Math 980—SPECIAL TOPICS IN PROBABILITY—1-3 cr. (1-3 and 0)
Math 981—SPECIAL TOPICS IN MATHEMATICAL STATISTICS—1-3 cr. (1-3 and 0)

Math 982—SPECIAL TOPICS IN ANALYSIS—1-3 cr. (1-3 and 0)

Math 983—SPECIAL TOPICS IN FUNCTIONAL ANALYSIS—1-3 cr. (1-3 and 0)

Math 984—SPECIAL TOPICS IN APPLIED MATHEMATICS—1-3 cr. (1-3 and 0)

Math 985—SPECIAL TOPICS IN ALGEBRA—1-3 cr. (1-3 and 0)

Math 986—SPECIAL TOPICS IN CONVEXITY—1-3 cr. (1-3 and 0)

Math 991—DOCTORAL RESEARCH—Credit to be arranged.

MICROBIOLOGY
M. J. B. Paynter, Department Head

The Master of Science degree is offered. The Doctor of Philosophy degree is offered in Plant Physiology with an emphasis in Microbiology. See Botany and Zoology for a listing of additional courses available.

Graduate work in Microbiology requires sound undergraduate training in the biological and physical sciences. This training may be received in an undergraduate program in biology (botany, microbiology, or zoology), chemistry, or pre-medicine or in one of the agricultural sciences. Undergraduate work in bacteriology or microbiology is desirable but not necessary.

Micro 601—ADVANCED BACTERIOLOGY—4 cr. (2 and 6) F

Micro 602—DAIRY MICROBIOLOGY—3 cr. (2 and 3) S, even numbered years.

Micro 604—FOOD MICROBIOLOGY—3 cr. (2 and 3) S, odd numbered years.

Micro 605—GENERAL MICROBIOLOGY—4 cr. (3 and 3) FS, SS

Micro 610—SOIL MICROBIOLOGY—3 cr. (2 and 3) S, even numbered years.

Micro 611—PATHOGENIC BACTERIOLOGY—3 cr. (2 and 3) S

Micro 612—BACTERIAL PHYSIOLOGY—4 cr. (3 and 3) S

Micro 613—INDUSTRIAL MICROBIOLOGY—3 cr. (2 and 3) F.
Micro 614—BASIC IMMUNOLOGY—3 cr. (2 and 3) F

Micro 615—MICROBIAL GENETICS—4 cr. (3 and 3) F

Micro 616—INTRODUCTORY VIROLOGY—3 cr. (3 and 0) F

Micro 801—BACTERIAL TAXONOMY—3 cr. (2 and 3) F, odd numbered years.

The history of determinative bacteriology and the basic morphological, cultural, and physiological differences used in distinguishing between the various taxonomic groups of bacteria. Opportunity is given in the laboratory to isolate and identify bacteria from natural sources. **Prerequisites:** Micro 601 and organic chemistry. May be taken concurrently with Micro 601.

Micro 802—BACTERIOLOGICAL TECHNIC—4 cr. (2 and 6) F

Analytical and experimental procedures used in bacteriology, including techniques for studying bacterial cytology, physiology, and metabolism. Designed to give students experience in more advanced methods of investigation.

Micro 803—SPECIAL PROBLEMS IN MICROBIOLOGY—Credit to be arranged.

Original research on special problems in microbiology not related to the thesis.

Micro 807—SEMINAR—1 cr. (1 and 0)

A study of areas of microbiology not covered by formal courses with special emphasis on the review of literature, and organization and presentation of material by students. (May be taken for credit only twice.)

Micro 810—SOIL MICROBIOLOGY—3 cr. (2 and 3) S, odd numbered years.

Characterization and ecology of soil microorganisms. Interrelations of soil microbial populations; associative and antagonistic effects. Effects of soil microorganisms on plant growth. Relations of plant rhizospheres to nutritional groups of microorganisms. **Prerequisite:** Micro 601 or 610.

Micro 811—BACTERIAL CYTOLOGY AND PHYSIOLOGY—4 cr. (4 and 0) S, odd numbered years.

A consideration of the structure, chemistry and physiology of the various bacterial cell components; the physiology of bacterial growth and reproduction in batch, continuous and synchronous cultures; the economy of the bacterial cell, including endogenous metabolism and maintenance requirements; the physiology of bacterial death; and the regulation of enzyme and nucleic acids syntheses. **Prerequisites:** Micro 605; Bioch 623 and 624 or concurrent registration in Bioch 624; Math 206; or permission from instructor.
Micro 812—BACTERIAL METABOLISM—3 cr. (3 and 0) S, even numbered years.

A consideration of the various biochemical pathways occurring in bacterial cells. Topics discussed include: the fermentations of carbohydrates and related compounds and of nitrogenous organic compounds; anaerobic and aerobic respiration, including electron transport systems and oxidative phosphorylation; bacterial photosynthesis; nitrogen fixation; the biosyntheses of amino acids, purines, pyrimidines, lipids, proteins, nucleic acids and polysaccharides. Prerequisites: Micro 605; Bioch 623 and 624 or concurrent registration in Bioch 624; Math 206; or permission of instructor.

Micro 813—BACTERIAL CYTOLOGY AND PHYSIOLOGY LABORATORY—2 cr. (0 and 6) S, odd numbered years.

Experiments to illustrate fundamental principles discussed in Micro 811. Students will participate in designing each experiment. Prerequisites: Micro 605; Bioch 623 and 624 or concurrent registration in Bioch 624; Math 206; or permission of instructor.

Micro 814—BACTERIAL METABOLISM LABORATORY—2 cr. (0 and 6) S, even numbered years.

Experiments to illustrate fundamental principles discussed in Micro 812. Students will participate in designing each experiment. Prerequisites: Micro 605; Bioch 623 and 624 or concurrent registration in Bioch 624; Math 206; or permission of instructor.

Micro 815—ADVANCED MICROBIAL GENETICS—3 cr. (3 and 0) S, odd numbered years.

An in-depth study of current developments in microbial genetics. Topics discussed will include: the integration of genetics and biochemistry, the analysis of genetic fine structure in microorganisms; the nature of bacterial variation and the expression of mutations; population dynamics; the physio-chemical mechanisms of heredity; regulation of gene action in microorganisms; the physiology and genetics of virulent and lysogenic bacteriophages. Readings and discussion will center on the current research literature. Prerequisite: Micro 615.

Micro 891—RESEARCH—Credit to be arranged.

PHYSICS

E. P. Stillwell, Department Head

The Physics Department offers the Master of Science and Doctor of Philosophy degrees.

For the Master of Science degree:

1. A student is admitted to candidacy for the Master of Science degree upon the completion of a written qualifying examination covering major
and minor fields. This examination must be completed one semester before the date on which the degree is expected.

2. A final oral examination on the subject matter of the major and minor fields and on the thesis. This examination will be given at least two weeks before the date on which the degree is to be granted.

For the Doctor of Philosophy degree:

1. A student who entered with a Bachelor’s degree will take the qualifying examination for the Master of Science degree. If he performs to the satisfaction of the faculty, he may by-pass the Master’s degree if he chooses. Otherwise he must obtain the Master of Science degree before he can be considered for continuance in the doctoral program.

2. Students are admitted to candidacy for the Doctor of Philosophy degree upon the successful completion of a written qualifying examination on the subject matter of the major and minor fields. This examination must be completed at least one academic year prior to the date on which the degree is expected.

3. The student must take a final oral examination on the dissertation only. This examination must be taken at least two weeks prior to the Convocation in which the degree is expected.

Teaching in undergraduate courses is an integral part of graduate study in physics and is required of all graduate students.

Phys 604—ASTRODYNAMICS—3 cr. (3 and 0)
Phys 605—PHYSICS FOR HIGH SCHOOL TEACHERS I—4 cr. (3 and 1)
Phys 606—PHYSICS FOR HIGH SCHOOL TEACHERS II—4 cr. (3 and 1)
Phys 632—PHYSICAL OPTICS AND INTRODUCTION TO SPECTROSCOPY—3 cr. (3 and 0)
Phys 641—ELECTRICITY AND MAGNETISM—3 cr. (3 and 0)
Phys 646—SOLID STATE PHYSICS—3 cr. (3 and 0)
Phys 652—INTRODUCTORY NUCLEAR PHYSICS—3 cr. (3 and 0)
Phys 655—QUANTUM PHYSICS I—3 cr. (3 and 0)
Phys 656—QUANTUM PHYSICS II—3 cr. (3 and 0)
Phys 660—MODERN PHYSICS FOR HIGH SCHOOL TEACHERS—3 cr. (3 and 0)
Phys 665—THERMODYNAMICS AND STATISTICAL MECHANICS—3 cr. (3 and 0)
Phys 671—ELECTRON MICROSCOPY—3 cr. (3 and 0)
Phys 672—ELECTRON MICROSCOPY OF SOILS—3 cr. (3 and 0)
Phys 673—X-RAY CRYSTALLOGRAPHY—3 cr. (2 and 3)
Phys 803—MODERN PHYSICS FOR HIGH SCHOOL TEACHERS—3 cr.
(3 and 0)
The Rutherford model of the atom, nature of intermolecular description
of matter is examined. Quantum theory of matter is described. Nuclear
forces, radioactivity, and special relativity.
Phys 804—ASTRONOMY FOR HIGH SCHOOL TEACHERS—3 cr.
(3 and 0)
A lecture and observation course designed to introduce the concepts and
descriptions basic to modern astronomy. Emphasis will be placed on de-
scriptive astronomy and the phenomena associated with the seasons, time
systems, and current interests. Fundamental physical principles necessary
to proper explanations will be introduced. The new Spitz planetarium at
the University and night observations of the heavens will be used to sup-
plement the lectures.
Phys 811—METHODS OF THEORETICAL PHYSICS I—3 cr. (3 and 0)
A course in which students are introduced to the analytical methods and
techniques which are used in theoretical Physics. Topics to be considered
are vector and tensor analysis as applied to physical problems, the use of
matrices and groups in classical and quantum mechanics, complex vari-
bles and the partial differential equation of Physics.
Phys 812—METHODS OF THEORETICAL PHYSICS II—3 cr. (3 and 0)
A continuation of Physics 811. Topics will include the use of integral
transforms, integral equations, special functions, calculus of variations
and numerical approximations in the solution of physical problems.
Phys 813—ADVANCED THERMODYNAMICS AND STATISTICAL
MECHANICS I—3 cr. (3 and 0)
Classical statistical mechanics and the derivation of the laws of thermo-
dynamics. Statistical treatment of the thermodynamics of irreversible
processes.
Phys 814—ADVANCED THERMODYNAMICS AND STATISTICAL
MECHANICS II—3 cr. (3 and 0)
Quantum statistical mechanics; the microcanonical, the canonical, and
the grand canonical ensemble theories. The ideal Fermi gas and the ideal
Bose gas. Special topics in advanced statistical mechanics.
Phys 821—CLASSICAL MECHANICS I—3 cr. (3 and 0)
Dynamics of particles, variational principles and Lagrange's equations,
two body central force problems, dynamics of rigid bodies. Matrix formu-
lations freely used.
Phys 822—CLASSICAL MECHANICS II—3 cr. (3 and 0)
Special relativity in classical mechanics, Hamilton's equations, canonical transformations, Hamilton-Jacobi theory, small oscillations.

Phys 841—ELECTRODYNAMICS I—3 cr. (3 and 0)
The field theory of electromagnetism. Maxwell's equations and their application to the study of electromagnetic wave production and propagation, wave optics and theories of interference and diffraction.

Phys 842—ELECTRODYNAMICS II—3 cr. (3 and 0)
The production and propagation of electromagnetic waves are studied using Maxwell's equations as a starting point. Discussions of wave guides, diffraction phenomenon, and boundary effects are included. An introduction to the theory of electrons and microscopic phenomena is given.

Phys 845—SOLID STATE I—3 cr. (3 and 0)
The study of the physical properties of crystalline solids. The topics treated are crystalline state determination by diffraction methods, theories of specific heat, properties of metallic lattices and alloys, lattice energy and ferroelectrics.

Phys 846—SOLID STATE II—3 cr. (3 and 0)
A continuation of Physics 845, but includes the electronic properties of solids. The topics treated are band theory of solids, rectifiers and transistors, theories of magnetism and magnetic resonance phenomena.

Phys 853—NUCLEAR PHYSICS I—3 cr. (3 and 0)
A study of selected topics in nuclear structure, nuclear forces and nuclear interaction processes. Shell structure, spins, and magnetic moments of nuclear particles.

Phys 854—NUCLEAR PHYSICS II—3 cr. (3 and 0)
High energy radiation processes, nuclear reactions including nuclear fission; scattering, natural and induced nuclear disintegration.

Phys 856—CRYSTALLOGRAPHY—3 cr. (3 and 0)
A systematic study of the external and internal symmetry of crystals as revealed by their physical properties.

Phys 875—SEMINAR IN CONTEMPORARY PHYSICS—1 or 2 or 3 cr. (1 or 2 or 3 and 0)
A joint study by graduate students and interested members of the faculty of some area of physics which is currently being extensively investigated.

Phys 885—COLLOQUIUM—1 cr. (1 and 0)
Selected topics. Required of all Physics graduate students each semester in residence.

Phys 891—RESEARCH—Credit to be arranged.
Phys 922—HYDRODYNAMICS—3 cr. (3 and 0)
The mathematical theory of the motions of an ideal fluid including effects produced by moving submerged bodies; theory of waves, ripples and vortices; effects of viscosity.

Phys 951—QUANTUM MECHANICS I—3 cr. (3 and 0)
Review of wave mechanics; operator algebra and theory of representation; approximate methods for stationary problems; theory of scattering applied to atomic and nuclear problems.

Phys 952—QUANTUM MECHANICS II—3 cr. (3 and 0)
Continuation of physics 951 including time dependent perturbations; radiation absorption and emission; relativistic quantum mechanics; introduction to quantum electrodynamics.

Phys 955—ADVANCED MODERN PHYSICS I—3 cr. (3 and 0)
An application of quantum mechanics and relativity theory to selected topics of recent interest in physics; atomic and nuclear structure, radioactivity and nuclear stability, molecular structure, and theory of solids are considered.

Phys 956—ADVANCED MODERN PHYSICS II—3 cr. (3 and 0)
A continuation of Physics 955. Topics of special interest to instructor and students will be considered.

Phys 966—RELATIVITY—3 cr. (3 and 0)
Gives a survey of the special and general theory of relativity including tensor calculus, the Lorentz transformation and three experimental tests of the general theory: (1) planetary motion and the advance of the perihelion of Mercury (2) the bending of light rays in gravitational fields and (3) the gravitational shift of spectral lines.

Phys 991—DOCTORAL RESEARCH AND DISSERTATION— Credit to be arranged.
May be taken more than one semester.

ZOLOGY
A. S. Tombes, Chairman
The Master of Science and the Doctor of Philosophy degrees are offered.

Zool 602—VERTEBRATE EMBRYOLOGY—3 cr. (2 and 3) F, S
Zool 603—PROTOZOOLOGY—3 cr. (2 and 3) S
Zool 604—ANIMAL PATHOLOGY—3 cr. (2 and 3) S
Zool 605—ANIMAL HISTOLOGY—3 cr. (2 and 3) F
Zool 608—PHYSIOLOGY AND DEVELOPMENT OF INVERTEBRATES —2 cr. (2 and 3) F
Zool 610—LIMNOLOGY—3 cr. (2 and 3) S
Zool 611—ANIMAL ECOLOGY—3 cr. (2 and 3) F
Zool 656—PARASITOLOGY—3 cr. (2 and 3) F
Zool 658—CELL PHYSIOLOGY—3 cr. (2 and 3) S
Zool 660—GENERAL PHYSIOLOGY—3 cr. (2 and 3) F, S, SS
Zool 661—ANATOMY—3 cr. (2 and 3) F, S
Zool 662—HERPETOLOGY—3 cr. (2 and 3) S
Zool 663—ICHTHYOLOGY—3 cr. (2 and 3) S
Zool 664—MAMMALOGY—3 cr. (2 and 3) F
Zool 665—ORNITHOLOGY—3 cr. (2 and 3) S
Zool 670—ETHOLOGY—3 cr. (2 and 3) S
Zool 675—GENERAL ENDOCRINOLOGY—3 cr. (2 and 3) F
Zool 801—ANIMAL HISTOLOGY—3 cr. (2 and 3) F '71 and alternate years.
   An advanced study in the microscopic structures of the tissues and organs of the animal body and the relation of histology to physiology and pathology.
Zool 802—HISTOLOGICAL TECHNIQUES—3 cr. (1 and 6) SS '71 and alternate years.
   The fixing, staining, sectioning, and identification of tissues, glands and organs of animals. **Prerequisites:** Zool 101, 103.
Zool 803—POPULATION DYNAMICS—4 cr. (2 and 6) S '72 and alternate years.
   A study of fundamental mechanisms basic to the regulation of natural animal populations. A laboratory research project in population dynamics will complement the theory.
Zool 805—ANIMAL PATHOLOGY—3 cr. (3 and 0) S ’71 and alternate years.
   Designed to acquaint the student with the cause, prevention, and treatment of pathogenic diseases.
Zool 806—COMPARATIVE ANIMAL PHYSIOLOGICAL—3 cr. (3 an 0) S '72 and alternate years.

An advanced level study of the physiological principles as they occur throughout the animal kingdom. The course is organized on a function-system rather than on a taxonomic basis. Prerequisite: Zool 658 or permission of instructor.

Zool 807—USE OF RADIOISOTOPEs IN BIOLOGICAL RESEARCH—
3 cr. (2 and 3) S '71 and alternate years.

The types of radioisotopes useful in biological research will be studied, including methods of detection and measurement in biological systems. Prerequisites: Graduate standing and permission of instructor.

Zool 808—RADIOBIOLOGY—3 cr. (2 and 3) F '72 and alternate years.

A study of the effects of various types or radiation upon cells, tissues, and organs of animals. Various methods of evaluation and quantitation of effects will be employed in the laboratory. Prerequisite: Permission of instructor.

Zool 809—TOXICOLOGY—3 cr. (2 and 3)

Toxicologic methods, modes of action, signs and symptoms of poison, and antidotes will be studied. Special emphasis will be given deleterious effects from commonly used chemicals. Quantitative aspects of toxicology will be demonstrated in the laboratory. Prerequisites: Permission of instructor.

Zool 812—SEMINAR—1 cr. (1 and 0) F, S, SS

A review of the current literature in the fields of Zoology.

Zool 813—ADVANCED EVOLUTION—3 cr. (3 and 0) F '71 and alternate years.

Covers the principles which have governed the evolution of plants and animals and also of the relationships of the Phyla and classes which are the results of this process.

Zool 830—HISTOCHEMISTRY-CYTOCHEMISTRY—3 cr. (2 and 3)

Orientation to procedures which allow valid inferences to be drawn concerning identity, quantity, and location of chemical moieties and endymatic activities within intact (non-homogenized) cells or tissues under control and experimental conditions, in normal and pathological states, and in different physiological conditions.

Zool 852—PRINCIPLES AND METHODS OF SYSTEMATIC ZOOLOGY—
2 cr. (2 and 0) F '72 and alternate years.

Presents the problems which confront the taxonomist in the zoological sciences and the conventional practices which have been developed to handle them.

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Zool 863—SPECIAL PROBLEMS—(1-4 cr.) F, S, S S
Original investigation of special problems in Zoology which are not related to a thesis but designed to provide experience and training in research or specialized areas of Zoology. Prerequisite: Permission of instructor.

Zool 891—RESEARCH—Credit to be arranged. F, S, S S

Zool 991—DOCTORAL RESEARCH—Credit to be arranged. F, S, S S
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Clemson University offers equal educational opportunity to all persons without regard to race, creed, color or national origin.

This policy applies in all matters, including:

1. Admission and education of students.

2. Availability of student loans, grants, scholarships and job opportunities.

3. Employment and promotion of teaching and non-teaching personnel.

4. Student and faculty housing situated on premises owned or occupied by the University.

5. Off-campus housing not owned by the University but listed with the University for referral purposes.

6. Activities conducted on premises owned or occupied by the University.