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College of Engineering
1988-89

The University of Michigan Bulletin

College of Engineering 1988-1989

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Contents

Academic Calendar 1988-89

Fall Term, 1988

Ann Arbor Campus

Orientation .... Sept. 4-7, Sun.-Wed.
Labor Day (Holiday) .... Sept. 5, Mon.
***Registration .... Sept. 6-7, Tues.-Wed.**
Classes begin .... Sept. 8, Thurs.
Thanksgiving recess 5 p.m. .... Nov. 23, Wed.
Classes resume 8 a.m. .... Nov. 28, Mon.
Classes end .... Dec. 13, Tues.
Study Days .... Dec. 14,17-18, Sat.-Mon.
Examinations .... Dec. 15,16,19-22, Thurs.-Fri., Mon.-Thurs.
Commencement .... Dec. 18, Sun.

Dearborn Campus

Registration .... Aug. 31, Sept. 1, Wed.-Thurs.
Classes begin .... Sept. 7, Wed.

Flint Campus (Contact Flint Registrar's Office, 762-3344.)

Registration .... Sept. 6, Tues.
Classes begin .... Sept. 7, Wed.

Winter Term, 1989

Ann Arbor Campus

Orientation .... Jan. 3-5, Tues.-Thurs.
***Registration .... Jan. 4-5, Wed.-Thurs.**
Classes begin .... Jan. 6, Fri.
Vacation begins 12:00 noon .... Feb. 25, Sat.
Classes resume 8:00 a.m. .... Mar. 6, Mon.
University Honors Convocation .... Mar. 19, Sun.
Classes end .... Apr. 19, Wed.
Study Days .... Apr. 20, 22-23, Thurs., Sat.-Sun.
Examinations .... Apr. 21, 24-28, Fri., Mon.-Fri.
Commencement .... Apr. 29, Sat.

Dearborn Campus

Registration .... Jan. 3, Wed.
Classes begin .... Jan. 5, Thurs.

Flint Campus (Contact Flint Registrar's Office, 762-3344.)

Registration .... Jan. 3-4, Tues.-Wed.
Classes begin .... Jan. 5, Thurs.

Spring-Summer Term, 1989

Ann Arbor Campus

Orientation .... Apr. 30, May 1-2, Sun.-Tues.
***Registration (Full Term & Spr. Half) .... May 1-2, Mon.-Tues.**
Classes begin .... May 3, Wed.
Memorial Day (Holiday) .... May 29, Mon.
Classes end (Spring Half) .... June 20, Tues.
Study Day .... June 21, Wed.
Examinations .... June 22-23, Thurs.-Fri.
Spring Half Term ends .... June 23, Fri.
***Registration (Summer Half) .... June 26-27, Mon.-Tues.**
Summer Half Term classes begin .... June 28, Wed.
Independence Day (Holiday) .... July 4, Tues.
Classes end .... Aug. 15, Tues.
Study Day .... Aug. 16, Wed.
Examinations .... Aug. 17-18, Thurs.-Fri.
Full Term & Summer Half Term end .... Aug. 18, Fri.

Dearborn Campus

Registration .... April 28, Fri.
Classes begin .... May 3, Wed.

Summer Half Term

Registration .... June 26, Mon.
Classes begin .... June 28, Wed.

Flint Campus (Contact Flint Registrar's Office, 762-3344.)

Registration .... Apr. 28, Fri.
Classes begin .... May 1, Mon.

Summer Half Term

Registration .... June 26, Mon.
Classes begin .... June 27, Tues.

***Check School Office for registration dates to avoid late registration fee.**

This Calendar is subject to change.

Office Directories

General University Offices

Academic Affairs
3080 Fleming Bldg.
Admission of Freshmen
1220 Student Activities Bldg. (SAB)
Career Planning & Placement
3200 SAB
Cashier's Office
1015 Literature, Science, and the Arts Bldg. (LSA)
Employment:
Student, 2503 SAB
Hospital, 300 N. Ingalls, 5th level
Campus, 2031 Ad Services & 1020 LSA
Extension Service
200 Hill Street
Financial Aid
2011 SAB
Foreign Student Counselors
International Center
603 E. Madison
Graduate School
1004 Rackham Bldg.
76-GUIDE, 24-hr. Telephone Counseling Svc.
3100 Union, 764-8433
Health Service
207 Fletcher
Housing, 1011 SAB
- Residence Halls Assignments
- Family Housing Assignments
- Off-Campus Housing
- Small Group Housing (fraternities, sororities, co-ops, etc.)
- Fees, payment of, Cashier's Ofc., 1015 LSA Bldg.

International Center
603 E. Madison
Ombudsman
3000 Union
Orientation
3000 Union
President's Office
2074 Fleming Bldg.
Secretary of the University
2014 Fleming Bldg.
Student Accounts
2226 SAB
Student Locator
764-2330
Student Organizations Development Center
2304 Union
Student Legal Services
3909 Union
Veterans Affairs
1514 LSA Bldg.

College of Engineering Offices

Information — General: (313) 764-8470
Information — Student: (313) 763-1168

Admissions:
Freshmen: 1220 SAB, 764-7433
Transfer: 2417 Electrical Engineering & Computer Science Bldg. (EECS), 763-6841
- Foreign
- Guest
- Special
- Undergraduates

Deans of the College:
Dean C.M. Vest
2401 EECS Bldg.
Assoc. Dean D.E. Atkins
2306 EECS Bldg.
Assoc. Dean L.A. Conway
2307 EECS Bldg.
Assoc. Dean E. Gulari
2305 EECS Bldg.
Assoc. Dean W.M. Hancock
168 Advanced Technology Labs Bldg.
Assoc. Dean J.R. Lohmann
2402 EECS Bldg.
Asst. Dean for Freshman Services
Gene Smith
2419 EECS Bldg.
Asst. Dean B.H. Karnopp
2417-B EECS Bldg.
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2310 EECS Bldg.
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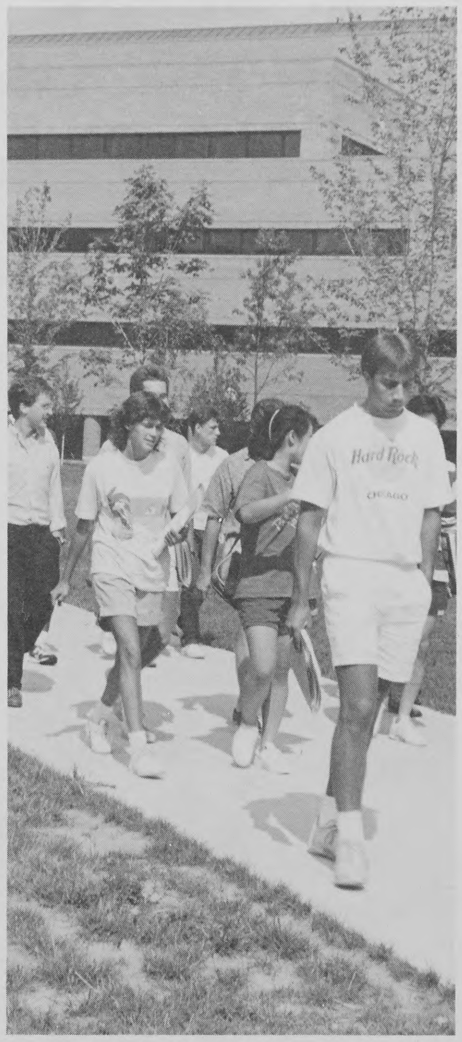
2403 EECS Bldg.
G.R. Carignan
Special Asst. to the dean for research
2304 EECS Bldg.
E.W. Harden
College Relations
2406 EECS Bldg.
H.H. Harger
Business & Finance
2301 EECS Bldg.
Dwight W. Stevenson
Director of Michigan Engineering Television Network
1020 Dow Bldg.
A.W. Monterio
Director of Academic Services
2419C EECS Bldg.
R.W. Schneider
Director of Corporate Relations
2409 EECS Bldg.
D.E. Scott
Director of Minority Engineering Programs
2316-B EECS Bldg.
Engineering Council
1230 EECS Bldg.
Engineering Learning Resource Center
2327 EECS Bldg.
Freshman Counseling
2419 EECS Bldg.
Lost and Found:
- 282 SAB
- 3415 EECS Bldg.

Minority Engrg. Prog. Office
2316 EECS Bldg.
Placement (student and alumni) Cooperative Education
201 Stearns Bldg. (and department offices)
Records Office
2420 EECS Bldg.
Society of Minority Engineers
1232 EECS Bldg.
Society of Women Engineers
1226 EECS Bldg.
Transfer students, admission of
2417-B EECS Bldg.
Withdrawal/Disenrollment
2417 EECS Bldg.



College of Engineering

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Director of Corporate Relations
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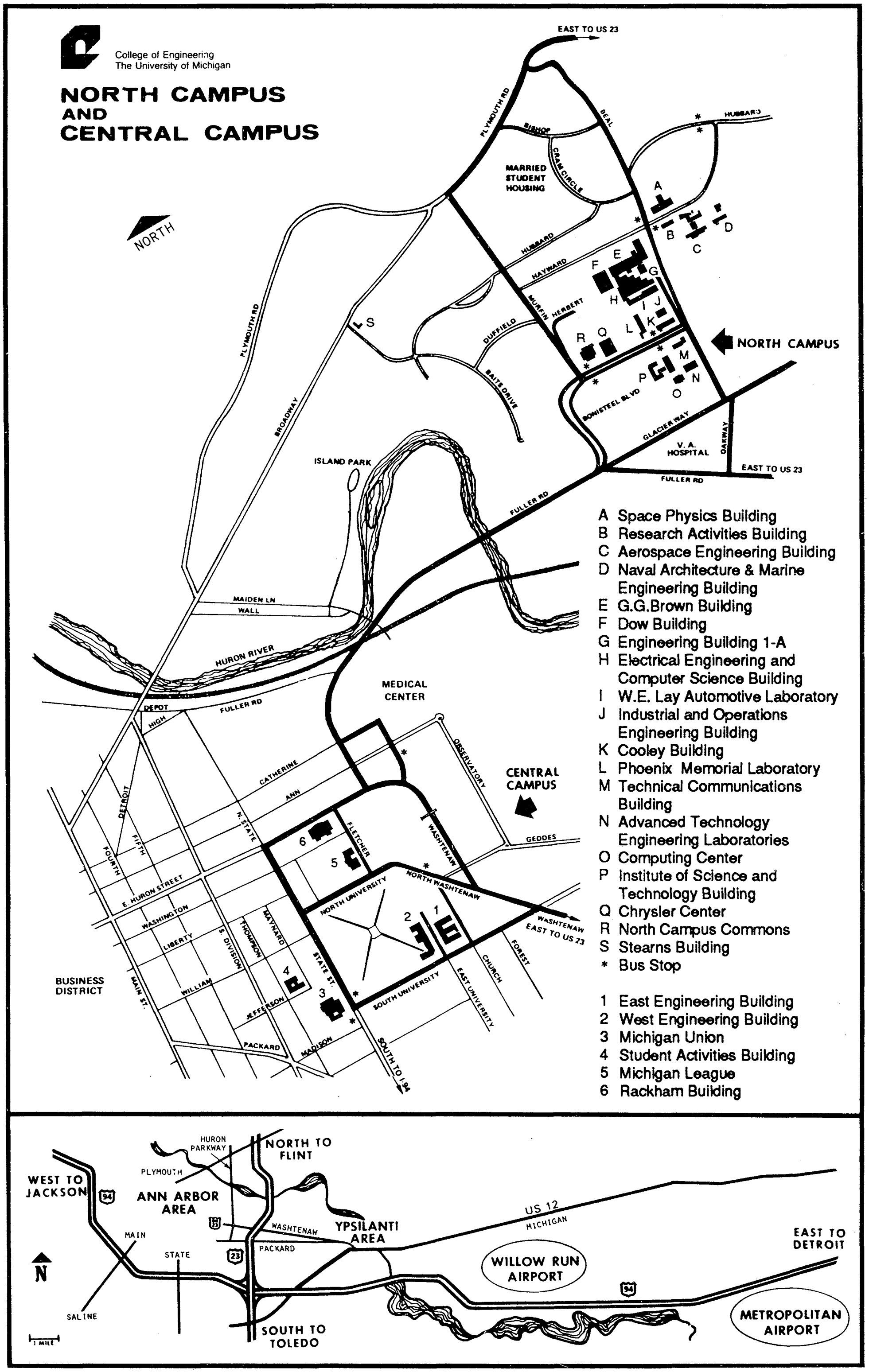
Director of Minority Engineering Programs
Diana H. Anderson, B.A.
Director of Publications

For Committees, see page 137.
Chairpersons and Faculty listed prior to each Department's Course Descriptions.



General Information

Our society is increasingly dependent on a scientific and technological base not only for its prosperity but for its very survival. Throughout the modern era, the need has been great for men and women who as scientists can discover the truths of nature, or as engineers can apply those truths "for the benefit of mankind." Never has the need been greater than it is today.

Engineers as well as scientists make their contributions to the storehouse of knowledge. It should be stressed, however, that engineers are occupied primarily with solving real-life problems. Engineering is a profession that began as a practical art, and although it has become less of an art and more of a science, its main concern is still "the benefit of mankind."

By bringing to bear on each problem a proper combination of knowledge, experience, and judgment, engineers seek the best or most economical solution. Every day of every year, they find more and more ways to make our way of life easier, safer, cleaner, and more comfortable—for more and more people. They invent methods for doing something never done before. Unhappy with what exists, they are always seeking ways to improve, to do things better and more efficiently. In the various processes of inventing, designing, manufacturing, and constructing, engineers are concerned continually with the use of manpower, and the effects of their creativity on people and their total welfare. They also find ways of coping with the problems that derive from their earlier successes—such problems as air and water pollution, mass transportation, the noises of supersonic travel, or the need for better forms of information storage and retrieval.

In our time, the engineering approach to problems has taken on particular importance because social and technological problems have become so closely interrelated. The problem of air pollution, to cite but one example, cannot be solved in terms of the underlying physical causes alone. We must know why it looms as such a major problem; what social, political, legal, and ethical conflicts it arouses; and how the alternative technological solutions would affect both individual and group interests or welfare. Positions in modern engineering demand a sensitivity to such problems across the full range of our social and economic concerns. The College of Engineering is dedicated to educating young men and women for such technological leadership.

To an increasing number of young people today, the words "environment" and "ecology" suggest a wide range of opportunities that lie ahead in solving the problems and meeting the needs of contemporary society. The solution to these problems certainly involves the contributions of the engineers who design, build, and operate our machines, plants, and processes.

Students in the College of Engineering have the opportunity to elect courses that will broaden their knowledge of the environment and ecology. Those who do will be particularly well qualified to utilize their technical knowledge in developing definitive solutions to environmental problems.

The College's enduring educational objective is that of preparing its students for positions of responsibility that are commensurate with their abilities and interests. But the means by which the College carries out this objective must be continually revised in the light of conditions that are continually changing in education and throughout the whole of society. Students enrolled in the College soon discover that its programs have been planned to prepare them for any one of a broad range of possibilities. According to their aptitudes and desires, the students may go on to become practicing engineers, or researchers, or administrators, or teachers. Moreover, the knowledge and discipline gained from undergraduate engineering study are proving to be excellent preparation for other careers, particularly in business, law, and medicine. Many graduates of the College remain after they have received an undergraduate degree to earn a master's or doctor's degree. Another opportunity for continued growth and development beyond the undergraduate degree is that of registration as a professional engineer. After a certain length of experience (usually four years), new engineers can take qualifying examinations offered by the state in which they seek registration.

At Michigan, students have an opportunity to associate with distinguished teachers who have not only solid academic grounding but also broad professional involvement, the result of continuing research and consultation on actual engineering projects. The College believes that such professional involvement is necessary if its faculty is to retain maximum efficiency both in the classroom and the laboratory. The benefits of such involvement are passed on to students through formal classroom exposure and through informal exposure as well. Often, teaching is most effective when a teacher can work together with students in fundamental scientific investigations, or on improved ways of applying scientific knowledge to the problems of industry and public well-being. Graduate and undergraduate students in the College have an opportunity to participate in such activities in well-equipped engineering laboratories and at a number of field locations.

The College's program for undergraduate study consists typically of a four-year program leading to a bachelor's degree. There are 12 programs that lead to the degree Bachelor of Science in Engineering, and four that lead to the degree Bachelor of Science; these are identified throughout this catalog as B.S.E. and B.S., respectively. By careful planning, an additional bachelor's degree (B.S. or A.B.) can be earned within the College of Engineering or in combination with the College of Literature, Science, and the Arts in about one year beyond the time required for a single degree. For further information, refer to the later section on Undergraduate Programs.

History

The College of Engineering observed the centennial of engineering education at The University of Michigan in 1953-54. In 1857, when the first engineering degree was awarded, there were but a few colleges providing opportunities for study leading to this degree; scientific instruction in engineering was first established at West Point in 1802 followed by instruction at Rensselaer, which in 1835 granted the first degrees in Civil Engineering in the United States.

As early as 1852, President Henry P. Tappan of the University proposed "a scientific course parallel to the classical course" containing "besides other branches, Civil Engineering, Astronomy with the use of an observatory, the application of chemistry and other sciences to agriculture, and the industrial arts generally." The early curriculum included mathematics, graphics, physics, natural science, elements of astronomy, language, philosophy, and engineering subjects including plain geodetics, railroad and mining surveying, leveling, nature and strength of materials, theory of construction, architecture, machines (particularly the steam engine and the locomotive), and motors, particularly steam and water.

Upon completion of the first four-year curriculum offered at the University, two students were granted first degrees in Civil Engineering in 1860. Today approximately 1,000 students graduate annually with bachelor's degrees. The opportunities for study have expanded to the point that students may select from about 950 engineering courses.

In the 1987 fall term, 3,893 undergraduate students (with 850 entering for the first time from high school) and 1,758 graduate students were enrolled in engineering. The total enrollment of the University for the Ann Arbor Campus is approximately 35,000.

The teaching staff of the College of Engineering numbers approximately 400, not including those who teach mathematics, chemistry, physics, and those elective subjects taken in other colleges.

The University is located in Ann Arbor, a city of about 110,000 including students; it is located about 40 miles from the heart of Detroit and is adjacent to one of the country's largest industrial communities with continually expanding needs for engineering facilities and services.

Career Choice

In choosing engineering as a career, the main criteria are usually an interest in and successful completion of high school mathematics and science courses; a desire and ability to investigate the "why" as well as the "how" of things; and an interest in the creative development of devices or systems that meet specific needs. The engineer of the future will be increasingly concerned with the preservation of our natural environment, the wise use of our natural resources, and the importance of individual creativity and initiative in the framework of a free democratic society. Certainly not all of these signs or interests will fit everyone, but they can be used as a rough guide.

More and more women are enrolling in engineering. Women who like science and mathematics will find engineering a satisfying career with a wide variety of employment opportunities. The College has one of the largest female enrollments of any engineering school in the country.

Officers and academic counselors within the College are glad to consult with high school or transfer students who are faced with a critical career choice or with the problem of choosing the school that best suits their interest and abilities. A student with questions in this regard may benefit from a leaflet titled Engineering — available by writing to the office of the Assistant Dean, College of Engineering, 2417 EECS Building, Ann Arbor, MI 48109-2116.

Registration as Professional Engineer

Modern civilization has found it necessary to regulate the practice of persons whose activities deal with the protection of life, health, property, or other rights. A profession such as engineering is judged by the qualifications and competency of all who use its name. Therefore, to provide the public with a clearly recognizable line of demarcation between the engineer and the non-engineer, the state establishes standards and provides the legal processes associated with the registration of individuals and their practices as professional engineers.

In Michigan, the State Board of Registration for Professional Engineers provides an opportunity for students during their senior year to take the first half of a 16 hour, two-part examination as the first step toward registration, provided the degree is awarded within six months after the examination, and the degree program is one that has been accredited at the College by the Accreditation Board for Engineering and Technology (ABET). The accredited degree programs are listed below. This first part is a general coverage of the fundamentals common to all fields of specialization including mathematics. After a minimum of four years of experience, which may include one year of graduate study, the applicant will take the second half of the examination which will involve the application of engineering judgment and planning ability.

On completion of registration, an engineer establishes professional standing on the basis of legal requirements and receives authority to practice the engineering profession before the public. While state laws may differ in some respects, an engineer registered under the laws of one state will find that reciprocal agreements between states generally make possible ready transfer of privileges to other states.

Accreditation

The following degree programs offered on the Ann Arbor campus have been accredited by the Accreditation Board for Engineering and Technology (ABET): Aerospace, Chemical, Civil, Computer, Electrical, Industrial and Operations, Materials Science and Engineering, Mechanical, Naval Architecture and Marine Engineering, and Nuclear.

Facilities

The offices and facilities used for instruction and research in engineering are located mostly in the following buildings on the Central and North Campuses:

North Campus

- Advanced Engineering Laboratories Building
- Advanced Technology Laboratory
- Aerospace Engineering Building and Laboratories
- George Granger Brown Laboratory
- Chrysler Center
- Mortimer E. Cooley Building
- Dow Building

Electrical Engineering and Computer Science Building
Engineering IA
University of Michigan Transportation Research Institute
Industrial and Operations Engineering Building
Institute of Science and Technology Building
Walter E. Lay Automotive Laboratory
Naval Architecture and Marine Engineering Building
Naval Architecture and Marine Engineering Ship Hydronamics Laboratory
Phoenix Memorial Laboratory with the Ford nuclear reactor
Research Activities Building
Space Research Building
Technical Information Design and Analysis Laboratory

Central Campus

West Engineering Building (Humanities Program)

The descriptions of the undergraduate degree programs include a reference to the facilities for the respective programs.

The **Computer Aided Engineering Network** (CAEN) of the College of Engineering is actually two entities — a computer network and an organization.

The network consists of hundreds of computer workstations in use by College of Engineering students, faculty, and staff. Most of the student systems are located in 10 student labs or workstation clusters. Two of these labs are located on Main Campus (in the Engineering Library) and eight are on North Campus (one in the Chrysler Center, two in the Dow Building, two in the EECS Building, one in the Auto Lab, one in G. G. Brown, and one in the Naval Architecture and Marine Engineering Building).

There are currently four types of computer workstations in public facilities: Apollos, Apple Macintoshes, and IBM XTs and ATs. The network is rapidly growing to include workstations from Sun Microsystems and DEC. The network also inclues several very fast server computers including an Allian FX/8 and a Harris HCX 9.

Many of the CAEN workstations are connected to local area networks so that data programs and expensive peripheral devices may be shared. In addition, most workstations are connected to the campus-wide computer network, UMnet. This allows access to the IBM 3090 computer running the Michigan Terminal System (MTS), and a variety of other computers, both on campus and at remote sites.

In addition to being a computer network, CAEN is also an organization within the College of Engineering. It has a full-time staff including the Director, office staff, programmers, and computer service people. A number of faculty members have partial appointments with CAEN to work on specific areas, such as networking and text processing. The CAEN staff receives direction from the CAEN Executive Committee. This group consists of Engineering faculty members, a representative from the Dean's office, and the Director. The Executive Committee reports to the Associate Dean for Research and Graduate Programs.

Additional information is available in the CAEN User Guide, which is available in department offices and at the CAEN office in 229 Chrysler Center.

The **Computing Center** is a research and service facility for the students, faculty, and research staff. Computing services are provided through an IBM 3090-400 running under an operating system called the Michigan Terminal System (MTS). MTS permits both conversational and batch processing from microcomputers, workstations and terminals. Active support is provided for microcomputer services and computer network development. For questions concerning Computer Center facilities and services, call the Computing Center Consultants, 764-HELP, weekdays 8 a.m.-midnight.

The **Engineering-Transportation Library,** located on the third floor of the Undergraduate Library, is one of the more than 25 divisional libraries in the University Library System. Its collection of approximately 450,000 volumes covers all fields of engineering except nuclear engineering. The library subscribes to almost 3,000 serial titles, maintains a large collection of technical reports and government documents, and accesses a wide variety of online databases. The Library also houses more than 70 microcomputers in the CAEN Network.

The **North Engineering Library,** located in the Dow Building on the North Campus, opened in the Fall of 1986 and includes a basic collection of engineering texts, reserve materials, and popular and heavily-used engineering journals along with the nuclear engineering collection. The Library uses a wide variety of online information services and also provides access to 100 microcomputers in the CAEN Network.

The Engineering Libraries provide trained staffs, course-related instruction programs, and computerized reference searching in order to assist the student in making effective use of information resources both on the University campus and around the world.

Use of Facilities. Laboratory, classroom and office equipment, shops, the library, and the computer are examples of a wide variety of facilities that serve as aids for instruction and research. Their use is limited to the purpose for which they are made available and any misuse will be subject to disciplinary action.

Other Physical Facilities

Health. While at the University, students may come to the University Health Service for all their health care needs.

The University Health Service (UHS) offers outpatient services and health education programs. Located at 207 Fletcher on the central campus, it is funded through student tuition fees. Most of the services provided are free of charge for enrolled students. Spouses of students may use the UHS by enrolling in its prepaid health care plan.

The general Medical Clinic sees patients by appointment and on a walk-in basis Monday-Friday, 8 a.m. - 4:30 p.m., and Saturday, 9 a.m. - noon. There is a Treatment Center for emergency care. For current building hours and services, call the UHS's INFO HOTLINE, 764-8320. If you have a medical emergency during hours when the UHS is closed, you may wish to go to the closest hospital emergency room. All fees incurred at the hospital are the responsibility of the patient.

The UHS also offers a wide range of specialty clinics provided free of charge for currently enrolled students. These clinics include: Allergy, Dermatology, Gynecology, Immunization, Neurology, Nutrition, Ophthalmology, Orthopedics, Ear, Nose and Throat, Sports Medicine, and Physical Therapy.

Medical support services include an X-ray department, laboratory, and pharmacy. The UHS also has an Eye Care Clinic, staffed by two full-time optometrists.

For details on what's available at the UHS, pick up a copy of its brochure or call the UHS Information Hotline at 764-8320. The Health Service Building is accessible to handicapped persons via its South entrance.

On request, the University will provide information on its facilities for housing, health care, recreation, physical education, and athletic participation.

Scholarships

Numerous University scholarships, fellowships, and prizes as well as loan funds, are available to qualified engineering students. In keeping with University practice and policy, financial assistance is available to qualified students regardless of sex, race, color, or creed.

Scholarships are established by gift or endowment. The University and the College of Engineering are fortunate that many of their alumni, along with industry, and various organizations, have contributed support through annual gifts and endowment funds, which earn annual income to be used for scholarship awards.

There is no direct obligation to repay a scholarship, but as recipients recognize their moral obligations to return gifts to the college scholarship fund, according to their abilities, other worthy students will benefit.

Below is a brief description of the broad range of undergraduate scholarships available to engineering students.

University Admissions Office Academic "Merit" Scholarships. Although families (students, parents, spouses) are primarily responsible for meeting college costs and are expected to contribute according to their ability, the University has established a variety of programs to recognize superior academic achievement. Participation in these programs is restricted to citizens of the United States and persons on permanent resident visas. Nominees are selected or identified from admissions applications or lists and are formally notified of their eligibility. Financial need is not a factor in the selection of scholarship recipients for merit awards. The stipends may change from year to year.

College of Engineering Academic "Merit" Scholarships. Each year a limited number of incoming freshmen are selected for a one-year (two terms) scholarship. A limited number of community college transfer students are selected for a one-term honorary scholarship. Students can request an application for a merit scholarship from the Engineering Scholarship Office, 2416 EECS Building, but selection is primarily made from the University's Admission Unit Roster and is based on SAT and/or ACT scores, high school or college grade point average (GPA), and class rank. These scholarships are restricted to citizens of the United States and persons on permanent resident visas.

Entering Students. Other than the Academic "Merit" scholarships granted by the University Admissions Office or the College of Engineering, incoming students (freshmen and transfer students) are not eligible for first-term need-based scholarship awards, but any student who meets the College's residency criteria can apply for an engineering scholarship for their second term enrolled. Application for second term awards MUST be made during the preceding term and will be held until grades are reported. (See Criteria and Deadlines below.)

Industry Sponsored Scholarships. Approximately 20 industries have annually contributed to the College of Engineering, generating 40-50 scholarships each year. Many of these scholarships offer summer work opportunities along with a monetary award. Recipients are selected based on the criteria established by the donor.

Need-Based Scholarships. All students must apply through the University's Financial Aid Office to qualify for a need-based scholarship. Engineering scholarships based on financial need are available to students who can demonstrate need and meet other requirements established by the College. Within the various scholarship funds are other criteria to be met. It is the task of the Scholarship Office and the College Scholarship Committee to match qualified students to the appropriate fund. Need-based scholarships are not renewable; students must reapply for scholarships each term and/or terms, at which time the applicants' needs are re-evaluated based on the new information.

Foreign Students. Foreign students must be prepared to finance their entire educations while enrolled in the College of Engineering. A guarantee of total financial backing must be provided when making application for admission. Scholarship applications are NOT accepted for foreign students.

Graduate Students. The College of Engineering does not have a scholarship program for graduate students, but in an emergency students can apply for a Ford Foundation short-term loan through the Engineering Scholarship Office. Graduate students can also apply to their departments or programs for a fellowship or an assistantship.

■ Criteria

Need-Based scholarships are restricted to full-time (12 credit hours) students who have completed one full term in the College of Engineering, have established a grade point average (GPA) of 2.7 or higher, and can demonstrate financial need. Need-Based scholarships are also restricted to students who are citizens of the United States or have a permanent resident visa. Since Need-Based scholarships are based on financial need, to qualify, students MUST also make application for financial aid through the University's Financial Aid Office, 2011 Student Activities Building. (See "Deadlines" below.)

Industry-Sponsored scholarships are restricted to full-time (12 credit hours) students who have completed one full term in the College of Enginering, have established a grade point average of 3.2 or higher, and are citizens of the United States or on permanent resident visas.

Where to Apply. Application forms for Need-Based or Industry Sponsored scholarships can be obtained at the Engineering Scholarship Office, 2416 EECS Building.

When to Apply. Scholarship application is always made one term preceding the term of the award; therefore, entering students should apply during their first term enrolled to receive an award during their second term. Scholarship applications from first term students are held until completion of the term and verification of credit hours and grades.

■ Deadlines

Applications for winter term are accepted from September 15th or October 15th. Applications for spring and/or summer terms, fall only or fall and winter terms, are accepted during the period of January 15th to February 15th.

Students applying for University Financial Aid must complete and submit their Financial Aid form to the Financial Aid Office no later than April 15th.

Industry Sponsored scholarships have no deadline for application. Awards are made as industry contributions are received.

Veterans and Social Security Benefits

Educational benefits are available to students who qualify under the several Public Laws providing benefits for veterans (or their children) and to orphans or children of a disabled parent who qualify under the Social Security Law. Questions may be referred to The Office of Student Certification, LSA Building.

Cooperative Education Opportunities

In 1982, the College began a voluntary cooperative (co-op) education program. Students interested in the program compete for a co-op position with participating employers based on the employer's criteria. Similarly, co-op students are free to make their selection of an employer based on educational opportunities they feel the various participating employers can offer them.

Students selected for the co-op program alternate (year-round) four-month terms of classroom study and work. Co-op students must be full-time students during alternate class terms and maintain good academic standing. Students will normally have at least three work periods with the same employer achieving about a year's work experience. Involvement in the program extends the graduation date at least one term, but many students will take five years to attain their degrees. Most of the employers will be located in Michigan and nearby states, but students could be placed in co-op positions across the country.

The co-op work experience is considered an integral part of the educational process. It will help the student to better understand the integration of theory and practice, and the student gains experience and expertise in a chosen field of study while building self-confidence. Co-op students will earn a substantial salary allowing them to be more financially independent. The student with co-op experience will have a competitive edge when it comes time for recruitment for permanent hire. Often co-op students are offered a permanent position by the employer they worked for as a co-op student.

Students will normally apply for the co-op program during the second term of the sophomore year or first term of the junior year. To be eligible, they must be U.S. citizens or permanent visa holders. Students applying must have at least a 2.75 GPA. Transfer students should be in the College one term before entering a work period, and application for the program can be made during the first term on campus.

Credit for cooperative program work is granted at the discretion of the department or program concerned.

In addition to co-op education, summer employment opportunities are available to many students. Some employers who visit the campus recruiting graduates for permanent hire also offer summer work to undergraduates, particularly those who have completed their junior year.

Placement

The College of Engineering considers the proper placement of its graduates to be very important, and it is recognized that the first years of professional experience are of great significance in developing the full capabilities of the young engineer. For these reasons the College provides an engineering placement service for students. This service includes the arranging of employment interviews on campus, the announcement of openings received by mail, and the providing of placement information through counseling and published material. Some of these services are available to alumni.

Summer and other short-term training positions are also offered by many employers, especially to students who have completed at least three years of an engineering program. The placement service provides all possible assistance in this area, since such experience is generally considered to be a valuable adjunct to formal technical education.

Foreign students should be informed that placement services for them are very limited. Almost all companies will interview only U.S. citizens and permanent visa holders. Further, companies involved in National Defense work will usually interview only U.S. citizens.

The University's Career Planning and Placement Office conducts lectures, discussion groups, and seminars each fall and winter on a number of career planning and job search topics; included are sessions on interviewing and resume writing. The Engineering Placement Office complements these sessions with individual counseling and meetings on how to use the Placement Office facilities and services.

Extracurricular Opportunities

Students at The University of Michigan have an opportunity to participate in a number of extracurricular activities. Some of these are associated with professional societies, others with social organizations, musical and drama groups, sports or service groups. In addition, a great many cultural programs are offered throughout the year — more than anyone could possibly attend.

The College of Engineering encourages participation in the wide range of activities—campuswide as well as those within the College. Used to advantage, college activities can provide a basis for many friendships and memorable times, as well as an opportunity for self-development.

The following is a list of organizations of particular interest to students in Engineering. Those interested in exploring other campuswide opportunities may obtain information concerning campus organizations at the Student Organizations, Activities, and Programs (SOAP) Office, 2400 Michigan Union.

College Student Government and Judiciary

Engineering Council. The University of Michigan Engineering Council is the student government of the College of Engineering and serves as the representative for engineering student opinion on College and University issues. The Council's work, done by committees, advisory boards, and a coordinating executive board, includes efforts in student-faculty relations, summer and permanent job placement, grades and grading, and faculty and course evaluation. Membership is open to all students of the College and the sole requirement for full membership is attendance at two of three consecutive meetings.

The Council welcomes the opinions of all students, from freshmen to seniors, as well as their active participation in its projects. New ideas and projects are always welcome. Those wishing to express opinions or to bring ideas to the Council should attend a Council Meeting or come to the Engineering Council Office, 1230 EECS Building, 764-8511.

Honor Council. The Student Honor Council, the student judiciary for the College, has the responsibility of conducting hearings and recommending action to the Discipline Committee in the case of alleged violations of the Honor Code or College rules on conducts.

Honor Societies

The criteria for election to one of the honor societies are based on the rules and regulations of the respective society. In general, the criteria include a scholastic requirement.

Student members of a society are responsible for election of new members. On request, the College will provide to each society, the names and local addresses of students who are eligible for election according to scholastic criteria specified by the respective society.

Membership in honor societies will be posted on the academic record upon receipt of the list of newly elected members from the secretary of the organization.

ADARA, Michigan senior women's honorary society
Alpha Nu Sigma, national nuclear engineering honor society
Alpha Pi Mu, national industrial engineering honor society
Alpha Sigma Mu, national materials science and engineering honor society
Chi Epsilon, national civil engineering honor society
Epeians, engineering leadership honor society
Eta Kappa Nu, national electrical engineering honor society
Golden Key, national honor society
Phi Beta Kappa
Phi Kappa Phi, national honor society for seniors of all schools and colleges
Phi Lambda Upsilan, national chemical engineering, chemistry, and pharmacy honor society
Pi Tau Sigma, national mechanical engineering honor society
Quarterdeck Honorary Society, honorary-technical society for the Department of Naval Architecture and Marine Engineering
Sigma Gamma Tau
Sigma Xi, a national society devoted to the encouragement of research
Tau Beta Pi, a national engineering honor society
Vulcans, senior engineering honor society

Professional Societies

American Institute of Aeronautics and Astronautics, student chapter
American Institute of Chemical Engineers, student chapter
American Institute of Industrial Engineers, student chapter
American Nuclear Society, student chapter
American Society of Civil Engineers, student chapter
American Society of Mechanical Engineers, student chapter
Institute of Electrical and Electronics Engineers, student chapter
Michigan Metallurgical Society, student chapter
National Society of Professional Engineers, student chapter
Operations Research Society of America, student chapter
Society of Automotive Engineers, student chapter
Society of Manufacturing Engineers, student chapter
Society of Minority Engineering Students
Society of Women Engineers, student chapter
Society of Engineering Science, student chapter
Society of Christian Engineers, student chapter

College Service Activities

IAESTE-US, International Association for the Exchange of Students for Technical Experience, United States, Michigan Chapter
Meteorology and Oceanography Student Council, for the Department of Atmospheric, Oceanic and Space Sciences
Engineering Student Publications, publishers of the *Michigan Technic* — student magazine for the College, and *Anvil* — student newsletter
University of Michigan Amateur Radio Club, organization of students interested in radio communications as a hobby

Minority Engineering Program Office
The Minority Engineering Program Office (MEPO) of the College of Engineering was founded in 1969. Its primary function is to provide a support system and a resource for minority students beginning in seventh grade and continuing through graduate school.

At the pre-college level students in grades 7 through 12 are actively exploring and preparing for engineering and technical career fields. MEPO is involved in three formal pre-college efforts across the state of Michigan: the Detroit Area Pre-College Engineering Program Inc. (DAPCEP Inc.); the Engineering Industrial Support Program (EISP), and Flint accelerated students potentially interested in research and engineering (ASPIRE).

At the college level, tutoring, study groups, orientation/professional development seminar series, career counseling, academic advising services and scholarship assistance is available through MEPO.

The Engineering Learning Resource Center, located in the Electrical Engineering and Computer Science Building, is maintained by MEPO. The Center provides a study room with reference books, study materials, and microcomputers, and is available for student use on a daily basis. In addition, MEPO provides support to the student-based organization, the Society of Minority Engineering Students (SMES).

At the graduate level, MEPO has represented the College of Engineering with the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM) since its inception in 1976. GEM is a national consortium involved in encouraging promising minority students to pursue graduate degrees in engineering.

The Society of Women Engineers
The Society of Women Engineers (SWE) is a national organization whose goal is to promote and support women in engineering and engineering-related sciences. The University of Michigan student chapter has identified its function as "a support group for women in engineering and technical sciences which provides an opportunity for members to share common experiences, questions, and goals, while also creating an atmosphere in which many friendships develop." Some of the SWE programs and activities include: pre-interview, annual scholarship banquet, annual career fair, monthly lectures, monthly newsletter, picnics and parties, and the annual ski trip. Members of SWE invite all interested students, men and women, to contact them with questions or comments.

Residence Regulations of The University of Michigan

1. Since normally a student comes to The University of Michigan for the primary or sole purpose of attending the University rather than to establish a domicile in Michigan, one who enrolls in the University as a non-resident shall continue to be so classified throughout his/her attendance as a student, unless and until he/she demonstrates that his/her previous domicile has been abandoned and a Michigan domicile established.

2. No student shall be eligible for classification as a resident unless he/she shall be domiciled in Michigan and has resided in Michigan continuously for not less than one year immediately preceding the first day of classes of the term for which classification is sought.

3. For purposes of these regulations, a resident is defined as a student domiciled in the State of Michigan. A non-resident is defined as one whose domicile is elsewhere. A student shall not be considered domiciled in Michigan unless he/she is in continuous, phisical residence in this state and intends to make Michigan his/her permanent home, not only while in attendance at the university but indefinitely thereafter as well, and has no domicile or intent to be domiciled elsewhere.

4. The following facts and circumstances, although not necessarily conclusive, have probative value in support of a claim for residence classification:
   a. Continuous presence in Michigan for periods when not enrolled as a student.
   b. Reliance upon Michigan sources for financial support.
   c. Domicile in Michigan of family, guardian or other relatives or persons legally responsible for the student.
   d. Former domicile in the state and maintenance of significant connections therein while absent.
   e. Ownership of a home in Michigan.
   f. Admission to a licensed practicing profession in Michigan.
   g. Long-term military commitment in Michigan.
   h. Commitments to further education in Michigan indicating an intent to stay here permanently.
   i. Acceptance of an offer of permanent employment in Michigan.

Other factors indicating an intent to make Michigan the student's domicile will be considered by the University in classifying a student.

5. The following circumstances, standing alone, shall not constitute sufficient evidence of domicile to effect classification of a student as a resident under these regulations:
   a. Voting or registration for voting.
   b. Employment in any position normally filled by a student.
   c. The lease of living quarters.
   d. A statement of intention to acquire a domicile in Michigan.
   e. Domicile in Michigan of student's spouse.
   f. Automobile registration.
   g. Other public records; e.g., birth and marriage records.

6. An alien who has been lawfully admitted for permanent residence in the United States shall not, by reason of that status alone, be disqualified from classification as a resident, provided, however, that aliens who are present in the United States on a temporary or student visa shall not be eligible for classification as a resident.

7. These regulations shall be administered by the Office of the Registrar, in accordance with the following residence review procedures:

a. It shall be the responsibility of the student to register under the proper residence classification, to advise the Office of the Registrar of possible changes in residence, and to furnish all requested information pertinent thereto.

b. Applications for reclassification shall be filed not later than 20 calendar days following the first day of classes of the term for which such reclassification is sought. Such application shall be filed with the Assistant Registrar for Student Certification and Residence Status (see "f" below for address) and shall set forth in writing a complete statement of the facts upon which it is based, together with affidavits or other supporting documentary evidence. Failure to timely file such an application shall constitute a waiver of all claims to reclassification or rebates for such term.

c. Any student may appeal the decision of the Assistant Registrar for Student Certification and Residence Status made pursuant to paragraph b, above, by taking the following steps within 20 calendar days after notice of such decision was served upon him/her, either in person, by mail, or by posting in a conspicuous place at 503 South State Street:

i. File with the Residency Appeal Committee a written notice of appeal stating the reasons therefor;

ii. File a copy of said notice with the Assistant Registrar for Student Certification and Residence Status, together with a written request that all documents submitted pursuant to paragraph b, above be forwarded to the Residency Appeal Committee. Failure to timely comply with this paragraph c shall constitute a waiver of all claims to reclassification or rebates for the applicable term or terms.

The decision of the Residency Appeal Committee shall be the final recourse within the University.

d. Reclassification, whether pursuant to paragraph b or c above, shall be effective for the term in which the application therefore was timely filed in accordance with paragraph b and for each term thereafter so long as the circumstances upon which the reclassification was based shall remain unchanged. Appropriate refunds shall be made or accounts credited within a reasonable time following such reclassification.

e. Classification or reclassification based upon materially erroneous, false or misleading statements or omissions by or in support of the applicant shall be set aside retroactively upon the discovery of the erroneous nature of such statements.

f. Inquiries should be addressed to: Student Certification Section, Office of the Registrar, Literature, Science, and the Arts Building, The University of Michigan, Ann Arbor, MI 48109-1382.

Approved by the Board of Regents, March 15, 1974.

Admission

Applicants for admission should be at least 16 years of age and officially recommended graduates of accredited high schools. Qualified applicants are considered without regard to race, sex, color, or creed.

Equal Opportunity/Affirmative Action. The University of Michigan as an Equal Opportunity/Affirmative Action employer, complies with applicable federal and state laws prohibiting discrimination, including Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973. It is the policy of The University of Michigan that no person, on the basis of race, sex, color, religion, national origin or ancestry, age, marital status, handicap, or Vietnam-era veteran status, shall be discriminated against in employment, educational programs and activities, or admissions. Inquiries or complaints may be addressed to the University's Director of Affirmative Action, Title IX and Section 504 Compliance, 2012 Fleming Building, Ann Arbor, MI 48109-1340. (313) 763-0235.

Admission as a Freshman

Freshman students are admitted to the College of Engineering by the Office of Undergraduate Admissions (1220 Student Activities Building, (313) 764-7433, The University of Michigan, Ann Arbor, MI 48109-1316) from whom appropriate forms and instructions are available. Michigan high school students who have begun the senior year may pick up application forms from their high school counselor. Please note that freshmen students are admitted to the College of Engineering and *not* to a degree program.

To complete the necessary enrollment and housing arrangements, an applicant should submit an application for admission to the Fall Term by March 1. Early application will make it possible to inform students of the probability of their admission and to call attention to any requirements still unfulfilled. Priority for admission to other terms is given to those who file an application at least three months before the starting date of the term. However, qualified Michigan applicants who seek admission after these dates will be given careful consideration consistent with the ability of the University to provide adequate facilities for instruction. Admission, when granted to a high school student is contingent upon completion of the student's high school program with grades consistent with those on which admission was granted.

Both the Office of Admissions and the College of Engineering welcome the opportunity to interview a prospective freshman prior to submitting an application; appointments for such interviews should be arranged in advance.

Criteria
The admission requirements are designed to assure that each student who is granted the opportunity to enroll in the College of Engineering has aptitude for the profession of engineering as well as intellectual capacity combined with the necessary interest and motivation to pursue college work successfully. Students' qualifications in these respects vary widely, and from long experience it is evident that no single criterion is sufficient to judge the ability of every applicant.

The College, therefore, takes into account each of the following four criteria in arriving at a decision for each applicant: subjects studied in high school, scholastic performance, aptitude test scores, and high school recommendation.

1. Subjects Studied in High School. A unit for admission is defined as a course covering a school year of at least 120 sixty-minute hours of classroom work. Two or three hours of laboratory, drawing, or shop work are counted as equivalent to one hour of recitation.

The following subjects and units are required for admission without deficiency:

Subject	Number of Units
English (Four units of English are strongly recommended.)	3
Mathematics To consist of a minimum of 1 1/2 units of algebra; 1 unit of geometry; 1/2 unit of trigonometry. (An additional 1/2 unit of algebra and 1/2 unit of analytical geometry are recommended.)	3
Laboratory Science (One unit of chemistry and 1 unit of physics are recommended. Other laboratory sciences are acceptable.)	2
Academic Electives Two units of foreign language are recommended; other acceptable subjects are history, economics, and biological science.	4
Free Electives May include any subjects listed above or any other subjects counted toward graduation by the high school such as art, music, business, shop, mechanical drawing, and computer programming.	3
Total	15

Deficiency: It is possible to be admitted with a deficiency. An applicant who has a deficiency is advised to consult the Director of Admissions concerning the particular program. Courses elected at the University to remove a deficiency will not count toward degree.

2. Scholastic Performance. The student's grades, particularly in mathematics, laboratory sciences, and courses that indicate verbal ability, together with the standing in the class, are considered important in determining ability for admission to the study of engineering. Interest and high achievement in these subjects will also help the student to decide whether or not the right choice of career is being made, as well as predicting the likelihood of success in the engineering profession.

3. Scholastic Aptitude Test. Tests in verbal and mathematical abilities have proven helpful for predicting success in engineering courses. Applicants are required to take during their junior or senior year in high school the College Entrance Examination Board Scholastic Aptitude Test (SAT) or American College Testing (ACT).

When a senior desires a decision before the SAT or ACT results are in, preliminary admission may be made if other acceptable test data are submitted along with the application.

For information and time schedules on the Scholastic Aptitude Test, the student should consult with the high school counselor or write to the College Entrance Examination Board, Box 592, Princeton, NJ 08540, or to Box 1025, Berkeley, CA 94701.

For information and time schedules on the ACT test, the student should consult with a high school counselor or write to The American College Testing Program, Iowa City, IA 52240.

4. High School Recommendation. Any statement by a representative of the applicant's high school is taken into account. This may relate to such qualities as the character and seriousness of purpose of the applicant, interests and attainments (both scholastic and extracurricular), intellectual promise, and potential for success. Such information provides additional background that may not be evident from the other criteria listed above.

Advanced Placement
Once a student has been accepted for admission to the College of Engineering, it is possible to earn advanced credit toward a degree through the Advanced Placement Program. Many students take Advanced Placement courses through the Advanced Placement Program in their high schools. Credit for these courses can be applied toward a degree, provided the student has performed satisfactorily (a three or higher) on the Advanced Placement Program examination conducted nationally by the College Entrance Examination Board.

For information and time schedules on the Advanced Placement tests, write to College Entrance Examination Board, Box 592, Princeton, NJ 08540, or to Box 1025, Berkeley, CA 94701. All other questions about Advanced Placement should be referred to the Office of the Assistant Deans, 2417 EECS Building, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2116.

University Placement Examinations
There are a number of courses for which credit may be received by getting a satisfactory score on a Placement Examination offered by a department of the University. (See list below.)

1. Mathematics. Placement Examinations for Math. 115 and 116 are usually offered in the first week of the fall term. Information as to the time and date will be available from Math. 115 and 116 instructors; the Mathematics Department Office, 3217 Angell Hall, 764-0337; and the Freshmen Counseling Office, 2417 EECS Building, North Campus, 764-5158. Students who have taken calculus in high school and have not taken the Advanced Placement examination for some reason but want credit for Math. 115 and/or 116, must take the Mathematics Department Placement Examination. **Members of the Mathematics Department DO NOT have the authority to exempt students from the Math. 115 or 116 degree requirements.**

NOTE: The purpose of the mathematics examination given during Orientation is to determine if students are prepared to take Math. 115. It is not a test for Advanced Placement. The same is true for the chemistry test.

2. Foreign Languages. The Foreign Language Placement Examinations are given during Orientation. Student must take both the reading and listening parts to receive credit. If a student misses the test during orientation, it can be taken during the next orientation period. Credit for 100-level courses cannot be used to satisfy the Humanities requirement; however, 100-level courses can be used as free electives. Because many of the programs have a limited number of free elective hours, credit for 100-level courses will not be posted on the official record unless the student requests it. Credit for 200-level or higher, or advanced placement or advanced credit for such courses can be used as Humanities. These courses will be posted on the student's record unless the student requests otherwise.

3. Credit By Examination Program. Advanced credit can be earned through the Credit by Examination Program. Information about this program is available from the Extension Service, 200 Hill Street, Ann Arbor, MI 48109-3297. Advanced credit for Physics 140 and 240 can be earned through this program.

Admission of Transfer Students

An applicant desiring to transfer from an approved college in the United States with advanced credit should write to Transfer Admissions, 2417 EECS Building, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2116, for an application form and instructions. The applicant will be required to arrange for an official transcript of both secondary school and college work, together with evidence of honorable dismissal from the previous college attended. This applies also to students planning to transfer from another unit in the University. Applicants are subject to departmental requirements for admission to a particular program, which means being a part of any quota the department may have and meeting the departmental GPA requirement.

Applications for admission should be submitted before March 1 for the following spring half term, summer half term, and fall term, and prior to October 1 for the winter term.

For admission without deficiencies, the applicant must satisfy the requirements for admission from high school as stated under Admission as a freshman. The college transcript must list the subjects studied, the number of credit hours and grades earned in each subject, and the basis upon which grades are assigned. Results of any aptitude tests that were taken in high school or college are helpful but not required.

The history of an applicant must demonstrate the ability of the applicant to meet the requirements of the College of Engineering for graduation. An overall scholastic average satisfactory for good standing at the previous institution may not in itself be sufficient. The grades earned in subjects related to the program elected by the applicant will be taken into account in judging ability to succeed. As a minimum requirement, the scholastic record as interpreted by the College of Engineering must be such that the applicant would be considered a better than average student if the work had been taken at this College.

While credit is not allowed for work or other experience, a student may be considered proficient in a designated part of the degree requirement if the student can qualify under provision 1(f) of Requirements for Bachelor's Degree.

A student transferring at the junior level has the opportunity to attain a commission in the Army, Navy, or Air Force by enrolling in the respective Advanced Course of the Military Officer Education program. As early as possible, the student should contact the unit on the campus to make the necessary arrangements for basic training during the summer. See section on Military Officer Education Program for details.

Attention of prospective transfer students is called to the section on Planning the Student's Program.

Program with Basic Courses Taken in Another Institution. Basic pre-engineering courses in mathematics, chemistry, physics, and English composition or literature are offered by many liberal arts colleges. Generally, such courses are offered as a complete two-year program designed to meet the requirements for study at the professional level in many engineering colleges (e.g., a mathematics sequence requiring four semesters or six quarters). While a student will be considered for admission with any amount of college credit, the advantages of completing the required basic program before seeking a transfer should be considered.

In many institutions a student is able to satisfy the requirements of economics, and some elective courses in humanities and social sciences; the student may also be able to elect engineering graphics, engineering materials, and engineering mechanics if adequate instruction is offered.

A student in another college or university who desires to transfer to the College of Engineering should examine carefully the program that the individual plans to elect at this College and arrange the work accordingly. Questions pertaining to choice of field or program and course elections not answered in this *Bulletin* may be addressed to the program adviser in the program the student wishes to elect. Other questions of general nature and those relating to admission requirements should be addressed to the Office of the Assistant Deans.

Combined Programs with Other Institutions. The College of Engineering cooperates with other institutions in providing an opportunity to earn two bachelor's degrees (A.B. or B.S. and B.S.E.) in approximately five years by satisfying the requirements for both degrees. Representative of institutions providing this opportunity are:

Adrian College
Albion College
Alma College
Beloit College
Bowling Green State University
Calvin College
Hope College
Kalamazoo College
Lawrence University (Wisconsin)
Marygrove College
Virginia Union University
Wooster College

Normally an interested student would enroll at one of these institutions for the first three years and include in the elections a pre-engineering program that, under conditions of satisfactory performance, will transfer as substantially equivalent to two years of the requirements of the College of Engineering.

For details on a combined program with the College of Literature, Science, and the Arts of the University, refer to Undergraduate Degree Programs.

Adjustment of Advanced Credit. An appraisal of the previous record of a student transferring from a college or university located in the United States will be made, usually at the time of admission, to indicate tentatively the credit that will be allowed toward a bachelor's degree in the program specified by the applicant. This appraisal is subject to review by representatives of the several teaching departments involved, and by the student's program adviser; the adjustment may be revised if it develops that the student is unable to continue successfully because of an inadequate preparation. Credit will not be allowed for a course in which a grade of C- or below is received. Class standing is determined by the number of hours transferred. (See under Class Standing.)

Grades earned while enrolled in another college are not recorded and the student's grade-point average is determined solely by the grades earned while enrolled in this College. This does not apply to students transferring from other academic units located on the Ann Arbor campus of the University. If at any time, a transfer student has any question regarding the adjustment of credit, the student should consult the Office of the Assistant Deans.

Prescribed Program. If an applicant meets our admission standards, and is acceptable to the Program Adviser in the program of the student's choice, the Program Adviser will prescribe a program that meets the requirements for a degree in that program. While the standard evaluation of credits is not required, the general requirements for a degree from this College should be met before the student is recommended for the degree. This would ordinarily apply to students with a degree from another college who could satisfy degree requirements in 30 to 40 credit hours here (at least 30 of which must be at the 300 or higher level). The student must attain a "C" or better in each course of his/her prescribed program.

Admitting Graduates of Other Colleges. A graduate of an approved college may be admitted as a candidate for a degree in engineering. The official transcript must certify the date of graduation. Upon satisfactory completion of the prescribed courses, covering at least two terms enrollment and a minimum of 30 hours credit, elected in the College of Engineering, Ann Arbor Campus, the student will be recommended for the appropriate degree. (See Prescribed Program above.)

Foreign Student Admission

Foreign students whose command of the English language and social maturity is equal that of students educated in the United States may apply for admission as freshmen to The University of Michigan, College of Engineering through the Office of Admissions, 1220 Student Activities Building, Ann Arbor, MI 48109-1316.

Foreign students must be prepared to finance their entire education while enrolled in the College of Engineering. It is estimated that a foreign student enrolled as a freshman would require approximately $75,000 to complete four years of study, a junior, $40,866, and a senior, $20,433. Because of the high cost of education, foreign students are encouraged to complete the basic college subjects of mathematics, chemistry, physics, and elections in humanities and social science in a college or university in their home country before seeking admission to The University of Michigan, College of Engineering. Students who have completed their basic subjects with superior marks or grades may apply for admission with advanced standing at the junior level.

Foreign students whose native language is other than English are required to complete basic college subjects, i.e., English, mathematics, chemistry, physics, before applying to the Assistant Dean for admission to the College of Engineering; they must also meet prescribed standards of proficiency in English. For many students these requirements may be met at a minimum of expense by enrolling in a home college for a period of two years. Others may prefer to enroll in a liberal arts or engineering college in the United States for their basic college subjects before seeking transfer; this provides the advantages to the student of becoming accustomed to the educational system of this country and of improving proficiency in English.

An applicant must submit an official copy in English of the scholastic record of secondary and college education, showing the grade (or mark) earned in each course together with maximum and passing grades.

Since English is the language of instruction in the United States, a foreign student attends classes with students whose background and education have been in English, and the foreign student must maintain the same scholastic standards. In order that the student may know that his or her competence in the English language is adequate to carry on studies without serious handicap, each student whose native language is not English is required to submit before admission the results of an English proficiency examination. This test is prepared and administered abroad as well as in the United States by the English Language Institute of the University. If the scholastic record of the applicant is satisfactory, the applicant will be instructed to make arrangements for the test with the English Language Institute. A score of 85 is required on the ELI test. The charge for this test is $30.00 (or its equivalent in the local currency). Applicants may submit TOEFL scores rather than the English Language Institute Test scores if they prefer. A TOEFL score of at least 550 is required for admission. Regardless of tests taken previously the College of Engineering reserves the right to require testing after arrival at the University of Michigan.

For students who need to improve their command of English considerably before beginning regular college studies, the English Language Institute offers the eight-week Intensive Course in English (ELI 100). For further information, write to the English Language Institute, 2001 North University Building, Ann Arbor, MI 48109.

A foreign student granted entry into the United States by virtue of admission to another institution of higher education is expected to complete one academic year of study at that school before seeking transfer. A student who wishes to transfer to this College is encouraged to submit an application for admission with advanced standing during the next to last semester or term of enrollment at the institution that issued the initial I-20 Form.

It is generally desirable that a foreign student elect a rather light schedule of studies for the first term enrolled in the College of Engineering because of an unfamiliar environment and a different educational system. To increase the probability of success, a student who observes any irregularity in adjustment or progress should report immediately to the program adviser or to the Assistant Dean's office.

English Language Institute. The English Language Institute offers instruction in the English language to non-native speakers enrolled in the University. Since the main purpose of this instruction is to help non-native speakers become effective and fully participating members of the academic community, the majority of ELI courses are concerned with English for Academic Purposes. Most courses address specific areas such as pronunciation, lecture comprehension, or academic grammar, and usually involve no more than 20 contact houts per semester. In order that students will enroll in the most suitable courses, they may be asked to take an *Academic English Evaluation* administered by the Testing and Certification Division of ELI. In major areas such as speaking and writing, a sequence of courses of increasing difficulty and specialization is available, including some that carry graduate credit.

ELI operates a Writing Clinic and a Speaking Clinic as one-on-one facilities for those who have taken or are taking ELI courses in the relevant areas or are deemed not to need regular classroom instruction.

In addition, ELI runs a Semi-Intensive Program for those who require more assistance in English and who are not therefore likely to be carrying a full course load in other subjects.

ELI also offers a Summer Half-Term Intensive Program for non-native speakers who have already received admission to the University but who wish to improve their language and study skills before beginning their academic program. There are two sections: a) English for Academic Purposes, and b) English for Business and Management Studies.

Finances. When a foreign applicant accepts an offer of admission, the applicant should clearly understand the financial obligations assumed. If assistance is needed, necessary arrangements must be made before the applicant leaves his or her country; no financial aid is available from the University for foreign students.

International Center. The International Center is housed in a wing of the Michigan Union building, with its entrance on East Madison Street. Services are provided here for both United States citizens anticipating

Counseling

travel abroad, and to foreign students coming into the United States.

For United States citizens planning to travel abroad, there are complete informational services, and experienced advisers to help individuals plan for trips abroad for the purpose of recreation, education, or employment. There is an extensive library of materials available to all interested individuals.

Foreign students will find assistance at the International Center in dealing with the United States Immigration and Naturalization Service, with their sponsors and governments, and with other individuals and organizations. Foreign Student Advisers are available to discuss personal concerns, housing, adjustment, finances, and other matters. The Center staff also works with community organizations which provide tours, home hospitality, speaking engagements, and assistance for wives of foreign students. In cooperation with nationality clubs, student associations, and other organizations, the International Center provides throughout the year a varied program of cultural and social events. Prospective foreign students may use the International Center as an advance mailing address.

Student Not a Candidate for a Degree (NCFD)

Special Students. A qualified candidate beyond high school age may be admitted as a special student in order to enroll in appropriately selected college courses without working for a degree. Special student admission will be granted only after all requests for admission from degree candidates have been honored.

Request for admission as a special student, and supporting evidence of qualifications should be addressed to the Office of the Assistant Deans. Previous education, experience, and age will be taken into account in judging fitness for success in engineering studies. Admission and program of study are subject to the approval of the program adviser of the program to be elected.

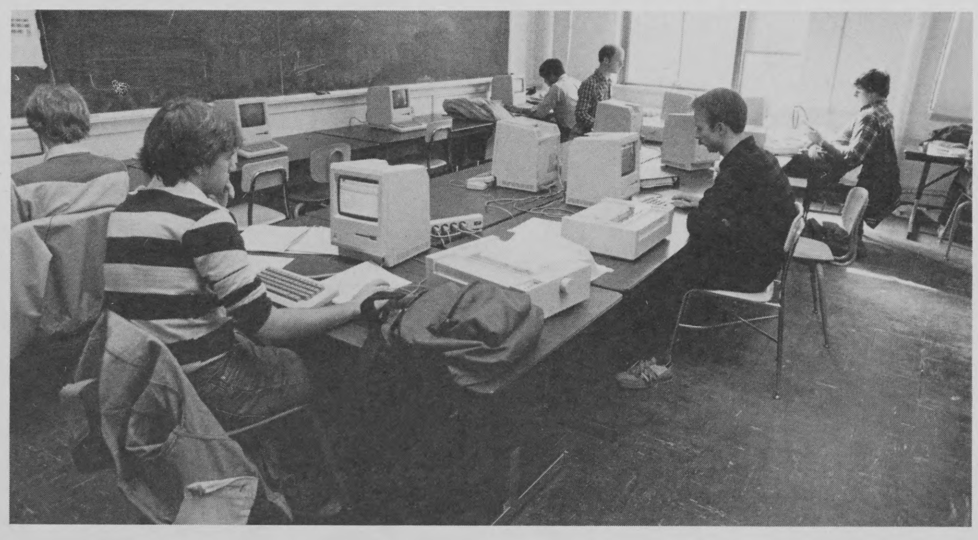
A qualified college graduate may be admitted as a special student to take engineering college courses for which the student has sufficient preparation.

To remain eligible for continued enrollment, a special student is required to meet the same academic standards as a degree candidate. The student may later become a candidate for a degree if he or she meets the regular requirements for admission.

A student who is a candidate for a degree cannot transfer to special status.

Guest Students. A student regularly enrolled in another college is permitted to elect appropriate courses as a guest student during the spring and summer half terms only. The applicant must apply for enrollment before the beginning of each term that he or she desires to attend. Guest student admission is offered on a term basis only, depending on availability of space.

Unassigned Status. When a student is no longer a candidate for a degree from the College of Engineering but is planning to transfer into another field of study, the student is advised to report to the Office of the Assistant Deans for Counseling on effecting a transfer and, if necessary, arrange for registration for an additional term in the College of Engineering on an "Unassigned" status.



Orientation. All new students, both freshmen and those transferring from other colleges, are assigned to small groups which are guided through the various steps of orientation: these include testing, preparation of the student's identification card, consultation with academic counselors, selection of courses, registration, assessment of fees, and attendance at the necessary orientation group meetings.

Each transfer student is instructed also on procedures relating to the adjustment of transfer credit from other colleges.

Freshmen entering in the fall term are encouraged to come to the campus during the summer for a three-day orientation schedule. At the same time, parents are invited to attend a program particularly arranged for them.

Transfer students for fall admission are also offered an opportunity to come to the campus during the summer for a two-day orientation schedule.

Each student is expected to assume a high degree of responsibility for his or her own welfare by making proper choices and effectively planning progress toward the educational goal. To do this wisely and efficiently, the individual should understand his or her own aptitudes, abilities, and interests and their relationship to the plans and decisions. A student with some question in this regard, or one who recognizes that a personal problem exists in which the individual might benefit from appropriate counseling, is urged to consult University people who are qualified to help.

A student who experiences in the first term any difficulty in making a satisfactory adjustment to the studies should report immediately to the academic counselor. If uncertain regarding procedures or if there is a problem that does not relate to a specific counseling service, the student may seek advice from the Office of the Assistant Deans, 2417/19 EECS Building.

Academic Counseling for Freshmen. Freshmen counselors, consisting of a group of well-qualified faculty from the engineering departments, are available in a central freshman counseling office for interviews throughout the fall and winter terms.

Each entering freshman meets with a counselor to determine a schedule of courses for the first term. This is covered in detail in the section "Planning the Student's Program."

Developing self-reliance and the ability to make choices, as well as to appraise one's own performance and intellectual growth is an important part of the student's education.

Undergraduate Degree Programs

Nevertheless, each freshman is encouraged to consult with freshmen counselors or program advisers at any time there is a question relating to career plans, or choice of academic program, or to discuss any matter of interest or concern. Midterm is a particularly appropriate time to examine progress.

Academic Counselor for Continuing and Transfer Students. Program advisers are assisted by associates on the faculty according to the needs of the respective programs. As academic counselors, they assume responsibility for elections as covered under Election of Studies or as specifically delegated.

Program Adviser. At the beginning of each of the undergraduate degree programs (described in this *Bulletin* beginning on page 27) is the name of the member of the faculty designated as program adviser. Upon selecting a degree program, the student is referred to the respective program adviser, who is responsible for the necessary academic counseling through graduation.

Certain authorities, as covered under Election of Studies, Grades and Scholastic Standing, and Requirements for Graduation, are specifically assigned to program advisers.

Other Counseling Services. In addition to academic counseling, the University provides specialized services to meet the various needs of students. A counseling service is available in the Counseling Center, Institute for Human Adjustment for those needing more specialized assistance to clarify their educational and vocational objectives. For those students experiencing personal difficulties requiring the assistance of specially qualified counselors, help is available at the Counseling Center or Counseling Services in the Michigan Union. Training in reading speed and comprehension is provided for students especially in need of such assistance at the Reading and Skills Center. Remedial training in speech is offered by the Speech Clinic. The churches in Ann Arbor provide counselors on religious problems. The Office of Student Services, 3010 Michigan Union, provides counsel and assistance on housing, employment, and other non-academic problems. The men's and women's residence halls, accommodating freshmen and a few upperclassmen, maintain a staff of advisers and student assistants who help the student make an effective adjustment to the University community. The Office of Financial Aid similarly provides counsel on financial problems.

Each of the undergraduate degree programs requires a minimum of 56 credit hours that are common to all Programs. (See Planning the Student's Program.) Descriptions are included at the beginning of the Departmental Undergraduate Degree sections.

The remaining 72 hours identify the majors or fields of specialization in which students will obtain a bachelor's degree as indicated for each program. In most cases, these may be classified as: Advanced Mathematics and Science; Related Technical Subjects; Program Subjects; and Technical or Free Electives.

Many of the courses required for one program are readily transferred to meet the requirements of another. This allows students the opportunity to change fields of specialization with a minimum of sacrifice, or to work toward satisfying the requirements for two degrees under the requirements of a minimum of 14 extra hours.

Choosing One of the Degree Programs. While the entering freshman does not need to select a specific field of engineering, there is some advantage in arriving at a decision early. To help the student with a choice, the departments will schedule a series of group meetings during the winter term that provide information about each of the programs and related career opportunities. If additional help is needed, the student should consult with a freshman counselor or a program adviser. The degree program in which a student plans to graduate should be selected during the second term.

Transfer of a student from the Freshman Counseling Office to a degree program depends on the student's being in good standing and having completed the freshmen level mathematics, chemistry, physics and digital computing courses. Transfer to a program involves obtaining the necessary approval forms from the Freshman Counseling Office. In addition, the Executive Committee of the College of Engineering, following a request of a particular degree program, may find it necessary to restrict admission to that program, based on grade point averages in mathematics, chemistry, physics, and digital computing courses elected in the first year. At the present time this applies to the Electrical Engineering and Computer Science programs. Students should contact the Office of the Assistant Deans if they have any questions concerning program changes.

Students who have not selected a program by the time they reach 55 credit hours, or who wish to change degree programs after they have reached 55 credit hours, are subject to grade point averages and quotas approved by the Executive Committee of the College of Engineering for admission to the various degree programs.

Opportunity to Attain Two Bachelor's Degrees. Students with interests in more than one program offered by the College may work for two bachelor's degrees concurrently if they plan the course elections carefully. Students will find that it is possible to satisfy the subject requirements of both programs in a minimum amount of time by conferring early with the respective program advisers. Also available is an opportunity to obtain an additional bachelor's degree in the College of Literature, Science, and the Arts. (See under Requirements for Additional Bachelor's Degrees.)

Combined Degree Program for Simultaneous Bachelor's Degree from the College of Literature, Science, and the Arts

Program Advisers:
Professor W.C. Bigelow, 2168 Dow Building
Katherine McKibben, 1223 Angell Hall

Students enrolled for a bachelor's degree in the College of Engineering or the College of Literature, Science, and the Arts (LSA) may obtain the degrees in both colleges simultaneously by enrolling in the Combined Degree Program, which has been established by the two colleges, and by fulfilling the requirements as outlined below. This program has been developed to make it convenient for students to obtain a broader education than would normally be possible by enrolling in only one college. It is particularly advantageous for students who wish to develop some depth of understanding in both the technically oriented studies offered in the College of Engineering and the physical, natural, or social sciences and humanities available in LSA. Such a combination can provide a truly liberal education in the modern sense and should be excellent preparation for meeting the problems of modern society, which involve to an ever-increasing extent both technical and sociological issues.

Program Requirements. Candidates for a Bachelor of Science in Engineering (B.S.E.) or Bachelor of Science (B.S.) or Bachelor of Arts (A.B.) in LSA must: (a) satisfy the requirements of one of the degree programs in the College of Engineering; (b) take a minimum of 90 credit hours of work in LSA, satisfying the distribution requirements of LSA, and fulfill the concentration requirements for one of the LSA programs; and (c) have a cumulative grade-point average of 2.00 or higher.

Candidates for a Bachelor of Science in Engineering (B.S.E.) or Bachelor of

Science (B.S.) in the College of Engineering, combined with a Bachelor of General Studies (B.G.S.) in LSA must: (a) satisfy the requirements of one of the degree programs in the College of Engineering; (b) take a minimum of 90 credit hours of work in LSA of which 40 credit hours must be for courses numbered 300 or higher that are passed with a grade of C or higher, with no more than 15 of these 40 credit hours to consist of courses in any one department; and (c) have a cumulative grade-point average of 2.00 or higher.

Students transferring to The University of Michigan with advanced standing and entering a Combined Degree Program must complete a minimum of 60 credit hours of work in LSA in residence.

Because of the great variety of combinations of Programs in the two colleges that might be chosen by students under the Combined Degree Program, it is not feasible to list course requirements in detail. Instead, all students should consult their Program advisers in their field of specialization in each college each term to develop an optimum set of courses for the particular combination of fields of specialization of interest to them.

In general, counselors working with students in this Combined Degree Program will attempt to minimize the total number of courses required by recommending those that will contribute toward fulfilling requirements in both colleges whenever possible. Thus, many of the courses needed to fulfill the requirements in mathematics, chemistry, and physics in the College of Engineering will contribute toward fulfilling natural science distribution requirements and prerequisites for concentration in fields such as astronomy, chemistry, geology-mineralogy, mathematics, and physics in LSA. Likewise, requirements in literature, humanities, and social sciences for the College of Engineering can be selected from courses taken to fulfill distribution requirements in LSA. In this way it is usually possible for students carrying average loads of 16 credit hours per term to complete the requirements of this Combined Degree Program in 10 or 11 terms.

In order to insure that the courses selected apply effectively and efficiently to both degrees, students must assume responsibility for maintaining liaison between their two advisers. They should become thoroughly familiar with the general regulations and procedures of both colleges and with the academic requirements and course offerings in both fields of specialization, as set forth in the Bulletins of the two colleges. If unusual difficulties or special problems arise, students should consult the Combined Degree Program advisers listed above. These Program advisers will work with the students and their faculty advisers in attempting to find a solution.

Regulations.

The following regulations for administering enrollment will apply:

1) Students initially enrolled in either the College of Engineering or LSA may enter this Combined Degree Program.

2) To be qualified for admission, students normally should have completed 30 credit hours of the appropriate course work. LSA students must have an overall grade-point average equal to or higher than the current minimum grade-point average for cross campus transfer for the particular engineering degree sought. Engineering students must have an overall grade-point average of at least 2.7.

3) Students considering this program should consult the Assistant Dean's office in the College of Engineering to apply for admission and to establish counseling procedures as soon as their interests are firmly established, preferably by the end of the first year.

4) Upon applying for admission, students must choose a field of specialization in each college. Application for admission must then be approved by the assistant dean of each college and then by the academic adviser in each of these fields of specialization.

5) After being admitted to this program, students will continue to register in the college in which they first enrolled, and that college will be responsible for maintenance of their primary academic records and for transmitting to the other college at the end of the term the number of copies of their transcripts needed for counseling and other official purposes in that college.

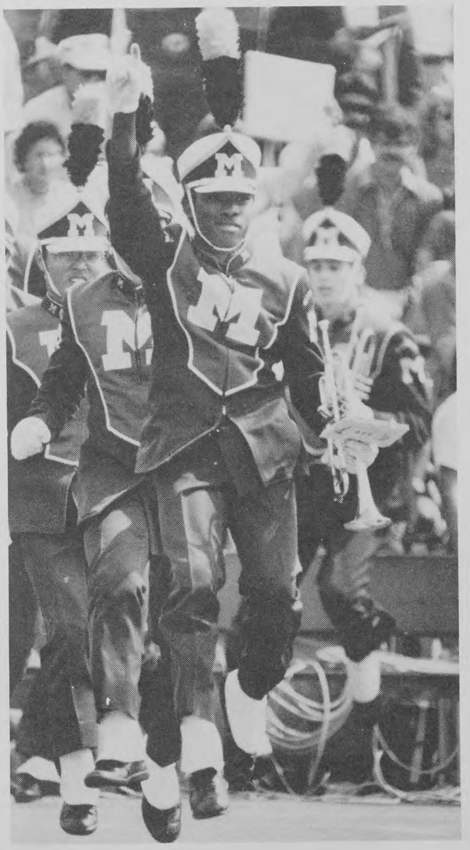
6) Students participating in this program should consult with the program adviser for their field of specialization in each college

prior to classification each term to obtain approval of course elections.

7) To be permitted to continue in this Combined Degree Program, students must satisfy the requirements of both colleges with regard to good scholastic standing.

8) Students in good scholastic standing who wish to withdraw from this Combined Degree Program may continue to enroll for a single degree in their original college. If they wish to transfer, they may do so provided their record is acceptable to the other college. For instructions regarding transfers, students should consult the assistant dean of the college in which they are registered. Students not in good scholastic standing will normally remain in the college in which they initially enrolled and be subject to the rules of that college.

9) Upon satisfying the program requirements of both colleges, students will receive both degrees on the same date. At the beginning of the term in which they expect to graduate, they must file a diploma application in each college and must request their program adviser in each college to submit an appropriate notification of their eligibility for graduation to the records of that college.



Planning Student's Programs

Students vary in their abilities and interests, in their level of achievement, and in their high school or pre-engineering preparation. Considerable variety and flexibility are provided to plan each student's schedule so that the individual may reach graduation as efficiently as possible. The objective is to place each new student in courses commensurate with previous preparation and ability, exercising care not to include any courses which the student is judged to be unable to handle successfully.

Most courses have prerequisites (see Description of Courses). The completion of courses on schedule and with satisfactory grades is essential to the student's progress.

The appropriate schedule for each student in each term will depend on a number of factors: past scholastic record, placement tests, extracurricular activities, election of Military Office Education Program, health, and need for partial self-support. A schedule of 13 to 16 hours is considered normal.

Military Officer Education Program. Opportunities are offered for officer training in military, naval, and air science leading to a commission on graduation. Enrollment is voluntary (see conditions of enrollment under the respective program). If elected, the grades earned will be recorded and used in the computation of grade-point averages, and credit hours for the 300- and 400-level courses will be included with the hours completed toward the degree. A maximum of 15 credit hours of 300- and 400-level ROTC courses may be used as free electives at the discretion of the program advisers.

Minimum Common Requirements

Each of the degree programs offered by the College includes the following 56 credit hours that are common to all programs, subject to appropriate adjustment for equivalent alternatives.

Freshman and Sophomore Programs

For each freshman, the counselor will use the student's high school record and the results of various tests to plan the courses for the first term. A student with an admission deficiency is required to remove it during the first year.

At the time of the first counseling interview, particularly for those who are counseled during summer orientation, all of the high school and advanced placement records may not be in the student's file. It is the student's responsibility to make certain that all evidence is brought to the attention of the counseling office before classes start in order that the counselor may make considered adjustment in the elections for the first term.

First Year. On the assumption that a student has no admission deficiency and no advanced placement credit, during the first year the individual will be expected to complete courses that include the following:

1. Mathematics 115 and 116
2. Chemistry 123 or 124, and 125, and for some—126
3. English 125
4. Physics 140 and 141
5. Engineering 103
6. The Counselor will provide information on a number of courses that the student may elect to make up approximately 30 credit hours for the year.

Second Year. All students will continue with the mathematics and physics courses common to all programs marked by * in the Group I listed below. A second-term freshman who has selected a degree program is referred to the respective program adviser for elections counseling for the third term; for the remainder of the second-year elections, the student should refer to the description of the program selected. If the program requires additional chemistry, the student must continue chemistry in order to satisfy

To be scheduled during first four terms as shown below.	Hours Credit
1) Mathematics 115, 116, 215, and 216	16
2) English 125	4
3) Engineering 103	3
4) Chemistry 123 or 124, and 125	5
5) Physics 140 and 141, and 240 and 241	8
Additional 18 hours (minimum)	
6) Senior Technical Communication (to be scheduled during senior year)	3
7) Humanities and Social Sciences (May be scheduled any term — see Elective Studies)	17*

Mechanical Engineering 101 is required by a number of the degree programs and may be used as an elective for a program that does not specify it.

*Several programs require more than the minimum of 17. For complete information on the requirements of the respective programs, see the individual departmental degree programs.

prerequisites of later courses and to avoid delays in the schedule.

When a freshman is not ready to select a degree program in the second term, it is possible to define a second-year schedule on an unassigned basis. The courses marked + in Group I satisfy requirements in a number of programs or may be applied as electives in other programs. Those in Group II will be found in the second-year schedule of certain programs and provide the student with an opportunity to continue the schedule with the understanding that if not used as a requirement in the program the student will select, they generally may be used as electives. The student should consult the course descriptions to help make appropriate selections. If a sophomore is ready to select a program during the third term, the student will be referred to the program adviser for the fourth-term elections.

Third Term	Credit Hours
Group I	
* Mathematics 215	4
* Physics 240 with Lab. 241	4
* Mech. Eng. 110, 210, or 211	5 or 4
Mat. Sci. & Eng. 250	3
+Humanities or Social Science	4
Group II	
Chemistry 225	3
Aero. Eng. 200	2
Chem. Eng. (Mat. Sci. & Eng.) 230	4
Civ. Eng. 232	3
EECS 250	3
A.O. & S.S. 304	3
Nav. Arch. 270	3

Also refer to courses listed under Engineering.

Fourth Term	Credit Hours
Group I	
* Mathematics 216 or 286	4 or 3
+Mech. Eng. 240	3
+Mech. Eng. 231	3
or 235	3
+Humanities or Social Science	4
Group II	
Chemistry 226 & 227	5
Physics 242	3
Civil Eng. 312	3
EECS 213	3
I.& O.E. 300, 310, or 333	3
Mech. Eng. 251	3
Mech. Eng. 252	3
Nav. Arch. 302	3

Honors Level Courses. A student whose record indicates qualifications for performance at an advanced level will be given an opportunity to review with a special counselor the individual's eligibility for electing honors level courses. Among those available to qualified freshmen are Math. 185 or 195, and Chemistry 196 or 197.

Mathematics. The mathematics sequence of 115 (4), 116 (4), 215 (4), and 216 (4) provides an integrated 16-hour sequence in college mathematics that includes analytic geometry, calculus, elementary linear algebra, and elementary differential equations.

While most freshmen select Math. 115 in their first term, it is in the best interest of students to be placed in the mathematics course which most closely matches their previous preparation and ability.

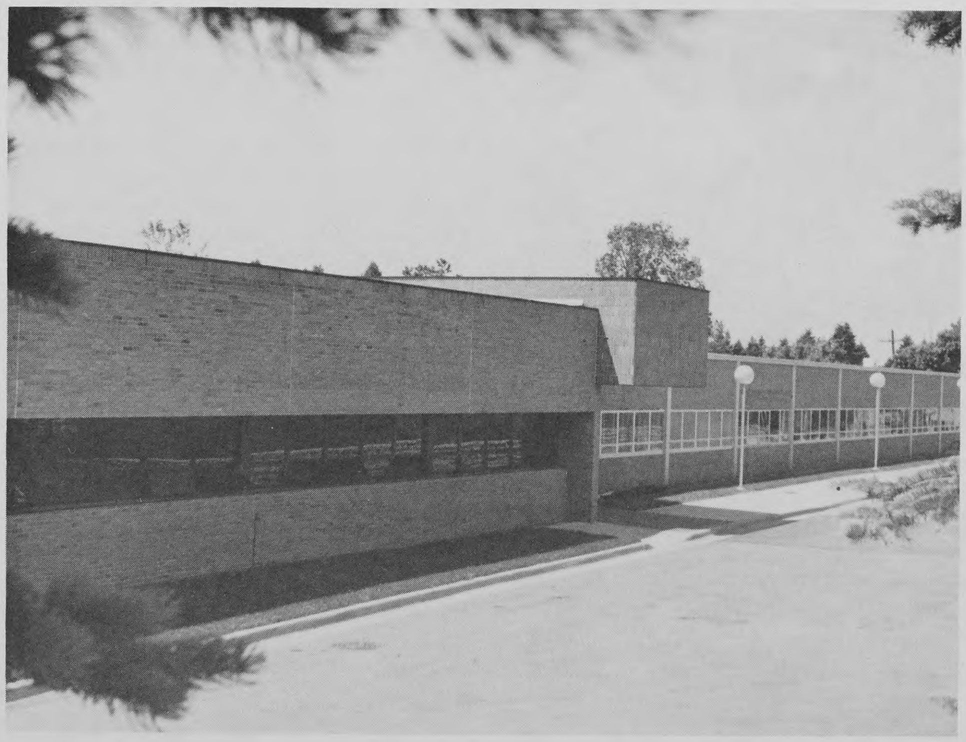
A student having an especially high level of mathematical preparation and ability may accelerate his or her training, with deeper penetration, in one of the honors-level sequences starting with Math. 185 (4).

A student who has completed a full year of calculus in high school and has received a sufficiently high score on one of the College Board Advanced Placement examinations in mathematics is eligible for advanced credit and placement. Likewise, a student who has taken calculus in high school may receive appropriate advanced placement after taking a placement examination administered by the Department of Mathematics; information on this examination may be obtained from the Department of Mathematics Office, 3217 Angell Hall.

The following outline will serve as a guide in determining the proper first elections in mathematics for freshmen:

Those Students Who:	Elect	Hours Credit
1. Are deficient in both algebra and trigonometry	Math. 105 or 106	4*
2. Are deficient in trigonometry	Math 107 or 108 (May accompany Math. 115)	2*
3. Have no deficiencies and are qualified by high school record and SAT scores	Math. 115	4
4. Qualify for honors level or have special permission of the Department of Mathematics	Math 185	4
5. Are allowed 4 hours of advanced placement credit	Math 116	4
6. Are allowed 8 hours of advanced placement credit	Math 215	4

*While these two courses will not provide credit toward the student's degree, the grades will be used in computing grade-point average.



Humanities and Social Sciences. *At least* 17 credit hours of Humanities and Social Sciences are required in all 14 degree programs offered by the College of Engineering. The complete College requirement is described under *Elective Studies.*

Introductory Composition Requirement. During the time of Orientation to the University and the College of Engineering, all freshmen will write an essay to be evaluated by the ECB (English Composition Board). According to the quality of their performance in this essay, students will be placed in one of four sequences: (1) required to complete tutorial work (ECB Introductory Tutorial 100-105 or ECB Transfer Tutorial 106-109), then write a post-test which will either place them into Introductory Composition, into another ECB Tutorial, or exempt them from Introductory Composition; or (2) required to enroll directly in Introductory Composition; or (3) exempted from Introductory Composition but required to attend the ECB Writing Workshop until certified for exemption; or (4) exempted from Introductory Composition.

Students exempted from taking Introductory Composition are granted advanced credit and need no further course work for this requirement.

The Introductory Composition requirement is met when the student has completed one of the four placement tracks described above. Note that Introductory Composition courses include English 125 and 167, University Course 101, Residential College Core 100 and Honors College Great Books 191 or Classical Civilization 101.

A grade of C- or lower is not acceptable in any program for the introductory composition course.

Transfer students with advanced credit for English composition from another college or university are not required to take the ECB writing test. Their advanced credit will be used to satisfy the introductory composition requirement. Transfer students without advanced credit for English composition must elect one of the introductory composition courses listed above. (English 220 is not acceptable.)

Freshmen with advanced credit for English composition from another college or university may use that credit to satisfy the introductory composition requirement.

English Composition Board: Writing Workshop

ECB lecturers who teach ECB Introductory and Transfer Tutorials also provide consultation and instruction in the Writing Workshop. During the hours that the Workshop is open, two experienced teachers of composition are available for half-hour appointments (on a drop-in or scheduled basis) to discuss writing with any undergraduate in the College. (Any student enrolled in a undergraduate course is eligible to come to the Writing Workshop for help with writing assignments in that course.) Extended appointments are available for students whose immediate needs cannot be met in half-hour sessions.

Instructors in the Writing Workshop do not make assignments and will not work as editors or proofreaders for their student clientele. They will discuss with undergraduates the meaning of and approaches to writing assignments made in any course in College, and then help those same students be aware of appropriate rhetorical, syntactical, and grammatical choices as they write their papers.

Foreign Languages. Although a foreign language is an important part of the high school education, it is not required for admission nor does it appear in any program requirement. It is recognized that a number of students are admitted with the equivalent of college-level work in a language. Advanced credit may be requested for foreign language study in high school by one of the following: (1) Advanced Placement Examination, (2) Foreign Language Placement Examination after arriving at the University. (Humanities credit for the first year of study in a foreign language, the equivalent of college courses at the 100-level, is not longer given; however, a 100-level course can be used as a free elective.) Credit for any foreign language course at the 200-level or higher, or advanced placement for such a course, can be used towards the fulfillment of the Humanities requirement. (See *Elective Studies.*)

Technical Communication. A required (3-hour) technical communication course is taken in the senior year. This requirement may be met by electing Technical Communication 497, 498, or 499.

Engineering. Three credit hours of digital computing or equivalent are required in each program. This requirement may be met by electing Engineering 103, Digital Computing for three credit hours. Occasionally special sections of Engineering 195 may be used to meet this requirement. FORTRAN-77 is the programming language used.

Engineering 103 is intended to help the student feel comfortable at interacting with a computer, and to give him or her a general awareness of the organization and capabilities of digital computers. The course meets twice weekly, a video-taped lecture being followed immediately by a laboratory in which the students use IBM personal computers both stand-alone and for communicating with the large mainframe Amdahl 5860 machine at The University of Michigan's Computer Center.

Chemistry. The minimum requirement in chemistry is five credit hours which can be met by Chemistry 123 (3) or 124 (3), and 125 (2), or Chemistry 196 (5). The counselor will recommend the most appropriate course for the student's first term, based on placement examination and other information. A student who is eligible for Chemistry 196 may elect Chemistry 124 instead. Either Chemistry 125 plus 126, or Chemistry 197, are prerequisites for more advanced courses in chemistry.

A student with Chemistry 123 or 124 who plans to enter programs in Chemical, Materials and Metallurgical Engineering, or Atmospheric and Oceanic Science, should elect Chemistry 126. Each student should refer also to the schedule of the respective program and, if in doubt, consult with the program adviser to determine the most suitable sequence of advanced chemistry.

A student with a grade of A in Chemistry 124 and 125 may be invited by the Chemistry Department to elect Chemistry 197 (5) instead of Chemistry 126. This combination provides the student with additional background and improves the student's ability to master advanced courses.

A student with advanced placement credit in chemistry will be given special counseling for the first-term elections.

Physics. The usual freshman schedule includes Physics 140 (3) with laboratory, Physics 141 (1). This course assumes knowledge of calculus.

A second choice, Physics 240 (3), with laboratory, is required by all programs and is normally scheduled in the third term. A third course Physics 242 (3) is required for programs in Aerospace Engineering, Electrical Engineering, Engineering Physics, and Nuclear Engineering.

Elective Studies

Each program provides some freedom for the student to elect subjects that satisfy the individual's particular interests and aptitudes. The humanities/social science counselor or program advisers are in a position to make helpful recommendations.

Humanities and Social Sciences. To provide a desirable breadth of education, each program in this College specifies a certain number of credit hours of elective courses (minimum 17) concerned with human cultures and relationships—generally identified as humanities and social sciences. In general, the humanities include literature (English and others), philosophy, history of art, music history, classical civilization, etc.; the social sciences include economics, history, psychology, anthropology, sociology, etc.

Specific requirements for all students (with or without College Board Advanced Placement Program credit or transferred credit) are outlined below. For information on specific courses offered by the Engineering College, see the course descriptions under Humanities. Also see Humanities (HU) and Social Sciences (SS) course offerings in the College of Literature, Science, and the Arts *Bulletin* and *Course Guide.* Courses designated as (N.S.), (N.Excl.), (Excl.), (Experiential), and (Independent) CANNOT be used to fulfill Humanities or Social Science credits.

1) Humanities (six credit hours)
—at least two courses in humanities, totaling at least six credit hours, selected from:
   (a) Any non-performance course designated as Humanities (HU) in the LSA Bulletin.
   (b) Any course designated as Humanities and taught in the College of Engineering.
   (c) Any non-performance course in the School of Music or School of Art.
   (d) Any second-year foreign language course or higher, designated FL or HU, or advanced placement for such course.
2) Sequence of humanities or social science courses (six credit hours)
—a sequence of at least two courses in either the humanities or the social sciences, totaling at least six credit hours, must be taken from the same department or division (for example, History), one of which must be a 300- or 400-level course. This requirement may overlap requirement (one).
3) The remaining (usually five) credit hours may be satisfied with elective courses in either humanities or social sciences as follows:
   (a) Any course designated as Humanities in (one).
   (b) Any course designated as Social Sciences (SS) in the LSA Bulletin.

Other Electives. Subject to the limitations of the student's program and to the approval of the program adviser, a student may also elect courses within the field in which the student is enrolled; courses in other

engineering departments; appropriate courses in other colleges or schools of the University such as mathematics, chemistry, physics, astronomy, biology, and the management sciences; and courses in military, naval, or air science.

Free electives may be selected from the offerings of any regular academic unit of the University and from the Pilot Program. All undergraduate degree programs will accept, as a free elective, a maximum of one performance course, with a maximum of three credit hours, in the School of Music or Art, including marching band. Tutorial courses are not acceptable for credit or grade points but will be included on the student's official record.

All undergraduate degree programs in the College of Engineering will accept up to three credit hours toward free electives from credits earned by a student in courses for which the requirements include tutoring of other students enrolled in courses offered under the Keller plan or similar plans.

All undergraduate degree programs in the College of Engineering will accept up to 15 credit hours toward free electives from credits earned by a student in 300 and 400 level courses in military, naval, or air science.

It is permissible and generally desirable for a student to elect courses in addition to those required for the degree, provided the student has a clear understanding with the program adviser. This provides an opportunity to explore areas of cultural and professional interests as well as to enhance the student's preparation for continued or professional interests as well as to enhance the student's preparation for continued or advanced study in a selected field, either in engineering and physical sciences or in other areas such as business administration, law, medicine, dentistry, or education.

Fee Regulations, Expenses, Indebtedness

A non-refundable fee of $30 will be required of each applicant for admission to the University.

The fees for one full term for the 1988-89 academic year were as follows:

	Michigan Resident	Non-resident
Lower Division	$362 for first hour + $107 for each additional hour	$645 for first hour + $387 for each additional hour
12-18 credit hours	$1,536	$4,904
Over 18 credit hours add	$107 per credit hour	$387 per credit hour
Upper Division (55 or more credit hours)	$378 for first hour + $121 for each additional hour	$674 for first hour + $419 for each additional hour
12-18 credit hours	$1,709	$5,260
Over 18 credit hours add	$121 per credit hour	$419 per credit hour

Students enrolled as special students or guest students in the College of Engineering will be assessed the upper division fees.

The following guideline may be used for the total expenses for upper division students:

Michigan resident (two terms, academic year)	$ 9,249
Non-Michigan U.S. citizen (two terms, academic year)	$16,399
Foreign (three terms, calendar year)	$25,029

Fees are subject to change at any time by the Regents of the University.

Detailed information relating to fees, deposits, payments, and refunds may be obtained in the Assistant Dean's Office and/or may be found in the first few pages of the Time Schedule.

Class Standing. The number of credit hours accumulated toward graduation at the close of a given term are used to determine a student's class standing for statistical purposes. Questions concerning class-level designations should be referred to the Assistant Dean's Office.

Lower Division Class	Hours
Freshman	0 to 24
Sophomore	25 to 54

Upper Division Class	Hours
Junior	55 to 84
Senior	85 or more

A transfer student is classified in this manner in terms of the tentative adjustment of credit applicable to the elected program; when on a prescribed program the student will be a senior when there are 35 hours or less to complete.

Withdrawal. A student withdrawing after registration shall pay a disenrollment fee according to the rules in effect at the time of withdrawal as published in the Time Schedule for each term.

Indebtedness to the University. Proper observance of financial obligation is deemed an essential of good conduct, and students who are guilty of laxness in this regard to a degree incompatible with the general standards of conduct shall be liable to disciplinary action by proper University authorities. Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the vice president in charge of business and finance.

When a student's account shows indebtedness, academic credits are withheld, no transcript of academic record or diploma will be issued, nor will future registration be permitted.

Rules and Procedures

General Standards of Conduct for Engineering Students

In establishing a standard of student conduct, The University of Michigan is committed to the basic principles of entrusting each student with a high degree of freedom to govern the life and conduct of the student while enrolled at the University.

The College of Engineering encourages its students to protect and utilize this freedom with wisdom and good judgment, and to accept and discharge the responsibility inherent to such freedom.

The student is expected to develop his or her relationships with integrity; to respect the rights and properties of others; to comply with University regulations and public laws; and to live with high standards of personal and social conduct.

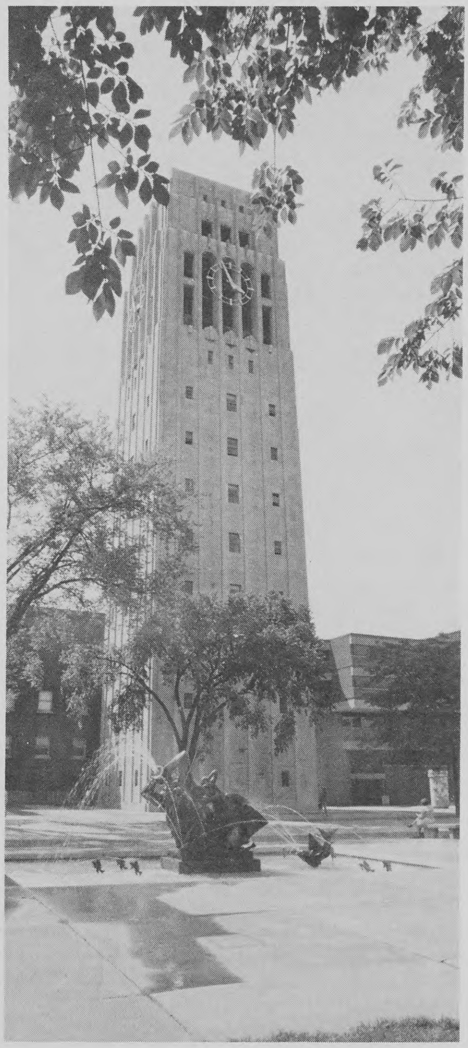
The College of Engineering welcomes the participation of students in decision making relevant to their affairs and provides channels of communication, both at the College and department level for that purpose. To benefit from such activity, each student should recognize his or her responsibility to fellow students and to the faculty, and should discharge all duties with the high standards that make such student-college relationships effective and valuable.

The College of Engineering reserves the right to discipline, exclude from participation in relevant activities, or dismiss any student whose conduct or performance it considers unsatisfactory. Such a decision will be made only after review by the appropriate student and faculty committees. During this review the student will have full opportunity to present his or her position. A student also has the right of appeal to the Executive Committee of the College.

The Honor Code of the College (below) bears witness to the deep trust that characterizes the student-faculty relationships in one of the most important aspects of student conduct.

Honor Code

The engineering profession has a long-standing record of fostering high standards of integrity in the performance of professional services. Not until the 1930s, however, was the first Canons of Ethics for Engineers developed and adopted by national professional engineering societies. The following statement relating to ethical conduct is part of a revision of the Canons approved by the Engineers' Council for Professional Development in 1963.



"The Engineer, to uphold and advance the honor and dignity of the Engineering Profession and in keeping with high standards of ethical conduct:

1. Will be honest and impartial, and will serve with devotion his employer, his clients, and the public;
2. Will strive to increase the competence and prestige of the engineering profession, and
3. Will use his knowledge and skill for the advancement of human welfare."

In 1915, a number of years before the first Canon of Ethics was published, the students of the College of Engineering proposed an Honor Code. This was approved by the faculty and has been in effect since its inception. The Honor Code truly is a distinguishing feature of enrollment in the College of Engineering. By observing the code, students do their work in an environment conducive to establishing high standards of personal integrity and professional ethics.

As a basic feature of the code, students are placed upon their honor during all examinations and written quizzes, and as required by the instructor, for computer questions, home work, and laboratory reports. Although the instructor is available for questions, the examination is not proctored. The student is asked to write and sign the following pledge at the end of the examination paper:

"I have neither given nor received aid on this examination."

Either a student or the instructor may by calling 764-8470 report a suspected violation which is then investigated by the Student Honor Council, resulting in a recommendation to the Faculty Committee on Discipline.

The Honor Council has prepared a booklet, available at the Assistant Dean's Office, which explains the principles and operation of the Honor Code.

Independent Study. In general, the principles of the Honor Code also apply to homework when the instructor requires the material turned in to be the student's own work. While independent study is recognized as a primary method of effective learning, some students may find that they benefit from studying together and discussing home assignments and laboratory experiments. When any material is turned in for inspection and grading, the students should clearly understand what cooperation between them, if any, is permitted by the instructor. When independent study and performance are expected, the deliberate attempt to present as one's own work any material copied from another student or from any source not acknowledged in the report is forbidden. In such cases, the instructor may require the signing of the pledge and expect the same high standards of integrity as during examinations; the instructor may report suspected violations.

Attendance and Absences

Regular and punctual attendance at classes is one of a number of expressions of interest, maturity, and devotion to recognized standards of conduct that contribute to the dignity of the profession. The reasons for good attendance should be obvious, and a student may expect unexcused absences to reflect in their final grade.

All students are required to account to their instructors for their absences. An instructor may report to the Assistant Dean when it is considered that the number of absences of an underclassman is excessive, and the instructor may require the student to present a written excuse approved by the Assistant Dean.

A student who has been absent from studies for more than one week because of illness or other emergency should consult the adviser to determine the advisability of reducing elections.

A student with an unresolved problem related to absences may consult the Assistant Dean.

Examinations

Classes may be examined at any time, with or without notice, on any part of the work. An examination at the end of the term is an essential part of the work of the course; the instructor is required to observe the official final examination schedule established by the University.

Any student absent from an examination is required to report to the instructor as soon thereafter as possible. If a student presents a valid excuse for being absent, the examination may be arranged by the instructor for another time.

See Honor Code for procedures pertaining to examinations.

Election of Studies

Term. A term is a period of enrollment extending over approximately four months, including examinations. Term requirements are equivalent to those of the conventional semester. Schedule, by months, of the University's year-round calendar is approximately as follows:

Name of Term	Period	Identification Used in Description of Courses
Fall	Sept., Oct., Nov., Dec.	I
Winter	Jan., Feb., Mar., Apr.	II
Spring	May, June, July, Aug.	III

The Spring-Summer term may be scheduled as two half terms, approximately as follows:

Spring half term	May, June	III*a*
Summer half term	July, Aug.	III*b*

In the following rules and procedures, the word "term" also applies to half term unless otherwise indicated.

Credit Hour. A credit hour represents, generally, one hour of recitation or lecture per week for a term, or two for a half term; preparation for each credit hour should require normally two hours of study. Generally, one period of laboratory work is considered to one hour of credit. "Credit hour" or "hours of credit" as used in this *Bulletin* and as reported on the student's academic record are synonymous with "semester hour" or "semester hours credit."

Work Load. The number of hours a student is able to carry in any one term depends upon a number of factors — including abilities, health, and the amount of time devoted to extracurricular activities or to outside work. Twelve credit hours are considered a minimum full academic schedule for a full term (six for half term). Reduced program fees apply to 11 credit hours or less for undergraduate students.

Unless approved by the program adviser (for freshmen, the Assistant Dean), the student may not elect courses (or change elections) for which the total number of hours for a term is less than 12 or more than 18, and for a half term, less than six or more than nine. A student should have a 3.0 average or more for the previous term to be permitted to carry a term load of more than 18 hours.

Attention is called to the section on Time Requirements for a statement on estimating the time needed for a bachelor's degree.

Course Offerings. The appropriate *Bulletins,* and the *Time Schedule* prepared for each term, will serve the student as a guide in planning each term's schedule.

The faculty reserves the right to withdraw the offering of any elective course not chosen by at least eight persons.

Classification and Registration. As needed, the Assistant Dean's Office will prepare instructions to program advisers, counselors, and students relating to election of courses, classification (including assignment to sections), and registration (official enrollment).

All students are required to have and use a Social Security number for registration and records purposes.

Completion of both the classification and registration procedures is required before a student attends any classes or uses any University facilities. Late registration is subject to a $15 fee and the fee increases by $10 at the end of each month that the registration is late, so that as much as an additional $40 may be added to the original $15 fee. The fee must be paid in advance by the late registrant.

Unless a student is classified and registered, there is no obligation on the part of faculty members to permit attendance in their classes.

A student who completes the registration procedure (including early) and fails to attend classes must officially withdraw from college through the Assistant Dean's Office and pay the usual disenrollment fee as stated in the current *Time Schedule.*

Change of Classification. After a term has begun, adding or dropping a course can be made official only through use of an "election change request" form, and upon authorized approvals.

A course may be added during the first few weeks of a term with the expressed permission of the instructor with whom arrangements must be made for the necessary make-up work. In most cases, this consideration puts a practical time limit of the first two weeks of a term (or the first week of a half term) for adding courses. Thereafter the program adviser (or the Assistant Dean for freshmen) also must approve any addition.

A change in classification from credit to audit must be made during the first six weeks of a term (the first three weeks of a half term). No change to audit status will be allowed after this period.

Any change of classification which changes a student's fee assessment must be reported by the student to the Assistant Dean.

Audit. With permission of the adviser and the course instructor, a student may enroll in a course as an auditor. In such a case, the course will be entered on the permanent record with a "VI" instead of a letter grade. The same fee will be charged whether the student enrolls for credit or as an auditor.

Program Selection. A student normally selects a program of study during the second term of the freshman year and is referred to the appropriate program adviser. A tentative program established at this time will be helpful as a guide to the student and the elections counseling through the completion of the degree requirements. Students who have not selected a program by the time they reach 55 credit hours, or who wish to change degree programs after they have reached 55 credit hours, are subject to grade point averages and quotas approved by the Executive Committee of the College of Engineering for admission to the various degree programs.

Changing or Adding a Program. When a student desires to change from one program to another, or to elect an additional program, the student must consult the program advisers of the programs involved and obtain the necessary approvals on a form supplied by the Records Office in the Engineering Student Services Building.

Transfer students or continuing students who have earned 55 credit hours or more are subject to grade point averages and quotas approved by the Executive Committee of the College of Engineering for admission to the various degree programs.

Elections Considerations. At any time, a student's elections must take into account the preparation (including deficiencies and prerequisites), demonstrated ability and performance, the need for repeating courses, interests and career plans, extracurricular activities or part-time employment, and recommendations of the Committee on Scholastic Standing, when applicable.

Any student who fails to maintain a satisfactory proficiency in English in any work in the College of Engineering shall be reported to the Assistant Dean. After consultation with the program adviser, the student may be required to elect such further work as may be deemed necessary.

Dropping a Course. The College expects students to finalize their academic schedules during the first three weeks (first two weeks of a half term). During this time changes may be made in academic schedules for educational reasons with approval of the student's counselor or program adviser subject to conditions stated under Work Load, above. Courses dropped during this period do not appear on the academic record. Fees are determined by the schedule in effect at the end of the third week of a full term and at the end of the second week of a half term.

Students will be permitted to drop courses of less than a full term's duration (mini-course) up to the mid-point of the course without it being recorded on the transcript.

Students withdrawing from the fourth week through the ninth week (three to four and one-half weeks for the half terms), must obtain permission from the instructor and the program adviser. A "W" will appear on the transcript.

From the ninth week to the end of the term (four and one-half to the end of half terms), the only approved drops will be for those students who present written evidence of extenuating circumstances; i.e., severe health problems, prolonged illness in the family, jury duty, and so forth. There must be documented evidence that the student was earning a C grade or better before the problem occurred. Approved drops will be posted to the official record with a grade of "W."

The grade for any course dropped without the permission of the program adviser or Assistant Dean will be recorded as "ED" (unofficial drop) and computed as "E" in the averages.

Junior and senior students enrolled in a Military Officer Education Program must have approval also of the chairman in charge of the unit before they can drop a Military Officer Education Program course or be relieved of the obligation assumed when enrolling in the program.

When a student requests dropping all courses, the program advisor will refer the student to the Assistant Dean's Office to effect a total withdrawal from the College.

A Change of Election Fee of $10.00 is charged to all students who drop/add, change credit hours, or change modifiers after the end of the third week in a full term, or the second week in a half term. The fee will be assessed for each student session, regardless of the number of changes made at that session.

Substitution. Substitution of a course for one which is a requirement for graduation must be approved by the program adviser of the student's degree program and appropriately reported to the Assistant Dean's Office. All substitutions approved are subject to review by the Curriculum Committee.

Electives. See guidelines under Elective Studies.

A student may elect courses in addition to those required for the degree. The student may not register in the College of Engineering and elect courses offered by another college if such elections do not contribute to a goal of a bachelor's degree in this college, except when approved by the Assistant Dean. See Unassigned Status.

Cross-Campus Transfer, Withdrawing, and Readmission

Cross-Campus Transfer. A student who wishes to pursue studies in another unit of the University must apply for admission to that unit and be accepted in order to continue enrollment in the University. In general, a student's scholastic standing determines eligibility for admission to other colleges. The Assistant Dean's office should be consulted for procedures to effect a transfer.

Withdrawing. In order to disenroll after having registered (including early registration), the student must report to the Assistant Dean's Office to complete a Withdrawal Notice form. A "W" will appear on the transcript when withdrawal occurs after the first three weeks of the full term or the first two weeks of the half term. Withdrawal from the College for a justifiable reason at any time during a term requires the approval of the Assistant Dean. A student under 18 may be required to present evidence of parent's approval.

After the third week of a term, or second for a half term, a student requesting withdrawal without record must present evidence of extraordinary circumstances. In any case, the Assistant Dean may specify the conditions for readmission.

Disenrollment fees vary from a minimum of $50.00 for first three weeks of a term to full assessed fees for the term after sixth week.

Honorable Dismissal. Honorable dismissal will be granted to a student who wishes to transfer to another college when the record of the student is void of any College of Engineering or University action regarding misconduct.

Readmission. A student who is non-enrolled for more than 12 months must apply for readmission through the Assistant Dean's Office and should do so at least two months before the date of desired enrollment. Readmitted students are subject to the rules in effect at the time of readmission.

Students who have graduated from the College and wish to elect courses for an additional term, must seek readmission through the Office of the Assistant Dean.

A student whose further enrollment has been withheld must first be reinstated on probation by the Committee on Scholastic Standing.

A student who withdrew for health reasons will be referred to the Health Service for clearance.

Grades and Scholastic Standing

Academic Record. Each student's "Academic Record" is that cumulative record maintained by the Engineering Records Office in the Office of the Registrar, of courses elected, grades, averages, and other matters relating to the progress of the student. A copy is given to the student's program adviser at the end of each term. Other copies are released by the Transcript Office, 555 LSA Building, 764-6280, only when requested by the student except as restricted under "Indebtedness to the University."

An individual may obtain an official copy of the academic record at any time upon payment of $4.00 per copy.

A student is provided with an official copy (free) of the academic record at the time of graduation.

Grade Reports. Unless withheld for infringement of rules, each term's grades are reported to the student.

Good Scholastic Standing. To be in good scholastic standing at the end of any term a student must have a term and cumulative grade-point average of 2.00 or more (twice as many grade points as hours computed); each course which is graded with A+ through E, or ED is included in the computations.

Averages. The term grade-point average and the cumulative grade-point average are computed for each student at the end of each term and become part of the academic record. The grades are valued per hour of credit on the basis of:

A+		4.0 grade points
A	excellent	4.0 grade points
A−		3.7 grade points
B+		3.3 grade points
B	good	3.0 grade points
B−		2.7 grade points
C+		2.3 grade points
C	satisfactory	2.0 grade points
C−		1.7 grade points
D+		1.3 grade points
D	passed	1.0 grade points
D−		0.7 grade points
E	not passed	0.0 grade points
ED	unofficial drop	0.0 grade points

These do not affect averages:

P	passed (See Pass-Fail Option)
F	not passed (See Pass-Fail Option)
I	incomplete
W	approved drop
VI	audit
NR	no report

In the remainder of this section of the *Bulletin,* the term "A grade" shall refer to any of the grades A+, A, or A−. "B grade" to B+, B, or B−, etc.

The grade-point average is computed by multiplying the number of points corresponding to the grade earned in each course by the number of hours of credit for the course and dividing the sum of these products by the total number of hours represented by all the courses assigned grade points. The word "average" is synonymous with grade-point average.

Grades associated with transfer credit are not recorded nor used in computing the cumulative average. The only exception to this rule is for courses elected on the Ann Arbor campus (effective November '85).

A course elected under Pass-Fail option does not affect a student's average.

Pass-Fail Option. A student who completed 30 hours of credit or more, including advanced credit, and is in good scholastic standing may elect courses on a pass-fail basis as follows:

Elective courses in Humanities and Social Sciences or courses to be used as Free Electives. The total is not to exceed four courses or 14 credit hours and is limited to two courses per term or one in a half term. Any course which is offered only on a P/F basis would not be counted in the above totals. The Introductory English composition requirement and Senior Technical Communication courses can not be elected as Pass/Fail courses.

The following regulations will apply:
1) The decision to elect a course on pass-fail basis must be made within the first six weeks of the term (or first three weeks of a half term). The student must abide by the decision to take a course for pass-fail once it has been made.

2) The Assistant Dean may approve for a freshman the election of a course offered only on a pass-fail basis.

3) Instructors are not notified of pass-fail elections; they will report grades as usual, A+ through E. The Records Office will then translate grades as follows:
   a) A grade of C− through A+ in a course elected on a pass-fail basis is considered satisfactory and will be recorded as P (pass—for credit toward the degree and no effect on the grade-point average).
   b) A grade of lower than C− in a course elected on a pass-fail basis is considered unsatisfactory and will be recorded as F (fail—no credit and no effect on grade-point average).

4) To be eligible for the Dean's Honor List a minimum of 12 credit hours (six for a half term) must be elected for grades.

5) To be eligible for Recognition on Diploma a minimum of 45 hours of credit must be completed with grades.

6) If a student has taken a course for pass-fail and subsequently changes the degree program of study such that the course comes into conflict with the stated constraints for pass-fail elections in the new program, the course will be accepted in the new program as follows:
   a) A record of P (pass) is regarded as a satisfactory completion of the program requirement.
   b) A record of F (fail) is regarded as unsatisfactory completion and the course must be repeated for grades.

Courses Offered on a Pass-Fail Basis. A department or instructor may offer an undergraduate course on the basis that the instructor will report the grade as pass-fail for each student enrolled, and that the grade will be treated on the same basis as when the student chooses to elect a course on a pass-fail basis if the following conditions are satisfied:
a) The course is not a required one for any program or department.

b) It is the type of course which might be considered appropriate to a pass-fail grading system.
Examples of such courses might be: design, survey type, individual directed research, laboratory, or undergraduate seminars.
c) It is announced by the instructor at the beginning of the term, and, with the exception of individual instruction courses, in the *Time Schedule.*

Rules Governing Scholarship Standing for Unsatisfactory Performance. Two degrees of scholastic deficiency identify a student's unsatisfactory performance: *Probation and Enrollment Withheld.*

Scholastic standing is determined by observing both the term and cumulative grade points. When a student has less than twice as many grade points as hours computed, the individual is deficient in the number of grade points required to make the total equal to twice the hours computed. (Example: Term — 15 hours computed with 29 grade points, student deficient 1 grade point. Cumulative — 80 hours computed with 150 grade points, student deficient 10 grade points.)

Scholastic standing will be determined as follows:

Rule 1. Probation: When a student has a deficiency of 0.001 to 9.999 grade points on either the term or cumulative record, the student will be placed on probation. The College Recorder will enter the notation "Probation" on the Academic Record. A student on probation may continue enrollment but must consult with the counselor (if freshman) or program adviser to initiate any adjustments in elections which might be necessary.

Rule 2. Enrollment Withheld: Students on probation for the third time and each time thereafter shall be put on enrollment withheld and be required to petition the Committee on Scholastic Standing for reinstatement.

Rule 3. Enrollment Withheld:
When a student has a deficiency of 10 grade points or more on either term or cumulative record, enrollment will be withheld. The College Recorder will enter the notation "Enrollment Withheld" on the Academic Record.

Rule 4. When a student's enrollment is withheld, the following procedures will be employed:
a) End of the fall term: "Enrollment Withheld" will be waived if student continues enrollment in the winter term. Further enrollment for students whose "Enrollment Withheld" has been waived will be determined by their scholastic standing at the end of the winter term. They will not be allowed to early register.
b) Students who have been extended the privilege of "Enrollment Withheld-Waived" for the winter term *must consult* with the counselor (if freshman) or program adviser to initiate any adjustments in elections which might be necessary.
c) A student with "Enrollment Withheld" for a fall term performance who does not continue enrollment in the following winter term may not register again without reinstatement on probation by the Committee on Scholastic Standing (Rule 5).
d) Beginning of the fall term: A student with "Enrollment Withheld," (i.e., as a result of grades earned during the previous half term) may appear before the Committee on Scholastic Standing and request a review (Rule 5). If reinstated on probation by the Committee, the student may register in the College again.

Rule 5. Reinstatement on Probation: When a student's future enrollment is withheld, the student has the privilege of presenting a petition complete with evidence of the associated circumstances for the unsatisfactory performance to the Committee on Scholastic Standing for consideration for an interview with the committee. If the student can show a satisfactory reason for the low record and can provide sufficient and convincing evidence that another opportunity should be given, the Committee may reinstate the student on probation.

For an interview, you must first petition the Committee for reinstatement in writing. Petition forms may be picked up in person or obtained by calling or writing the Dean's Office, 2407 EECS Building (313/763-5462). Appointments for interviews should be made through the same office.

The petition must be received at least three days prior to the interview. Notice of your meeting with the Committee will be given to your program adviser or counselor for comments. On the petition you will be asked to state what difficulties you have encountered, what you already have done to correct the situation, and what additional plans you have to improve your academic performance. If illness has been a factor, please include supporting information, including a statement (with dates) from your doctor.

For the fall term, all students must be in one of the following classifications:
a) Good Standing — better than 2.00 term and cumulative average.

b) On Probation — 0.001-9.999 grade-point deficiency on term or cumulative.

c) Reinstated on Probation — 10 or more grade-point deficiency but reinstated on grounds of extenuating circumstances surrounding poor record.

It is the policy of the College and the Scholastic Standing Committee not to reinstate students with 128 credit hours solely for the purpose of improving their grade point average or removing honor point deficiency to meet the 2.0 grade point average requirement for the baccalaureate (B.S.E.) or (B.S.) degree requirements.

C– and D Grades. Credit is allowed for a course in which a grade of C– or D is earned while enrolled in the College of Engineering. The D level of performance is not considered satisfactory for a course that is a prerequisite for a later elected course; in this case the course must be repeated before electing the next course unless waived by the Assistant Dean (for Freshman) or the Program Adviser (for students who have selected a program). A grade of C– is not a satisfactory level of performance in some programs and is not acceptable in any program for the introductory composition course. It is the student's responsibility to review such performance with the adviser as soon as the grade is known and before continuing enrollment in order to make any changes in elections that may be necessary.

Credit is not transferable for courses in which C– grades, or equivalent, were earned while the student was enrolled in another college.

E Grades. Neither credit nor grade points are allowed for a course in which a student earns the grade of E. A course required by the student's program must be repeated as soon as possible.

Incompletes. When a student is prevented by illness, or by any other cause beyond the student's control from taking an examination or from completing any vital part of a course, or if credit in a course is temporarily withheld for good reason, the mark "I" may be reported to indicate the course has not been completed. This mark should be used only when there is a good probability that the student can complete the course with a grade of D– or better and without enrolling in the class again. As soon as possible the instructor and student should mutually understand the reasons for the "I" mark and agree on methods for completing the work. No qualifying grade will be recorded on the student's academic record. The "I" mark will not be used in computing either the term or cumulative averages. Scholastic standing at the end of any term is determined on the basis of work graded as A+ through E, or ED.

The required work may be completed and the grade submitted by the instructor regardless of whether or not the student is enrolled. The student should plan to complete the work as soon as possible; however, in order that credit may be allowed, the required work must be completed by the end of the first term (not including spring-summer term) in which the student is enrolled after the term in which the "I" mark was recorded. It is the student's responsibility to remind the instructor to send a supplementary grade report to the Engineering Recorders in the Office of the Registrar when the work is completed.

Other Irregularities. Irregularities associated with failure to submit change in classification to the Records Office, 2420 Electrical Engineering and Computer Science Building, are identified on the student's Academic Record by an appropriate designation such as ED (unofficial drop), or NR (no report). No credit will be allowed a student for work in any course unless the election of that course is entered officially on the proper form. Unofficial drop (ED) will be considered the same as an E in computing the term and cumulative averages and will affect the scholastic standing.

If there has been an error, the student must consult the Assistant Dean's Office on the necessary procedures for resolving such cases. An NR (no report) will be changed to ED if the student initially elected the course and takes no action to have it cleared by the end of the next term enrolled.

Repeating Courses. For C–, D and E grades, see above. Except as provided for grades C– through D–, a student may not repeat a course he or she has already passed. In exceptional cases, this rule may be waived by the student's program adviser (for freshmen, the Assistant Dean) after consultation with the department of instruction involved. If the rule is waived, the course and grade will appear on the transcript, but no additional credit or honor points will be granted.

A student repeating a course in which a C– through D– was previously earned will receive honor points but no additional credit. In effect, the two grades are averaged.

Honors

The Dean's List. Degree candidates who elect courses and complete a minimum of 12 credit hours with grades (six for a half term) and earn 3.50 term average or better, attain the distinction of the Dean's Honor List for the term.

Convocations and Awards. Annually, those students who have earned distinguished academic records, based on a minimum of 14 credit hours per term, participate in the University's Honors Convocation. The College and several employers of engineers give special recognition or awards to students with high scholastic achievement, with records of service to the College and its student organizations, or with evidence of extraordinary potential for professional leadership. Informatin on qualification requirements can be picked up in the Dean's office.

Society Recognition. Distinguished scholarship and services to the College are also recognized by election to any of a number of honor societies that are included with the list of organizations under Extracurricular Opportunities. A student's election to a recognized society will be posted on the academic record.

Recognition on Diploma. A student graduating with at least 45 hours of credit which have been completed with grades while enrolled in this College (or as directed by the Executive Committee) will be recommended for a degree (and for each degree, if more than one) with recognition on the diploma if the student qualifies according to the following:

Grade Point Average	Distinction
3.20-3.49	cum laude
3.50-3.74	magna cum laude
3.75-4.00	summa cum laude

Time Requirement for a Bachelor's Degree

The time required to complete a degree program depends on the background, abilities, and interests of the individual student. A full-time schedule averaging 16 hours of required subjects will allow a student to complete the degree requirements (128 credit hours) in eight terms as may be noted from the sample schedules appearing with the several program descriptions. A student who is admitted with advanced preparation, with demonstrated levels of attainment, or with ability to achieve at high levels may materially accelerate his or her progress. A student who elects a Military Officer Education Program or who is partially self-supporting while at the campus may find it desirable to plan a schedule longer than eight terms.

A student who plans to continue studies beyond the bachelor's degree may (after attaining senior standing) elect a limited number of graduate-level courses concurrently with the courses required for the bachelor's degree. A course required for the bachelor's degree cannot be used for graduate credit also. For details, refer to the regulations published by the Horace H. Rackham School of Graduate Studies.

Requirements for a Bachelor's Degree

As a basic principle, the quality and level of attainment reached by the student are considered to be of greater significance in determining the requirements and standards for graduation than the completion of a specified number of credit hours.

In order to obtain a bachelor's degree in the College of Engineering, Ann Arbor campus, a student shall meet the following requirements, subject to approval of the program adviser:

1) The student must achieve a satisfactory level of attainment in those subjects specified by the program of his or her choice. A grade of D in a required course may not be considered a satisfactory level of attainment unless approved by the program adviser. A student may be considered proficient in a designated part of the degree requirement and be allowed recognition of the level of attainment in one or more of the following ways:

a) By passing a course for credit on the Ann Arbor campus. (D grades may not be acceptable as a proper level of attainment, for a required course, as noted above.)

b) By Advanced Placement Program examination for college-level work done in high school. (See Advanced Placement, under Admission.)

c) By an examination regularly offered by a department of the University (e.g., mathematics and language), or by a recognized testing service.

d) By transfer of equivalent credit from another recognized college. (See Adjustment of Advanced Credit, under Admission.)

e) By demonstrating qualification for enrollment in a higher-level course or series—e.g., honors-level, in which case a student may achieve a saving in credit hours.

f) By demonstrating equivalent and parallel knowledge which enables the student to enroll at an advanced level. In this case, the student will not be allowed credit hours on the academic record, but may be excused from enrolling in those courses in which the program advisers judge the student proficient. To qualify, the student must petition the program adviser and, as a condition, may be required to demonstrate his or her proficiency by an appropriate examination.

2) The student must complete a minimum of 30 credit hours of advanced level (300 or higher) courses, as required for the degree program while enrolled in the College of Engineering, Ann Arbor campus.

3) The student must complete at least 30 of the last 36 credit hours of work while enrolled in the College of Engineering, Ann Arbor campus.

4) The student must accumulate a final grade point average of 2.00 or more for all credit hours not taken under the pass-fail option while enrolled in the College of Engineering. In addition, a student must earn a cumulative grade-point average of 2.00 or higher in all courses taken within the student's department, or in courses designated by the program in the case of interdisciplinary programs.

5) The student must file formal application for the diploma. (See Diploma and Commencement.)

Requirements for an Additional Bachelor's Degree

1) To obtain two bachelor's degrees (including prescribed) in the College of Engineering, a student must complete the requirements of both degree programs. In addition, for the second degree, the student must complete at least a minimum of 14 credit hours in pertinent technical subjects over the number required for the first degree. The credit hours used to satisfy each of the two programs must satisfy the cumulative grade-point average requirement of 2.00 or more.

2) To obtain an additional bachelor's degree in the College of Literature, Science, and the Arts (LSA), refer to program requirements under Combined Programs with LSA.

Diploma and Commencement

For the College to recommend the granting of a degree, a student who satisfies all other requirements must also file formal application for the diploma. A student completing the requirements for more than one degree in the College of Engineering or a second degree in LSA must file an application for each.

The application must be submitted to the student's department office, at the beginning of the term in which the student is reasonably certain of completing the work for the degree.

When a student does not meet the requirements as planned, or if the degree is not awarded because of indebtedness, the student must renew the application at the appropriate time. Degrees are awarded at the end of the fall, winter, and spring-summer terms.

All student who are entitled to receive diplomas are expected to be present at the Commencement exercises appropriate to the date of graduation. Making all arrangements for attending is the student's responsibility.

Representative Sample Schedules

In an effort to provide the interested student, both freshman and transfer, with a sample schedule, the information for a number of the degree programs includes a schedule that is an example of one leading to graduation in eight terms; this is for informational purposes only and should not be construed to mean that students are required to follow the schedule exactly. Generally, it will be modified for a student electing Military Officer Education Program or a freshman admitted with advanced placement.

A transfer student attending a community or liberal arts college and pursuing a pre-engineering degree program may not be able to follow a similar schedule because of a lack of certain offerings. If this is the case, the student should elect humanities and social sciences subjects in place of the professional courses listed in the schedule during terms three and four.

Even though a student is unable to maintain the pace of the schedule printed, it will be desirable to follow the order in which the courses are scheduled to satisfy prerequisites.

Military Officer Education Program courses are not included in the sample schedules; a student who elects and completes the advanced program for a commission should consult the program adviser on the use of a maximum of 15 credit hours of advanced (300 and 400 level) courses for free elective credit.

Departmental Undergraduate Degree Programs

Thirteen of the programs first listed are offered under the jurisdiction of a particular department of the College. Following these is one program that is interdisciplinary in nature and is administered on a College-wide basis. See Contents at front of this *Bulletin* for listing.

Aerospace Engineering

Program Adviser:
Professor H. Buning
312 Aerospace
Engineering Building
(313) 764-4310

Aerospace technology has grown out of the problems of design, construction, and operation of vehicles that move above the earth's surface, vehicles ranging from ground-effect machines and helicopters to aircraft and spacecraft. Design of such vehicles has always been challenging, not only because of the requirement that they operate in a hostile environment but also because of the high premium placed on light-weight vehicles performing efficiently and with great reliability. These same requirements exist not only for future spacecraft and high performance transport aircraft but apply equally to the next generation of ground transportation such as high speed trains, over-water transportation, and automated motor vehicles. In addition to working on vehicle-oriented design problems, aerospace engineering graduates are often involved in systems management in the broadest sense. Because of the anticipated life mission of the aerospace student, the undergraduate curriculum at The University of Michigan is designed to convey a clear understanding of the fundamental aspects of the fields most pertinent to aerospace engineering. Real-life problems in aerospace and related areas are emphasized in the applications of the theory. In the senior year the students select a design course in which they are given an appreciation of the interrelation of the various areas of study in the design of an overall system.

Aerospace Engineering Program

The degree program gives the student a broad education in engineering by requiring basic courses in aerodynamics and propulsion (sometimes collectively referred to as "gas dynamics"), structural mechanics, flight dynamics and control systems. These courses cover fundamentals and their application to the design and construction of aircraft, spacecraft and other vehicular systems and subsystems. Courses in gas dynamics treat fluid and gas flow around bodies and through turbojet engines and rocket nozzles; also involved is the study of large and small scale air motion in the atmosphere and its relationship to environmental and noise problems. In courses on structural mechanics, light-weight structures are studied not only from the strength point of view but also in their elastic dynamic behavior. Flight dynamics and control systems deal with the dynamical behavior of vehicles and systems as a whole, their stability and controllability both by man and automatic pilots. Integration of all this material takes place in the design course in which the student has a wide choice of design topics.

The program in aerospace engineering offers considerable flexibility through technical and free electives in which the student has an opportunity to study in greater depth any of the basic areas mentioned earlier. In addition, there are other technical elective areas which the aerospace engineering students are encouraged to consider, including aerophysical sciences, environmental studies, computers, man-machine systems, and transportation. Elective courses in each technical elective area include courses taught both inside and outside the aerospace engineering department.

This program is accredited by ABET.

Laboratories

Engineering knowledge is gained in part through experience with engineering problems and the experimental approach to their solution. In required laboratory courses, the student is introduced to the basic principles of operation and use of modern laboratory instrumentation. These courses, taken in the junior year, may be followed by additional experimental work either in formal elective courses or in projects of the student's choosing.

The department's laboratories include subsonic, supersonic, and hypersonic wind tunnels; extensive structural test equipment; turbo-jet and rocket motors; and atmospheric measurement equipment. Students also gain experience in the use of computers for system design and simulation.

Undergraduate students at Michigan profit by their contact with graduate students and faculty members, who carry out research work parallel to the areas of undergraduate instruction and student projects.

Combined Degrees

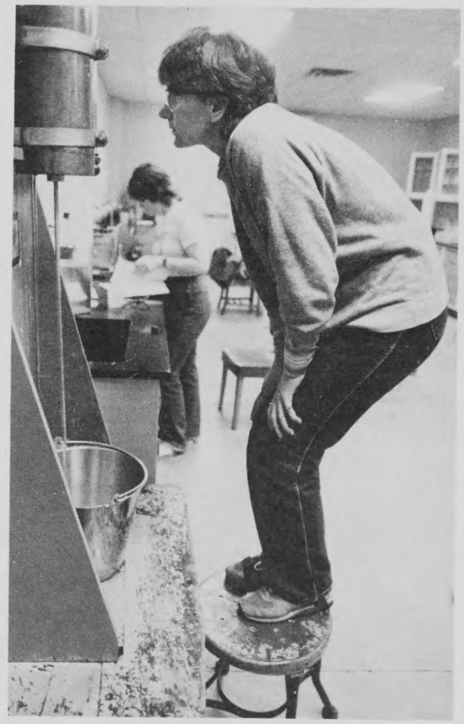
For students with special interests, combined degree programs leading to two bachelor's degrees are available. The flexibility of the Aerospace curriculum makes it feasible to obtain a second bachelor's degree with only one additional term of study. Favorite second degree areas of concentration among aerospace engineers are Mechanical Engineering and Applied Mechanics and Naval Architecture and Marine Engineering, but combined degrees with other departments can be arranged.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Aerospace Engineering)—B.S.E. (Aerospace E.)—must complete the program required. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.

Required Program | **Sample Schedule**

Courses	Hrs.	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.) See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124	3	3	-	-	-	-	-	-	-
Chemistry 125	2	-	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	4	-	-	3	3	3	4
Advanced Sciences (3 hrs.)									
Physics 242	3	-	-	-	3	-	-	-	-
Related Technical Subjects (20 hrs.)									
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mech.	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Intro. to Dynamics	3	-	-	-	3	-	-	-	-
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Mech. Eng. 235, Eng. Thermodynamics	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Anal. & Electronics	3	-	-	-	-	3	-	-	-
Engineering 303, Computing Methods	3	-	-	-	3	-	-	-	-
Program Subjects (33 hrs.)									
Aero. Eng. 200, Gen. Aeron. and Astro.	2	-	-	2	-	-	-	-	-
Aero. Eng. 301, Laboratory I	2	-	-	-	-	2	-	-	-
Aero. Eng. 302, Laboratory II	2	-	-	-	-	-	2	-	-
Aero. Eng. 314, Structural Mech. I	3	-	-	-	-	3	-	-	-
Aero. Eng. 320, Comp. Flow & Propulsion I	3	-	-	-	-	3	-	-	-
Aero. Eng. 330, Aerodynamics II	3	-	-	-	-	-	3	-	-
Aero. Eng. 340, Mechanics of Flight	3	-	-	-	-	-	3	-	-
Aero. Eng. 350, Aero. Eng. Anal.	3	-	-	-	-	3	-	-	-
Aero. Eng. 414, Structural Mech. II	3	-	-	-	-	-	3	-	-
Aero. Eng. 420, Aerodynamics III	3	-	-	-	-	-	3	-	-
Aero. Eng. 430, Propulsion II	3	-	-	-	-	-	-	3	-
Aero. Eng. 471, Automatic Control Sys.	3	-	-	-	-	-	-	3	-
Design and Technical Electives (10 hrs.)	10	-	-	-	-	-	-	4	6
These must include one of the following design courses: Aero. Eng. 481, Airplane Design, or Aero. Eng. 483, Aerospace System Design Aero. Eng. 484, Computer Aided Design Technical electives are to be chosen from advanced courses in Aero. Eng. and related areas, with approval of program adviser.									
Free Electives (6 hrs.)	6	-	-	-	-	-	-	3	3
Total	**128**	**14**	**16**	**16**	**16**	**17**	**17**	**16**	**16**



Atmospheric, Oceanic, and Space Sciences

Program Advisers:
Professor
S. R. Drayson
(Atmospheric Science)
2104 Space Research Building
(313) 764-3335

Professor
Guy A. Meadows
(Oceanography)
214 NA & ME Building
(313) 764-5235

Atmospheric, oceanic, and space sciences is concerned with the description and explanation of all phenomena in the atmosphere, the oceans, and the boundaries between them. Both basic and applied problems are encompassed. The increased recognition of the importance of the atmosphere and the oceans in a wide range of human activities has created a demand for meteorologists and oceanographers with a broad basic knowledge of the many processes that take place in the water and the air, and an ability to apply this knowledge to specific problems ranging from the bottom of the ocean to the outermost fringes of the atmosphere. The qualified meteorologist or oceanographer may find employment in the official weather services, in the space sciences, in industry, government, teaching, research, and in private practice.

The understanding of processes in the atmosphere and oceans requires knowledge in many areas of the mathematical and physical sciences. Although the fundamental laws are those of classical hydrodynamics and thermodynamics, it is as a rule necessary to modify these laws before applying them to a specific problem of atmospheric or oceanic interest, because the atmosphere and oceans are thermodynamically active systems receiving energy from many physical processes such as short and long wave radiation, condensation, and interaction with the other medium and dissipating energy through frictional processes.

The applied aspects of the two sciences cover a wide range of activities and interests. The applied meteorologist will be called upon to solve meteorological problems in connection with air pollution, industrial plant location and processes, the design of structures and the wind loading of them. Many

Required Program

Sample Schedule

Courses	*Hrs.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Subjects required by all programs (56 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Soc. Sci. *(Note A)*	19	-	3	4	6	3	-	-	3
Advanced Science (3 hrs.)									
Chem. 126, Gen. and Inorganic Chem.	3	-	3	-	-	-	-	-	-
Program Subjects (6 hrs.)									
A.O.&S.S. 304, Atmos., Oceanic and Space Sciences I	3	-	-	3	-	-	-	-	-
A.O.&S.S. 305, Atmos., Oceanic and Space Sciences II	3	-	-	-	3	-	-	-	-
Free Electives (6 hrs.)	6	-	2	-	-	-	-	-	4
Option 1. Meteorology (B.S.) (55 hrs.)									
Mech. Eng. 240, Intro to Dynamics	3	-	-	-	-	3	-	-	-
Mech. Eng. 325, Fluid Mechanics	3	-	-	-	-	-	-	3	-
Stat. 412, Intro to Probab. & Stat.	3	-	-	-	-	-	3	-	-
Aero. Eng. 350, Aerospace Engineering Analysis	3	-	-	-	-	-	3	-	-
A.O.&S.S. 310, Synoptic Lab. I.	1	-	-	1	-	-	-	-	-
A.O.&S.S. 311, Synoptic Lab. II.	2	-	-	-	2	-	-	-	-
A.O.&S.S. 312, Climatology	3	-	-	-	-	-	3	-	-
A.O.&S.S. 330, Thermo. of Atmosphere	3	-	-	-	-	3	-	-	-
A.O.&S.S. 332, Radiative Proc. in the Atmos.	3	-	-	-	-	-	3	-	-
A.O.&S.S. 401, Geophysical Fluid Dynamics	3	-	-	-	-	3	-	-	-
A.O.&S.S. 451, Atmospheric Dynamics I.	4	-	-	-	-	-	-	-	4
A.O.&S.S. 454, Lab. in Weather Anal.	3	-	-	-	-	-	-	3	-
A.O.&S.S. 479, Atmospheric Chemistry	3	-	-	-	-	-	-	3	-
Technical Electives *(Note B)*	18	-	-	-	-	5	3	4	6
Total	**128**	**16**	**16**	**16**	**15**	**17**	**15**	**16**	**17**
Option 2. Oceanography (B.S.) (55 hrs.)									
Geol. 117, Intro. to Geology	5	-	-	-	5	-	-	-	-
Biol. 112, Intro. to Biology	4	-	-	4	-	-	-	-	-
A.O.&S.S. Sci. 308, Lab. in Ocean. Data	2	-	-	2	-	-	-	-	-
A.O.&S.S. Sci. 334, Physical Oceanography I	3	-	-	-	-	3	-	-	-
A.O.&S.S. Sci. 335,	3	-	-	-	-	-	3	-	-
Elective Sequence in Oceanography (23-24 hrs.)									
Physical, Chemical Geological, or Biological) *(Note C)*	24	-	-	-	-	6	6	6	6
Technical Electives *(Note D)*	14	-	-	-	-	4	4	4	2
Total	**128**	**16**	**16**	**17**	**16**	**16**	**16**	**16**	**15**

Term Enrolled (columns 1–8)

continued

Note A. Oceanography majors will take four hours of Humanities and Social Sciences in the 4th term, three in the 2nd, 5th, 6th, 7th, and 8th terms.

Note B. A minimum of six hours of Technical Electives must be chosen from the Atmospheric, Oceanic and Space Sciences Department. In addition, EECS 300, or Math. 455 is strongly recommended.

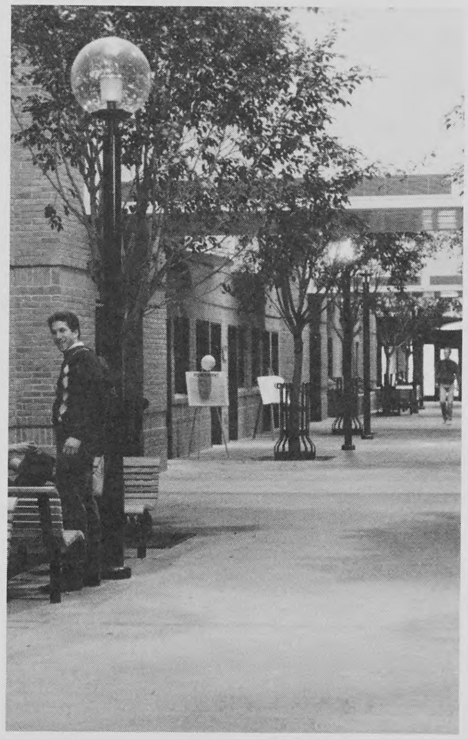
Note C. Mech. Eng. 240 and 325 and Chem. 365 are included in the Elective Sequence in Oceanography when required.

Note D. A course in statistics (Stat. 402, Nat. Res. 438) is strongly recommended.

*Another approved engineering design course may be substituted.

Option 3. Meteorology (B.S.E.) (55 hrs.)

Mech. Eng. 240, Intro. to Dynamics	3	-	-	-	-	3	-	-	-
Mech. Eng. 325, Fluid Mechanics	3	-	-	-	-	-	3	-	-
Statistics 412, Intro. to Probab. & Stat.	3	-	-	-	-	-	-	-	3
Math/Aero Eng. 350, Aerospace Engr. Anal.	3	-	-	-	-	-	3	-	-
A.O.&S.S. 310, Synoptic Lab. I	1	-	-	1	-	-	-	-	-
A.O.&S.S. 311, Synoptic Lab. II	2	-	-	-	2	-	-	-	-
A.O.&S.S. 312, Climatology	3	-	-	-	-	-	3	-	-
A.O.&S.S. 330, Thermo. of Atmos.	3	-	-	-	-	3	-	-	-
A.O.&S.S. 332, Radiative Proc. in the Atmos.	3	-	-	-	-	-	3	-	-
A.O.&S.S. 401, Geophysical Fluid Dynamics	3	-	-	-	-	3	-	-	-
A.O.&S.S. 408, Environ. Problem Solving with Computers	3	-	-	-	-	-	-	3	-
A.O.&S.S. 451, Atmospheric Dynamics I	4	-	-	-	-	-	-	-	4
A.O.&S.S. 454, Lab. in Weather Analysis	3	-	-	-	-	-	-	3	-
A.O.&S.S. 460, Satellite Meteorology	3	-	-	-	-	-	-	3	-
A.O.&S.S. 461, Air Pollution Instrumentation*	2	-	-	-	-	-	-	-	2
A.O.&S.S. 462, Meteorological Instrumentation*	3	-	-	-	-	-	-	3	-
EECS 314, Circuit Anal. and Electronics*	3	-	-	-	-	-	3	-	-
EECS 315, Circuit Anal. and Electronics Lab.*	1	-	-	-	-	-	1	-	-
Technical Electives	6	-	-	-	-	4	2	-	-
Total	**128**	**16**	**16**	**16**	**15**	**16**	**16**	**17**	**16**



important decisions on transportation, whether by land, water, or air, depend critical on meteorological factors. The applied oceanographer is concerned with water supply and control, water pollution, wave action on structures and beaches, biological and geological processes in the ocean, and many other problems.

It is recognized that the undergraduate program cannot, in the time available, adequately treat all areas of importance. Graduate work, therefore, is strongly encouraged.

The undergraduate student elects one of three options, two of which lead to the degree B.S. (Meteorology) and B.S. (Oceanography); the student thus acquires knowledge in depth in one discipline while obtaining good working knowledge in the other. The third stresses the engineering applications of meteorology and leads to a B.S.E. (Meteorology). The options are:

Option 1. (B.S.) Meteorology is the science of the lower atmosphere, including dynamics, thermodynamics, chemistry, radiation, cloud physics and precipitation processes, interaction with the ground and ocean, the general circulation of the atmosphere and weather forecasting. With suitable choices of electives, a student may receive preparation in weathercasting for radio and television. Students in Radio & TV Weathercasting should include Comm. 100 and Geo. 201 in their Hum./Soc. Sci. electives, substitute A.O.&S.S. 408 for Aero. 350, and include as technical electives Comm. 421 & 425 and at least two of the following: Astro. 221, A.O.&S.S. 462, 463, 424, 499, advanced Comm. courses.

Option 2. (B.S.) Oceanography is the science of the oceans. Its basic subdivisions involve the application of biology, geology, chemistry, physics, and mathematics to oceanic studies. Oceanographers investigate oceanic life, sea-water chemical composition and reactions, geologic history of the oceans and their basins and oceanic structure, circulation, waves, and tides. Students may major in any one of a suitable combination of these several subdivisions.

Option 3. (B.S.E.) Meteorology. In addition to the basic Meteorology described under Option 1, the student will elect a number of design courses in such areas as: meteorological instrumentation, design and implementation of field experiments, environmental impact studies, and computer modeling.

Facilities

Meteorology. Laboratories include Air Pollution Meteorology, Meteorological Instrumentation, and a Synoptic Meteorology Laboratory where current weather data including satellite information are received over a satellite link. A recently acquired weather radar is now operational. The Department also operates a Radiation Measurement Analysis Facility, which includes comprehensive solar and infrared radiation measuring devices with automatic data acquisition. The Space Physics Research Laboratory houses teaching and research activities for studies of all regions of Earth's atmosphere and space probe studies of the atmospheres of other planets.

Oceanography. The oceanography program has laboratories devoted to the studies of physical oceanography and data processing, marine and lacustrine sedimentation, marine and environmental geochemistry, organic geochemistry, and underwater technology.

Requirements

Candidates for the degree Bachelor of Science (Atmospheric, Oceanic, and Space Sciences)—B.S. (Atmos., Ocean. & Space Sci.) or B.S.E. (Meteorology)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Chemical Engineering

Program Adviser:
Professor Dale E. Briggs
Program Office:
3126 Dow Building
(313) 764-7413

The degree program in Chemical Engineering was established in 1898 at The University of Michigan, one of four schools to introduce the profession in the United States in the last decade of the nineteenth century. The Michigan Student Chapter of the American Institute of Chemical Engineers was the first established by that professional society.

Chemical Engineering, of all branches of engineering, is the one most strongly and broadly based upon physical and life sciences. It has been defined by the Directors of the American Institute of Chemical Engineers as "The profession in which a knowledge of mathematics, chemistry, and other natural sciences gained by study, experience, and practice is applied with judgment to develop economical ways of using materials and energy for the benefit of mankind." Because of a broad and fundamental education, the chemical engineer can contribute to society in many functions, such as pure research, development, process design, plant operation, and corporate or government administration.

The work of the chemical engineer encompasses many industries, from the manufacture of chemicals and the refining of petroleum to nuclear energy and space technology. Because of this breadth, there are many special fields in which chemical engineers may concentrate.

The program allows six hours of free electives. A student may use this elective freedom to develop individual abilities and interests, and to prepare for graduate studies or for other professional programs such as law, business administration, medicine. The electives also provide the opportunity for combined degree programs or for preparation in fields within or related to chemical engineering such as petroleum, polymers, environmental engineering, chemical reaction engineering, control systems, computers, nuclear energy, biochemical processes, solar energy, and natural resource usage.

This program is accredited by ABET.

Note: Transfer students may require a program different from that printed below. Details of such programs are not shown here, but may be obtained from the program adviser.

Required Program

Sample Schedule

Courses	Hrs.	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (58 hrs.) See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Human. and Social Sciences (to include a course in economics)	17	-	6	-	-	3	4	4	-
Advanced Science (20 hrs.)									
Chem. 126, General and Inorganic Chemistry	3	-	3	-	-	-	-	-	-
Chem. 225, Organic Chemistry	4	-	-	4	-	-	-	-	-
Chem. 226 and 227, Organic Chem. and Lab	5	-	-	-	5	-	-	-	-
Chem. 468, Physical Chemistry	4	-	-	-	-	4	-	-	-
Chem. 469, Physical Chemistry	4	-	-	-	-	-	4	-	-
Related Technical Subjects (10 hrs.)									
EECS 314, Cct. Anal. and Electronics	3	-	-	-	-	-	-	3	-
EECS 315, Cct. Anal. and Electronics Lab	1	-	-	-	-	-	-	1	-
Engineering 303, Comp. Meth. Engr.	3	-	-	-	-	3	-	-	-
Elective Course in Engineering	3	-	-	-	-	-	-	-	3
Program Subjects (36 hrs.)									
Chem. Eng. 230, Thermo. I	4	-	-	4	-	-	-	-	-
Chem. Eng. 330, Thermo. II	4	-	-	-	4	-	-	-	-
Chem. Eng. 341, Fluid Mechanics	3	-	-	-	3	-	-	-	-
Chem. Eng. 342, Heat and Mass Transfer	3	-	-	-	-	3	-	-	-
Chem. Eng. 343, Separation Processes	3	-	-	-	-	3	-	-	-
Chem. Eng. 344, Reaction Eng. and Design	3	-	-	-	-	-	3	-	-
Chem. Eng. 360, Chem. Eng. Lab I	3	-	-	-	-	-	3	-	-
Chem. Eng. 460, Chem. Eng. Lab II	3	-	-	-	-	-	-	-	3
Chem. Eng. 466, Process Control and Dynamics	3	-	-	-	-	-	-	3	-
Chem. Eng. 486, Eng. Materials in Design	3	-	-	-	-	-	-	3	-
Chem. Eng. 487, Prin. of Chem. Eng. Des.	4	-	-	-	-	-	-	-	4
Free Electives (6 hrs.)	6	-	-	-	-	-	-	3	3
Total	**128**	**16**	**17**	**16**	**16**	**16**	**14**	**17**	**16**

Facilities

The facilities located in the Dow Building include biochemical engineering, catalysis, coal liquefaction, energy logistics, ecosystem simulation, electrochemical, heat transfer, light scattering and spectroscopy, petroleum research, polymer physics, process dynamics, real time computing, and surface science laboratories; and in the George Granger Brown Laboratory, large and pilot scale heat transfer, mass transfer, kinetics, and separations processes equipment.

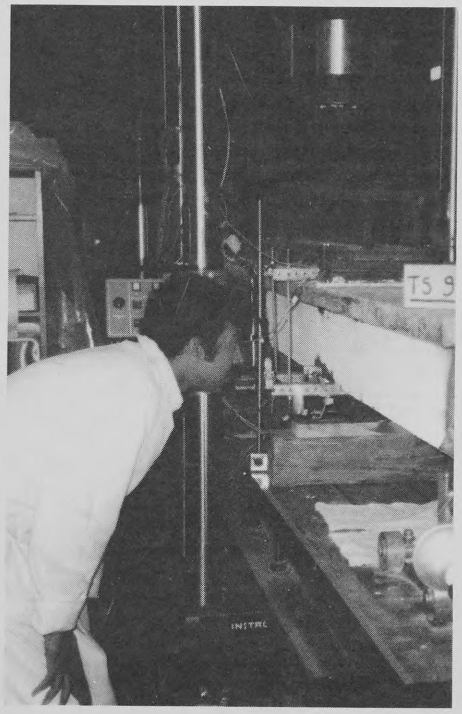
Requirements

Candidates for the degree Bachelor of Science in Engineering (Chemical Engineering)—B.S.E. (Ch.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Transfer students may find that it is necessary to extend their schedule to 8½ or nine terms.

Combined Programs

Chemical and Materials Science and Engineering

A combined degree may be obtained in chemical engineering and materials science and engineering. Chemical engineering students who choose a second degree in the metallurgical option will take a minimum of fourteen additional hours in the field of process, physical, and mechanical metallurgy. Those who choose the materials option will take at least fourteen additional hours in physical metallurgy, physical ceramics, and polymers.



Civil Engineering

Professor E. A. Glysson
2342 G. G. Brown Building
(313) 764-9412

Civil Engineering, originally named to distinguish it from military engineering, has always covered a wide field of engineering practice. Civil engineers plan, design, and manage the construction of engineered facilities needed for industrial development and public works. They are responsible for the safe and efficient operations of many of these facilities. They plan the conservation, utilization, and control of water resources. They operate in the field of surveying and mapping. The nature of the civil engineer's work requires that the individual not only have a broad basic foundation in the physical sciences but also be alert to the economic and social significance of what he or she plans and builds. This aspect of the educational foundation has been a strong contributing factor in qualifying the civil engineer for positions of leadership in both industry and government. In the junior and senior years the Civil Engineering curriculum, accredited by ABET, provides an opportunity for elective courses in one of the following areas which exemplify the more important fields of civil engineering.

Construction Engineering and Management. Planning, estimating, scheduling, and managing the construction of engineered facilities using modern construction methods, materials, and equipment. Business and legal principles of construction contracting.

Environmental Engineering. Municipal and industrial water distribution and waste collection, water quality and water pollution control, the improvement and regulation of natural waters for municipal, industrial, and recreational use; water resources development and management, the analysis and design of water resource systems; environmental design for control of solid wastes and air and water pollution, management of engineering problems in the urban environment.

Geotechnical Engineering. The evaluation of soil properties and environmental conditions in foundations of earth-supported structures; mass stability in excavations and subsurface construction; use of soil characteristics and properties and soil classification in design and construction of highways, railways, airports, and other surface facilities.

Highway and Transportation Engineering. Location, design, construction, and maintenance of various types of transportation facilities, roads and streets, including material, surveys, plans, specifications, economics, financing, and administration.

Hydraulic and Hydrological Engineering. The application of the fundamental principles of hydraulics and hydrology to the optimum development of surface water and groundwater resources for various water uses. The area includes the study of flood prediction and flood control, pollutant discharges and other diffusion phenomena, transients in pipe lines and channels, coastal engineering, and hydraulic design of involved structures.

Municipal Engineering. The design, construction, maintenance, and management of the water, wastes, and transportation systems of the urban population along with consideration of the many other factors which affect the urban environment so as to maintain safe and wholesome physical conditions within the city.

Structural Engineering. The theory, analysis, design, and construction of structures such as bridges, buildings, chimneys, tanks, and towers, involving the use of steel, reinforced concrete, aluminum, timber, and other materials; studies of inelastic behavior of materials and structures; studies of dynamic forces and their effects on structures.

Facilities

The Civil Engineering Department has its departmental offices in the G. G. Brown Building.

The George Granger Brown Building on the North Campus houses construction engineering and management laboratory, the structural research laboratory, hydraulic engineering laboratory, the F.E. Richart Soil Dynamics Laboratory, and the William S. Housel Civil Engineering Materials Laboratory and facilities for transportation and large wave tank, wave-making machine, and the instruments required for the study of problems arising from the action of water along shores, is located in the east wing of this building.

The Engineering Building IA, a wing of the G. G. Brown Building, contains laboratories for Environmental Engineering. Equipment is available for both teaching and research in these laboratories.

The Walter E. Lay Automotive Laboratory houses the surveying instrument room.

Required Program *Courses*	*Hrs.*	**Sample Schedule** *Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.) See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences *(Note A)*	17	-	4	-	-	4	4	4	1
Advanced Mathematics (3 hrs.) (Note B)									
Elective	3	-	-	-	-	3	-	-	-
Engineering Sciences (20 hrs.)									
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mechanics	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Introduction to Dynamics	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Anal. and Electronics	3	-	-	-	3	-	-	-	-
Mech. Eng. 235, Thermodynamics I *(Note C)*	3	-	-	-	3	-	-	-	-
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Civ. Eng. 325 (Mech. Eng. 325), Fluid Mech.	3	-	-	-	-	3	-	-	-
Program Subjects (17 hrs.)									
Civ. Eng. 303, Computational Methods	3	-	-	-	3	-	-	-	-
Civ. Eng. 312, Theory of Structures	3	-	-	-	-	3	-	-	-
Civ. Eng. 315, Design of Structures	3	-	-	-	-	-	3	-	-
Civ. Eng. 400, Contracts and Engr. Legal Rel.	2	-	-	-	-	-	-	2	-
Civ. Eng. 421, Hydraulics	3	-	-	-	-	-	3	-	-
Civ. Eng. 445, Eng. Properties of Soil	3	-	-	-	-	3	-	-	-
Technical Electives (20 hrs.) (Note D)	20	-	-	-	-	-	8	9	3
Technical Electives must include 5 of the following: Civ. Eng. 232, Construction Surveying; Civ. Eng. 351, Civil Eng. Materials; Civ. Eng. 405, Civil Eng. Systems; Civ. Eng. 413, Design of Metal Structures or Civ. Eng. 415, Design of R/C Structures; Civ. Eng. 420, Hydrology; Civ. Eng. 470, Transportation Engineering; Civ. Eng. 480, Environmental Chemodynamics; Civ. Eng. 485, Water Supply & Waste-water Eng.									
Technical Concentration (9 hrs.) (Note E)	9	-	-	-	-	-	-	3	6
Free Electives (3 hrs.)	3	-	-	-	-	-	-	-	3
Total	**128**	**16**	**14**	**14**	**16**	**16**	**18**	**18**	**16**

Requirements

Candidates for the degree Bachelor of Science in Engineering (Civil Engineering)—B.S.E. (C.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms. Electives should be carefully planned in consultation with advisers so that the complete program includes the equivalent of two terms of engineering science and one term of engineering design.

Note A. At least three hours must be in economics.

Note B. The elective in advanced mathematics may be satisfied with any course in mathematics, probability, statistics, operations research, mathematical programming, or computer science that has the equivalent of at least Math. 215 as a prerequisite.

Note C. Chem. Eng. 230(3) may be substituted for Mech. Eng. 235 (3).

Note D. The technical electives are meant for the professional development of the student. These electives will be selected by the student in conference with the adviser to meet individual needs.

Note E. The technical concentration will be composed of an approved sequence of subjects in some area of civil engineering practice and appropriate electives. As early as possible a student should select a particular area of interest and confer with the adviser in that field regarding the electives required for the completion of the program. Groupings of subjects which meet the technical concentration requirements are available in the following areas:

1) Construction Engineering—Adviser: Professor Carr
2) Environmental Engineering—Adviser: Professor Weber
3) Geotechnical Engineering—Adviser: Professor Gray
4) Highway and Transportation Engineering—Adviser: Professor Tons
5) Hydraulic and Hydrological Engineering—Adviser: Professor Wright
6) Municipal Engineering—Adviser: Professor Glysson
7) Structural Engineering—Adviser: Professor Hanson

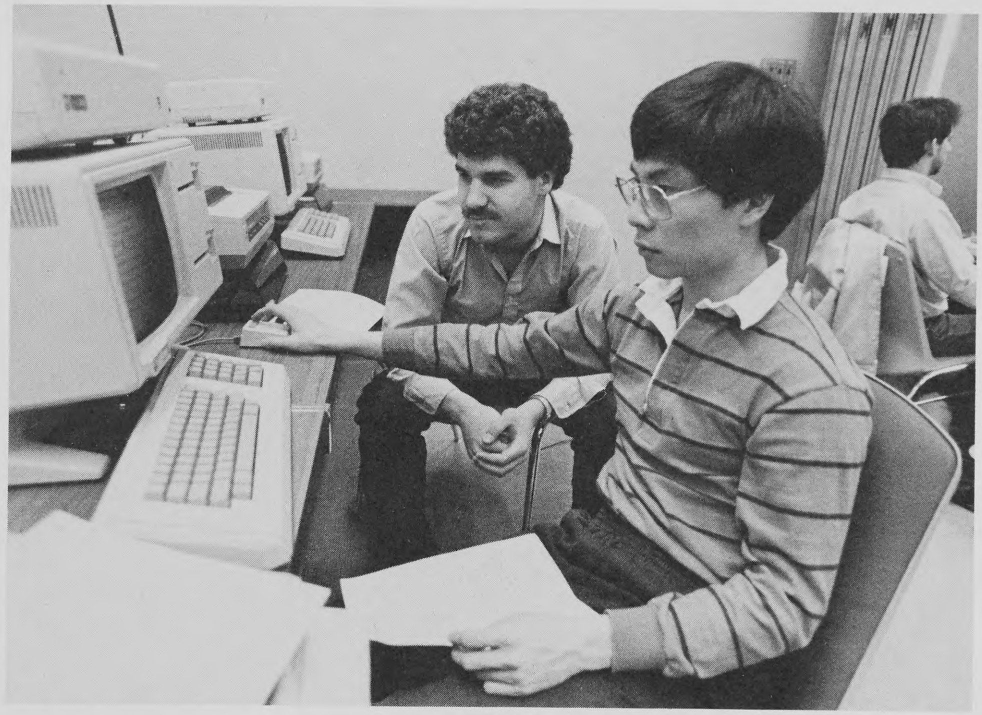
Electrical Engineering and Computer Science

Modern electrical engineering is a broad and diverse field; the computer science and engineering area has achieved its full role as a profession and rivals all engineering fields in terms of its impact on society. The expanding roles of both electrical and computer engineers and scientists in today's society reflect the variety and scope of these exciting professions. In recognition of the distinct qualifications required of engineers and scientists entering these fields, the Electrical Engineering and Computer Science Department offers three undergraduate programs: The electrical engineering program leads to a Bachelor of Science in Engineering (Electrical Engineering)—B.S.E. (E.E.); the computer engineering program leads to a Bachelor of Science in Engineering (Computer Engineering)—B.S.E. (Comp. E.) and the computer science program leads to a Bachelor of Arts or Bachelor of Science degree in Computer Science (consult the LSA *Bulletin*).

Throughout the program students work with modern laboratory equipment and are exposed to the most recent analytical techniques and technological developments in the field. Association with outstanding faculty, most of whom are actively engaged in research or professional consulting, serves to acquaint students with the opportunities and rewards available to practicing electrical or computer engineers and scientists. If further specialization and a high degree of competence in a particular area is desired, students may be encouraged to seek an advanced degree. The advanced degrees available are described under Graduate Studies.

Facilities

The facilities of the Electrical Engineering and Computer Science Department include instructional laboratories in Electrical Engineering and Computer Science and the following laboratories devoted primarily to research: communications and signal processing, radiation, solid-state electronics, systems engineering, bioelectrical science, electro-optics, computing research, robotics, vehicular electronics, and program in technology assessment, advanced computer architecture, computer vision and cognitive science, and artificial intelligence. The instructional laboratory facilities available to the student provide access to many types of digital computers, logic design modules, and modern instrumentation for the design of discrete analog and digital circuits and systems. In addition, there are specialized facilities for communications and signal processing, robotics, integrated circuit and solid



state device fabrication, image processing, electromagnetics and optics, VLSI design, distributed systems, computer vision, and artificial intelligence.

Computer Engineering

Chief Program Adviser:
Professor Y. C. Lee
Student Counseling
Office: 3115 EECS Building
(313) 936-2971

Academic Counselor
Marion Frost
Student Counseling
Office: 3415 EECS Bldg.
(313) 747-1763

CSE UNDERGRADUATE—Computer Engineering Option (College of Engineering Degree)

The program in Computer Engineering provides the student with a broad and well-integrated background in the concepts and methodologies that are needed for the analysis, design, and utilization of information processing systems. Although such systems are popularly called "computers," they involve a far wider range of disciplines than merely computation, and the Computer Engineering Program is correspondingly broad. A set of required technical courses (along with the college-wide requirements of the first two years) gives the essential material in electronic circuits, digital logic, discrete mathematics, computer programming, data structures, and other topics. Following completion of this work, the student is free to select courses in a wide range of subject areas. These include digital systems design, software engineering, operating systems, compiler construction, database management, computer vision, computer graphics, robotics, computer-aided design, computer components and subsystems, fault-tolerant computation, control engineering, artificial intelligence, and computer networking, among others. A broad selection from these areas is recommended for most undergraduate students with specialization in particular areas being more typical of graduate programs of study.

This program is accredited by ABET.

Requirements

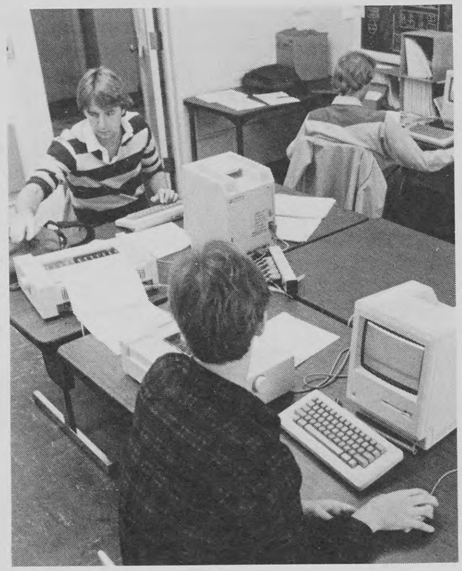
Candidates for the degree Bachelor of Science in Engineering (Computer Engineering)—B.S.E. (Comp. E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Counseling

Appointments with program advisers are scheduled at 3415 EECS Building or by calling 763-2305.

I. Subjects Required by all Engineering Programs (59)

Mathematics (16 hrs.)
  Math 115, 116, 215, and 216
Physics (8 hrs.)
  Phys 140, with Lab. 141;
  Phys 240, with Lab. 241
Chemistry (5 hrs.)
  Chem 123 or 124, and Lab 125
Engineering (3hrs.)
  Engr 103 or Engr 104, computing
English (4hrs.)
  English 125, introduction to composition



Required Program

Courses	Hrs.	Sample Schedule *Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all engineering programs (56 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
*Engineering 104, Computing	3	3	-	-	-	-	-	-	-
*Chemistry 123 or 124, and 125 Lab.	5	3	2	-	-	-	-	-	-
Physics 140, with Lab. 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (see page 17)	17	3	7	-	4	3	-	-	-
Program Subjects (43 hrs.)									
EECS 213, Network Anal. *(Note A)*	4	-	-	4	-	-	-	-	-
EECS 270, Intro. to Logic Design	4	-	-	-	4	-	-	-	-
EECS 280, Computer Science I	4	-	-	4	-	-	-	-	-
EECS 300, Math. Meth. Sys. Anal.	3	-	-	-	-	3	-	-	-
EECS 303, Algebraic Found. Comp. Eng.	3	-	-	-	3	-	-	-	-
EECS 313, Electronic Circuits	4	-	-	-	-	-	4	-	-
EECS 370, Microcomputer-Based Systems I	4	-	-	-	-	4	-	-	-
EECS 380, Computer Science II	4	-	-	-	-	4	-	-	-
EECS 381, Assembly Language Programming	3	-	-	-	-	-	3	-	-
EECS 401 or Stats 412, Probablistic Methods	3	-	-	-	-	-	3	-	-
EECS 351 or 360, Dynamic Sys. or Signal Proc.	4	-	-	-	-	-	-	4	-
EECS 400 or Math. 419, Lin. Spcs. & Matrix Theo	3	-	-	-	-	3	-	-	-
Technical Electives (20 hrs.) (Note A)	20	-	-	-	-	-	3	10	7
Free Electives (9 hrs.)	9	-	-	-	-	-	-	3	6
Total	**128**	**17**	**17**	**16**	**15**	**17**	**13**	**17**	**16**

***When Chem. 124 is taken, take Chem. 125 in Term 1 and Eng. 104 in Term 2.**

Note A. Must include at least 16 hours at the 300 level or higher. Must include at least 11 hours of courses whose primary orientation is in computer-related areas such as those listed on succeeding pages, and must also include at least 6 hours of courses whose primary orientation is not in computer-related areas. Electives should be carefully planned in consultation with advisors so that the complete program includes the equivalent of two terms of engineering science and one term of engineering design.

Humanities and Social Science (17hrs.)
Any nonperformance courses listed in either Humanities or Social Science in L.S.A. *Bulletin* must include a sequence of at least 2 courses elected from the same area, must include at least 6 hrs. in Humanities.
Technical Communications (3 hrs.)
Senior writing requirement

II. CE Program Required Subjects (39 hrs.)

Network and Circuits Analysis (8 hrs.)
EECS 213 and 313
Logic Design and Microcomputer-based Systems (8 hrs.)
EECS 270 and 370
Computer Science I and II (7 hrs.)
EECS 280 and 380
Mathematical Methods and Algebraic Foundations (6 hrs.)
EECS 300 and 303
Assembly Language (3 hrs.)
EECS 381
Dynamic Systems or Signal Processing (4 hrs.)
EECS 351 or 360
Probabilistic Methods (3 hrs.)
EECS 401 or STAT 412
Linear Spaces and Matrix Theory (3 hrs.)
EECS 400 or MATH 419

III. Non-Computer Oriented Technical Electives (Min. 6 hrs.)

Must include at least 6 hours of courses whose primary orientation is not in computer-related areas. Courses can be selected with the approval of the counselor from EECS, IOE, ME, NE, AERO, AO & SS, PHYS, and MATH.

IV. Computer Oriented Technical Electives (Min. 14 hrs.)

A broad selection from the following areas is recommended.
Artificial Intelligence
EECS 492, 546, 547, 591, 592, and 595
Communications Signals and Systems
EECS 351, 453, 455, and 456
Computer Graphics
EECS 487 and 588
Computer Vision and Image Processing
EECS 442, 472,542, and 543
Control Systems
EECS 360 and 460
Data Structures and algorithms
EECS 480, 584, amd 585
Database Management Systems
EECS 480 and 586
Digital Computer Design
EECS 373, 413, 474, 478, 570, and 577
Networks
EECS 557
Operating Systems
EECS 482 and 582

Programming Languages and Compilers
EECS 483, 485, 486, and 583
Software Engineering
EECS 481 and 581
Theoretical Computer Science
EECS 476, 574, and 575
Robotics
EECS 467 and 567
VLSI
EECS 427 and 627

Additional Computer Oriented Technical Electives

Industrial and Operations Engineering
IOE 436, 471, 474, 511, 512, 564, 573, 574, 575, and 578
Mathematics
MATH 371, 471, 571, and 572

V. Free Electives (9 hrs.)

Any courses except those which substantially duplicate courses already taken.

Electrical Engineering

Program Adviser:
Assoc. Prof. E. L. McMahon
(Chief Adviser)
Student Counseling
Office: 3415 EECS Building
(313) 763-2305

Academic Counselor:
Barb Toma
Student Counseling
Office: 3415 EECS Building
(313) 747-1762

The program in Electrical Engineering is designed to provide students with a fundamental background in the basic theoretical concepts and technological principles that constitute the foundations of modern electrical engineering and, at the same time, the opportunity to emphasize subject areas in which they have a particular interest. The curriculum requirements are flexible enough so that students, with the assistance and approval of the program adviser, may design an academic program to achieve a variety of objectives. Furthermore, students may emphasize the applied and experimental aspects of electrical engineering or may concentrate on subjects requiring an analytical or theoretical treatment.

Ten areas of concentration in which electrical engineering students may specialize are listed under Technical Electives. Electives should be carefully planned in consultation with advisers so that the complete bachelor's program includes the equivalent of two terms of engineering science and one term of engineering design. Detailed programs for each major area are available at the counseling office.

This program is accredited by ABET.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Electrical Engineering)—B.S.E. (E.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Students may find that it is necessary to extend their schedule to 8½ or nine terms.

Required Program

Sample Schedule

Courses	*Hrs.*	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125 Intro. Composition	4	4	-	-	-	-	-	-	-
*Engineering 103, Computing	3	3	-	-	-	-	-	-	-
*Chemistry 123 or 124, and 125	5	3	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
*aHumanities and Social Sciences (see page 37)	17	3	6	5	-	-	-	-	3
Related Technical Subjects (12-13 hrs.)									
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Physics 242, General Physics III	3	-	-	-	3	-	-	-	-
Group Requirements (6-7 hrs.)	6-7	-	-	-	-	-	-	6	-
One course from each of two of the following groups:									
A. Chem. 365, Princ. Phys. Chem. (4)									
Mech. Eng. 231, Classical & Statistical Thermodyn. (4)									
Physics 406, Stat. & Thermal Physics (3)									
B. Mech. Eng. 240, Intro. to Dynamics (3)									
Physics 401, Intermediate Mechanics (3)									
C. EECS 401, Probabilistic Methods in Eng. (3)									
Stat. 412, Intro. to Prob. & Stat. (3)									
Program Subjects (31 hrs.)									
EECS 216, Circuit Analysis	4	-	-	-	4	-	-	-	-
EECS 270, Intro. to Logic Design	4	-	-	-	4	-	-	-	-
EECS 300, Math Methods in Sys. Anal.	3	-	-	-	-	3	-	-	-
EECS 316, Circuits and Systems	3	-	-	-	-	3	-	-	-
EECS 317, Digital Electronics	3	-	-	-	-	3	-	-	-
EECS 318, Analog Electronics	4	-	-	-	-	-	4	-	-
EECS 320, Intro. to Semiconductor Device Theory	3	-	-	-	-	-	3	-	-
EECS 331, Electromag. Fields I	4	-	-	-	-	4	-	-	-
EECS 332, Electromag. Fields II	3	-	-	-	-	-	3	-	-
Laboratory Requirement: (2-4 hrs.)	2-4	-	-	-	-	-	-	2	-
Any EECS hardware-oriented laboratory course									
Technical Electives (18-21 hrs.)	21	-	-	-	-	-	6	6	9
All Technical Electives (either EECS or non-EECS) must be 300 level or higher (exception EECS 280, 282, or 283). No more than 4 credit hours for independent study courses are permitted.									

Courses in this category are to be selected in consultation with the program adviser and must include a minimum of 12 hours in EECS courses and a minimum of 3 hours in non-EECS courses. Areas of concentration in which courses appropriate to the student's program may be selected include:

1. Circuits and Electronics
2. Bioelectrical Sciences
3. Applied Control and Robotics
4. Applied Electro-Magnetics
5. Digital Circuits and Applications
6. Solid-State Devices and Integrated Circuits
7. Computer Circuits and Architecture
8. Electro-Optics
9. Communications and Signal Processing
10. Measurements and Instrumentation

	Hrs.	1	2	3	4	5	6	7	8
**bFree Electives (6hrs.)*	6	-	-	-	-	3	-	-	3
Total	**128**	**17**	**16**	**16**	**15**	**16**	**16**	**17**	**15**

*When Chem. 124 is taken, take Chem. 125 in Term 1 and Eng. 103 in Term 2.
**a* Eight hours of Foreign Language, 200 level or above is acceptable.
**b* ROTC 300-4— level courses acceptable as free electives.

Engineering Science—Administered by the Department of Mechanical Engineering and Applied Mechanics

Professor R. A. Scott
118 W. E. Lay Auto Lab
(313) 764-4254

Rapid and diverse scientific and technological advances have created a wide variety of career opportunities for graduates whose education has provided depth and breadth of understanding of the sciences, as well as an engineering problem-solving capability.

The Engineering Science Program is administered jointly by the Department of Mechanical Engineering and Applied Mechanics and by a committee of faculty members from other departments within the College. The interdisciplinary program combines a strong background in the engineering sciences with a specialization in a subject area of particular interest to the student. Each of the many possible areas of specialization requires electives in science and mathematics, as well as in engineering. Program counselors will help in the selection of courses that best fulfill the student's academic objectives. Each student, however, is expected to assume the basic initiative and responsibility in developing his/her own program.

Subject areas frequently chosen include applied mechanics, applied mathematics, and bioengineering. Broadly speaking, mechanics refers to the branch of physics that deals with the action of forces on rigid and deformable solids and on liquids and gases. The term "applied mechanics" designates this area of science when it is related and applied to engineering. Applied mathematics combines the techniques of mathematics with the sciences of physics and engineering, to enable the student to better understand and analyze mathematical models of technical and social phenomena. Bioengineering is the application of the principles of engineering to the life sciences. Living systems are sustained by complex but ordered interplay of chemical, electrical, and mechanical phenomena. Bioengineers are concerned with technological understanding of these systems—their function, performance, and repair. The bioengineering program outlined here satisfies the course requirements for admission to graduate study in bioengineering (see page 53).

Requirements

Candidates for the degree Bachelor of Science in Engineering (Engineering Science)—B.S.E. (Eng. Sci.)—must complete the required program. *The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or 9 terms.*

Required Program / **Sample Schedule**

Courses	Hrs.	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (58 hrs.) See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103—Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 214	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	19	-	6	3	-	4	6	-	-
Program Subjects (34 hrs.)									
Mechanics									
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mech.	3	-	-	3	-	-	-	-	-
Mech 240, Intro. to Dynamics	3	-	-	-	3	-	-	-	-
Mech. Eng. 324, Fluid Mechanics	4	-	-	-	-	4	-	-	-
Electrical Engineering Science									
EECS 213, Network Analysis	4	-	-	-	4	-	-	-	-
EECS 313, Electric Circuits	4	-	-	-	-	4	-	-	-
Electromagnetics or Electrical Biophysics (Phys. 405 or EECS 417)	3	-	-	-	-	-	-	3	-
Materials, Thermal, and Chemical Sciences									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials	3	-	-	3	-	-	-	-	-
Mech. Eng. 231, Classical and Stat'l. Thermodyn.	4	-	-	-	4	-	-	-	-
Heat Transfer, Mech. Eng. 371	4	-	-	-	-	-	-	4	-
Technical Electives (36 hrs.)									
Engineering electives (upper level)*	16	-	-	-	-	-	4	6	6
Electives in Advanced Mathematics or Science	12	-	-	-	-	4	4	-	4
Other (Eng., Sci., or Math.)	8	-	-	-	-	-	2	3	3
Total	**128**	**16**	**16**	**17**	**15**	**16**	**16**	**16**	**16**

*This must include a Senior Design Course.

Outlined below are typical programs of study in three major subject areas. Courses of study emphasizing other fields of engineering science can be arranged with the help of a faculty adviser.

Applied Mathematics

Program subjects: 34
EECS 314 (3), 315 (1), 331 (4), 457 (3); Mat. Sci. & Eng. 250 (3); Mech. Eng. 110 (2), 210 (3), 231 (4), 240 (3), 324 (4), 371 (4)
Math. Elec.: 20
(mathematics-equivalent courses may be substituted): Math. 417 (3), 450 (4), 454 (3), 455 (4), 471 (3); Stat. 425 (3)
Eng. elec.: 16
upper level courses

Applied Mechanics

Program subjects: 34
EECS 314 (3), 315 (1), 331 (4), 457 (3); Mat. Sci. & Eng. 250 (3); Mech. Eng. 110 (2), 210 (3), 231 (4), 240 (3), 324 (4), 371 (4)
Eng. elec.: 16
Aero. Eng. 314 (4); Appl. Mech 402 (3), 413 (3), 422 (3), 440 (3)
Sci. and Math. elec.: 12
Math 350 (3), Eng. 303, Math. 454 (3); Math. 555 (3) or Eng. 508 (3)
Other elec. in eng., sci., math. 8

Bioengineering

Program subjects (engineering): 34
EECS 210 (4), 310 (3), 458 (4); Mat. Sci. & Eng. 250 (3); Mech. Eng. 110 (2), 210 (3), 231 (4), 240 (3), 324 (4), 371 (4)
Elec. in Sci. and Math.: 20
Chem. 126 (3), 225 (3); Biol. 152 (4), Biol. elec. (6); Math. elec. (4)
Eng. elec. 16

The technical electives are chosen in consultation with a faculty advisor so they form a coherent sequence toward reaching the student's professional goal. Each program must include one term of engineering design. The electives in science may be chosen from the physical and/or biological sciences, depending on the student's interests. At least one course must be elected in advanced mathematics. The 16 hours of engineering electives are to be courses numbered 300 and above. The technical electives must include a minimum of two credit hours in laboratory work in engineering or science. Sample elective sequences are available from faculty advisors.

Industrial and Operations Engineering

Program Adviser:
Professor Tony C. Woo
242 Industrial and
Operations Engineering
Building
(313) 763-0455

Industrial and Operations Engineering is concerned with the efficiency in which work is performed by machines, people, and computers. An industrial engineer is concerned with the design, improvement, and installation of integrated systems of people, materials, and equipment, drawing upon specialized skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design, for specifying, predicting, and evaluating the results to be obtained from such systems. About one half of the program of study for the B.S.E. degree consists of basic science and engineering courses, accompanied by studies in the humanities. The rest of the work is in areas such as management engineering, computers and information systems, human performance and safety engineering, operations research, and manufacturing engineering.

This program is accredited by ABET.

Facilities

As an aid to the student's education, the department has well-equipped laboratories in the following areas: human performance, industrial systems, plant flow analysis, and computation.

In addition to the facilities on campus, the department has excellent relationships with various local firms around the Ann Arbor-Detroit Area so that students are exposed to actual operating industrial, service, and other business systems.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Industrial and Operations Engineering)—B.S.E. (I.&O.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Required Program

Sample Schedule

Courses	*Hrs.*	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124	3	3	-	-	-	-	-	-	-
*Chemistry 125	2	-	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication 498	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences	17	3	3	-	-	4	-	4	3
Related Technical Subjects (13 hrs.)									
Mech. Eng. 211, Intro to Solid Mech.	4	-	-	-	-	-	4	-	-
Mech. Eng. 235, Thermodynamics I	3	-	-	-	-	3	-	-	-
Mech. Eng. 252, Elem. of Mfg. Sys.	3	-	-	-	-	-	-	-	3
EECS 314, Circuit Analysis and Electronics	3	-	-	-	-	-	-	3	-
Program Subjects (36 hrs.)									
I.&O.E. 300, Mgmt. of Technical Change	3	-	-	-	3	-	-	-	-
I.&O.E. 310, Intro. to Optim. Methods	3	-	-	-	-	3	-	-	-
I.&O.E. 315, Stochastic Industrial Proc.	3	-	-	3	-	-	-	-	-
I.&O.E. 333, Human Performance	3	-	-	3	-	-	-	-	-
I.&O.E. 334, Human Performance Lab	1	-	-	1	-	-	-	-	-
I.&O.E. 365, Engineering Statistics	4	-	-	-	4	-	-	-	-
I.&O.E. 373, Data Processing	4	-	-	-	-	4	-	-	-
I.&O.E. Senior Design Course (See Note)	3	-	-	-	-	-	-	3	-
I.&O.E. Electives (12 hrs., see Note below)	12	-	-	-	-	3	6	-	3
Technical Electives (15 hrs.)									
(6 hrs. must be I.&O.E.)	6	-	-	-	3	-	-	-	3
(9 hrs. must be non-I.&O.E.)	9	-	-	-	-	-	3	3	3
Free Electives (8 hrs.)	8	-	3	-	3	-	2	-	-
Total	**128**	**17**	**16**	**15**	**17**	**17**	**15**	**16**	**15**

*Chemistry 125 cannot be elected in same term as Chemistry 123.

Note on Departmental I.&O.E. Electives:
Within the 12-hour elective requirement, the student must elect at least one course from four of the following five I.&O.E. core groups shown below:

1. I.&O.E. 441 (Production and Inventory Control) or I.&O.E. 447 (Facility Planning)
2. I.&O.E. 451 (Engineering Economy)
3. I.&O.E. 463 (Work Measurement and Prediction)
4. I.&O.E. 465 (Experimental Design) or I.&O.E. 466 (Statistical Quality Control)
5. I.&O.E. 473 (Information Processing Systems) or I.&O.E. 474 (Simulation)

Note on I.&O.E. Senior Design Requirement:
During the senior year, each student must elect one of the following design courses:

1. I.&O.E. 424 (Special Projects in Production and Service Systems.
2. I.&O.E. 481 (Special Projects in Hospital Systems)
3. I.&O.E. 499 (Senior Design Projects)
4. Other I.&O.E. courses satisfying the design requirement, if approved by the undergraduate program advisor and with the consent of the course instructor.

Materials Science and Engineering

Program Adviser:
Professor W. C. Bigelow
2168 Dow Building
(313) 764-3321

Materials scientists and engineers specialize in the development, production, and utilization of the metallic, ceramic, and polymeric materials that are employed in all fields of technology.

Engineering materials have been crucial to the development of civilization since the dawn of history as evidenced by the naming of the Stone Age, the Bronze Age, and the Iron Age for the most advanced material available then for constructing tools and weapons. More recently, materials scientists and engineers have developed a variety of important materials to meet the needs of our modern technological society, including: high temperature superconductors; ultra-high-purity semiconductor materials for solid state electronic devices; high-strength alloys for use at the very high temperatures encountered in jet and rocket engines; strong, light alloys for aerospace applications; specialized glasses and ceramics having high thermal, mechanical, and chemical stability for use in the chemical industry; and a host of polymeric materials which are replacing metal, glass, wood, and natural fibers in dozens of applications.

The role of materials scientists and engineers in the future promises to be even more important and challenging than in the past. It is already widely recognized that we are facing a crucial energy shortage. It is less widely appreciated, but equally important, that the supplies of copper, lead, zinc, nickel, tin, manganese, chromium, and a number of other important materials are as limited as those of petroleum and natural gas.

New processes that will consume less energy and reduce pollution must be developed for producing all types of materials. To conserve our dwindling natural resources, methods must be developed for recycling many materials that are now discarded. New materials will be needed to replace current materials that are being depleted. In addition, new and better materials will be required to meet the needs of our advancing technology. Materials scientists and engineers of the future will continue to be at the forefront of all of these important and challenging activities.

The program in Materials Science and Engineering should be particularly attractive to students who enjoyed their introductory courses in chemistry and physics. Information from these basic sciences is used throughout this program to explore the chemical bonding, atomic and molecular arrangements, crystal structures, phase distributions, and microstructures of the various types of materials and to understand how these structural characteristics determine their mechanical and physical properties.

Students may elect one of three options within this curriculum: materials, metallurgy, or electronic materials.

The beginning courses are the same for all options and, in addition to exploring the fundamental principles described above, provide laboratory experience with basic processing operations such as melting, casting, sintering, rolling, and heat treating, and with the basic techniques used for studying structures and measuring properties. At the upper class level the materials option allocates roughly equal time for general studies of the selection, control, and utilization of metals, ceramics, and polymers. The courses in the metallurgy option cover in detail all phases of metallurgy including extractive methods, mechanical processing, heat treating to control structure and properties, and the selection and utilization of metals, while the electronic materials option deals with the structure, properties, and processing of materials for electronics applications.

Laboratory work provides experience with modern research equipment such as X-ray diffraction units, electron microscopes, and X-ray microprobes and fluorescence analyzers. Students become familiar with the laboratory techniques for metallographic examination, heat treatment, and property testing.

For a well-rounded technical education, materials scientists and engineers require a sound basis in thermodynamics, mechanics, electrical circuits, and other engineering science subjects plus advanced courses in mathematics, physics, and chemistry. In addition, they are urged to elect significant courses in the humanities and social sciences to provide the best possible basis for future enjoyment of, and participation in, the cultural, political, economic, and social activities of their communities.

This program is accredited by ABET.

Combined Programs

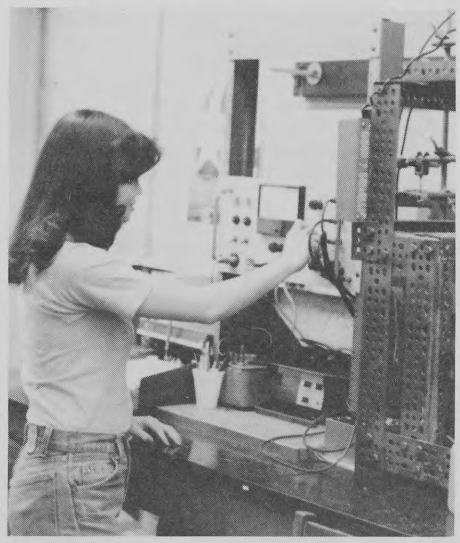
Materials are critically involved in all fields of engineering; therefore, a B.S.E. degree in materials science and engineering can be advantageously combined with a B.S.E. degree in most other fields of engineering. Students interested in developing such double degree programs should consult the program advisers in both programs as early as possible to work out optimum combinations of courses.

Facilities

The facilities for the programs in materials science and engineering are housed, primarily, in the Dow Building. These include laboratories equipped for basic studies of the structures and properties of metals, ceramics, and polymers; special purpose laboratories for studies of cast metals, electrochemical and corrosion processes, high temperature materials, crystal plasticity, and liquid metals systems; and instrument laboratories containing X-ray diffraction and fluorescence units, optical microscopes, transmission and scanning electron microscopes, an electron microprobe analyzer, and precision mechanical testing equipment.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Materials Science and Engineering)—B.S.E. (Matl. Sci. & E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedules to 8½ or nine terms.



Required Program

Courses	*Hrs.*	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Science, including Economics	17	-	3	3	3	3	3	2	-
Free Electives (6 hrs.)	6	-	2	-	2	-	2	-	-
Science and Technical Subjects (31 hrs.)									
Chemistry 126, Gen. and Inorganic Chem.	3	-	3	-	-	-	-	-	-
Chemistry 365, Prin. of Physical Chem.	4	-	-	-	-	-	4	-	-
Mech. Eng. 211, Intro. to Solid Mech.	4	-	-	4	-	-	-	-	-
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Anal. and Electronics	3	-	-	-	3	-	-	-	-
EECS 315, Cct. Anal. and Electronics Lab.	1	-	-	-	1	-	-	-	-
Mech. Eng. 470 or Chem. Eng. 342, Heat Transfer	3	-	-	-	-	-	-	3	-
Science and Technical Electives*	10	-	-	-	-	4	-	-	6
Program Subjects (35 hrs.)									
Option 1. Materials									
Mat. Sci. & Eng. 351, Structure and Props. of Matls.	4	-	-	-	-	4	-	-	-
Mat. Sci. & Eng. 371, Engineering Alloy Systems	4	-	-	-	-	-	4	-	-
Mat. Sci. & Eng. 430, Thermodynamics	4	-	-	-	-	-	-	4	-
Mat. Sci. & Eng. 450, Eng. Physical Ceramics	4	-	-	-	-	-	4	-	-
Mat. Sci. & Eng. 456, Ceramics-Proc. and Char.	2	-	-	-	-	-	-	2	-
Mat. Sci. & Eng. 457, Fund. Polymeric Matls.	3	-	-	-	-	3	-	-	-
Mat. Sci. & Eng. 480, Engr. Design	3	-	-	-	-	-	-	3	-
Elect 2: Mat. Sci. & Eng. 451(4), 452(3), 472(3)	6	-	-	-	-	-	-	-	6
Program Electives	5	-	-	-	-	2	-	-	3
Total	**128**	**16**	**16**	**15**	**16**	**16**	**17**	**17**	**15**
Option 2. Metallurgy									
Mech Eng. 325 or Chem. Eng. 341, Fluid Mech.	3	-	-	-	-	-	-	3	-
Mat. Sci. & Eng. 351, Structure and Props of Matls.	4	-	-	-	-	4	-	-	-
Mat. Sci. & Eng. 371, Engineering Alloy Systems	4	-	-	-	-	-	4	-	-
Mat. Sci. & Eng. 430, Thermodynamics	4	-	-	-	-	-	-	4	-
Mat. Sci. & Eng. 480, Engr. Design	3	-	-	-	-	-	-	3	-
Mat. Sci. & Eng. 489, Met. Process Design	4	-	-	-	-	-	-	-	4
Elec 2: Mat. Sci. & Eng. 423(3), 472(3), 475(3)	6	-	-	-	-	-	3	-	3
Program Electives	7	-	-	-	-	4	-	-	3
Total	**128**	**16**	**16**	**15**	**16**	**15**	**16**	**18**	**16**
Option 3. Electronic Materials									
Mat. Sci. & Eng. 351, Structure and Props. of Matls.	4	-	-	-	-	4	-	-	-
EECS 320, Solid State Devices	3	-	-	-	-	3	-	-	-
Mat. Sci. & Eng. 430, Thermodynamics	4	-	-	-	-	-	-	4	-
Mat. Sci. & Eng. 450, Engr. Phys. Ceramics	4	-	-	-	-	-	4	-	-
Mat. Sci. & Eng. 480, Engr. Design	3	-	-	-	-	-	-	3	-
EECS 422, Electronic Prop. of Semicond. Matls.	3	-	-	-	-	-	3	-	-
EECS 423, Solid-State Devices Lab.	2	-	-	-	-	-	-	2	-
Elect. 2: Mat. Sci. & Eng. 472(3) EECS 424 (3) 425 (2)	6	-	-	-	-	-	-	-	6
Program Electives	6	-	-	-	-	2	-	-	4
Total	**128**	**16**	**16**	**15**	**16**	**16**	**16**	**17**	**16**

Sample Schedule: *Term Enrolled* (columns 1–8)

*Must include Organic Chemistry for Materials Option.

Mechanical Engineering

Program Adviser:
Professor Klaus Borgnakke
307 Auto Lab
(313) 936-0432

Academic Counselor:
Susan J. Gow
2230 G.G. Brown
(313) 764-2530

The scope of activities of mechanical engineering includes all aspects of the mechanics of equipment and processes used in the rapidly developing technical era in which we live. Mechanical engineers play a major role in the national space program, in energy utilization and conservation, in solar energy, in the design of both conventional and nuclear power plants, in heating and air conditioning, refrigeration and cryogenics, in the transportation and automotive fields, and in the fields of automation, fluid machinery, production and processing machinery including the petroleum and chemical fields, and consumer goods and appliances

They have responsibility for research, design, development, testing, control, and manufacture in these many and diverse fields. Many mechanical engineering graduates assume positions of management, while others prefer a career along technical and professional lines.

Because a mechanical engineer might work in any one of these fields, an academic program has been planned that offers a challenging and basic education. It is designed to provide a knowledge of the basic physical sciences, and to encourage the development of ingenuity for the purpose of creating well-engineered solutions to technological problems.

A basic science program in physics, chemistry, and mathematics, an engineering science program in thermodynamics, fluid mechanics, heat transfer, solid mechanics, dynamics, materials, and electronics integrated with laboratory experiences in measurement, and studies in design and manufacturing, will prepare the student equally well for any of the fields of application. The program includes a number of both technical and non-technical electives that permit the student to undertake further studies in an area of particular interest. Technical electives may be grouped under one of three specialized technical option areas, Energy and Power, Manufacturing, or System/Design, or may be elected under a General option.

Students who do well in their undergraduate program are encouraged to consider graduate work, and may take some of their electives in preparation for graduate study. Information and assistance regarding fellowships and assistantships for graduate study may be obtained in the Office of the Department of Mechanical Engineering and Applied Mechanics.

This program is accredited by ABET.

Facilities

The laboratories of the Department of Mechanical Engineering and Applied Mechanics, located in the George Granger Brown and Walter E. Lay Automotive Laboratory buildings on the North Campus, provide facilities for both instruction and research.

The George Granger Brown Laboratory contains the thermodynamics, heat transfer, and fluid mechanics laboratories, a drop-tower for zero-g heat transfer studies and a large centrifuge for high-g investigations, a two-phase flow loop, holographic measurements laboratory, and thermal systems research. Also located in this building are the Calma-VAX CAD laboratory facility, bio-mechanics laboratory, robotics laboratory, the manufacturing processes and integrated manufacturing laboratories, and materials laboratories, which provide facilities for investigations in such areas as adaptive controls, welding, acoustic emission, brittle fracture, heat treating, plasticity, friction and wear, surface phenomena, and mechanical properties.

The Walter E. Lay Automotive Laboratory houses the mechanical analysis laboratory with a wide variety of electromechanical instrumentation and computers for the experimental analysis of dynamics of mechanical systems; the cavitation and multiphase flow laboratory for theoretical and experimental investigations into many aspects of such phenomena; the automatic controls laboratory for demonstrating and investigating principles and applications of control systems; the combustion laboratory with a gas chromatograph and an infrared spectrometer; and the facilities for automotive engineering, which include a number of well-instrumented test cells for reciprocating engines, a test cell for a small aircraft gas turbine, an automotive gas turbine installation, as well as a number of single cylinder engines.

Required Program

Courses	Hrs.	Sample Schedule: Term Enrolled 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216 +	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition +	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241 +	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences (to include a course in economics) (see page 17)	17	-	4	-	3	3	4	3	-
Advanced Mathematics (3 hrs.) (Note)									
Elective	3	-	-	-	-	3	-	-	-
Related Technical Subjects (20 hrs.)									
Mat. Sci. & Eng. 250, Prin. of Eng. Materials +	3	-	-	-	3	-	-	-	-
Mech. Eng. 101, Intro to CAD	2	-	2	-	-	-	-	-	-
Mech. Eng. 110, Statics +	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mechanics +	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Intro. to Dynamics +	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Anal. & Electronics	3	-	-	-	-	3	-	-	-
EECS 315, Cct. Anal. & Electronics Lab	1	-	-	-	-	1	-	-	-
Chem. 126 or Phys. 242	3	-	-	-	3	-	-	-	-
Program Subjects (32 hrs.)									
M.E. 236, Thermodynamics +	4	-	-	4	-	-	-	-	-
M.E. 251, Mech. Behav. of Solids +	3	-	-	-	-	3	-	-	-
M.E. 324, Fluid Mech. +	4	-	-	-	-	-	4	-	-
M.E. 340, Dynamics of Mech. Sys. +	4	-	-	-	-	4	-	-	-
M.E. 362, Mech. Design I +	3	-	-	-	-	-	3	-	-
M.E. 371, Heat Transfer	4	-	-	-	-	-	-	4	-
M.E. 381, Manuf. Proc.	3	-	-	-	-	-	3	-	-
M.E. 460, Mech. Design II	3	-	-	-	-	-	-	-	3
M.E. 461, Automatic Control	4	-	-	-	-	-	-	-	4
Option Area (15 hrs.) (see option requirements following)									
Technical Electives are included in Options	15	-	-	-	-	-	3	6	6
Free Electives (2 hrs.)	2	-	-	2	-	-	-	-	-
Total	**128**	**16**	**16**	**17**	**16**	**17**	**17**	**16**	**13**

Note: A mathematics course (other than Math. 216) that requires at least Math. 215 as a prerequisite. See Department for a listing of appropriate courses.

*These courses may be supplemented from time-to-time by additional courses. See the option adviser for current information. Limitation of six credit hours outside of Mechanical Engineering courses for Technical Electives in Options. Program of studies under options must be approved by the option adviser.

+Students must earn a C or better in prerequisite courses marked (+). However, one C- is permitted.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Mechanical Engineering)—B.S.E. (M.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Option Requirements

General Option	*Hrs.*
M.E. 336, Thermodynamics II	3
EECS 457, Instrumentation	3
Technical Electives (Including three advanced M.E. courses at the 400* level)	9
Total	15
Energy and Power Option	
M.E. 336, Thermodynamics II	3
Technical Electives (four courses from the following: M.E. 426,432, 436, 437, 474, 475, 478, 490, 496, 497)*	12
Total	15
Manufacturing Option	
At least one course from M.E. 482, M.E. 487	3 to 7
At least one course from M.E. 483, M.E. 488	3 to 6
Technical Electives (one to three courses from the following: M.E. 484, 490, M.S.&E. 371, 452, I.&O.E. 451)*	2 to 9
Total	15
Systems/Design Option	
M.E. 311, Strength of Materials	3
Technical Electives (four courses from the following: M.E. 424, 440, 442, 464, 483, 484, 488, 490, 498, A.M. 411, 412, 443)*	12
Total	15

Naval Architecture and Marine Engineering

Program Adviser:
Professor R. A. Yagle
210 Naval Architecture and Marine Engineering Building
(313) 764-9138

The program of study in naval architecture and marine engineering covers primarily the design of ship hulls and ship power plants. Such topics as the form, strength, stability and seakeeping qualities, internal arrangement, and resistance and propulsion characteristics of ship hulls are included. The various types of propelling machinery, such as conventional and nuclear steam plants and the several categories of internal combustion engines, are considered. Other subjects of concern are the economic aspects of ship design and ship operation, special platforms and other work systems of various types for operation in and on the ocean, pleasure boats and other small craft, high performance marine vehicles, ship model testing, maneuvering and other control considerations, propeller theory, vibration problems, and piping and electrical system analysis and design.

Since the design of a modern ship—or any marine system of whatever configuration or function—encompasses many engineering fields, graduates of this department are called upon to handle diverse professional responsibilities. It is therefore essential that the program include training in the fundamentals of the physical sciences and mathematics, as well as the engineering aspects of as broad and comprehensive an array of the elements that constitute ship design as possible. To provide the appropriate educational breadth, it is also desirable that as many courses in the humanities and social sciences, and other disciplines, as can be accommodated be elected. But the marine industry needs graduates with some specialization as well, and often students themselves wish to explore certain areas in greater depth than others. It is recognized that the undergraduate program cannot, in the time available, commensurately treat all these important considerations and graduate work therefore is encouraged.

Undergraduate students seeking the degree B.S.E. (Nav. Arch. & Mar. E.)—Bachelor of Science in Engineering (Naval Architecture and Marine Engineering)—must complete a series of program subjects. These include among others the four first courses in four areas of concentration that constitute the basic engineering educational interests and concerns of naval architecture and marine engineering. These four areas are: (1) Ship Strength, (2) Ship Resistance and Propulsion, (3) Ship Power Systems, and (4) Ship Dynamics. Among their technical electives all students must also select two of the second courses in these same four areas of concentration, plus another elective in one of these.

Students may earn an additional B.S.E. degree in aerospace engineering, mechanical engineering, or in several other branches of engineering under combined programs with the respective engineering departments. These combined programs allow substantial substitution of courses required in one regular program for those required in the other, and typically can be completed in one extra term.

The department is in constant touch with the country's ship design offices, shipyards, and ship operators, including the cognizant governmental agencies and organizations concerned with other phases of ocean development. It is therefore able to assist its graduates in obtaining positions in the marine industry.

A large ship model towing tank, complete with appropriate shops and instrumentation, are operated by the department for teaching and student and faculty research.

This program is accredited by ABET.

Requirements

Candidates for the degree Bachelor of Science in Engineering (Naval Architecture and Marine Engineering)— B.S.E. (Nav. Arch. & Mar. E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Required Program

Sample Schedule

Courses	*Hrs.*	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.) (see under "Minimum Common Requirements" page 15 for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	4	-	3	2	4	4	-
Advanced Mathematics (3 hrs.)									
Elective	3	-	-	-	-	-	-	3	-
Related Technical Subjects (22 hrs.)									
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Mech. Eng. 101, Intro to CAD	2	-	2	-	-	-	-	-	-
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mechanics	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Intro. to Dynamics	3	-	-	-	3	-	-	-	-
Mech. Eng. 235, Thermodynamics I	3	-	-	-	-	3	-	-	-
Mech. Eng. 325, (Civ. Eng. 325), Fluid Mech.	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Anal. and Electronics	3	-	-	-	-	3	-	-	-
Program Subjects (32 hrs.)									
Nav. Arch. 270, Ship Design I	3	-	-	3	-	-	-	-	-
Nav. Arch. 302, Static Stability of Marine Vehicles	3	-	-	-	3	-	-	-	-
Nav. Arch. 310, Ship Strength I	4	-	-	-	-	4	-	-	-
Nav. Arch. 320, Ship Resistance & Propulsion I	4	-	-	-	-	-	4	-	-
Nav. Arch. 330, Ship Power Systems I	4	-	-	-	-	4	-	-	-
Nav. Arch. 340, Ship Dynamics I	4	-	-	-	-	-	4	-	-
Nav. Arch. 380, Maritime Management I	4	-	-	-	-	-	4	-	-
Nav. Arch. 470, Ship Design II	3	-	-	-	-	-	-	3	-
Nav. Arch. 475, Design Project	3	-	-	-	-	-	-	-	3
Technical Electives (12 hrs.)									
These must include at least two of the second courses in the four areas of concentration— Nav. Arch. 410, Ship Strength II; Nav. Arch. 420, Ship Resistance & Propulsion II; Nav. Arch. 430, Ship Power Systems II; or Nav. Arch. 440, Ship Dynamics II	6	-	-	-	-	-	-	3	3
Plus another elective in one of these areas of concentration	3	-	-	-	-	-	-	-	3
Plus another elective	3	-	-	-	-	-	-	3	-
Free Electives (3 hrs.)	3	-	-	-	-	-	-	-	3
Total	**128**	**16**	**16**	**17**	**16**	**16**	**16**	**16**	**15**

Nuclear Engineering

Program Adviser:
Professor G. C. Summerfield
229 Mortimer E. Cooley Building
(313) 764-6364

Nuclear Engineering applies the basic sciences to the design and development of nuclear energy sources and to the beneficial application of nuclear radiation. Primary sources of nuclear energy are fission and fusion reactions and radioactive decay. Engineers involved in these activities require a broad background combining an extensive knowledge of basic principles from physics, chemistry, and other basic sciences, together with expertise in the engineering sciences and engineering design. Specific topics range from microscopic phenomena involving nuclear and atomic interactions through large scale engineering systems such as nuclear power plants. The Department of Nuclear Engineering has teaching and research programs in:

a) Nuclear reactor engineering including reactor theory, reactor design applications, nuclear power plant analysis, and reactor safety analysis;
b) Radiation effects including radiation detection, radiation damage, and nuclear measurements in medicine;
c) Materials studies using neutrons and ion beams;
d) Theoretical and experimental plasma physics and thermonuclear theory;
e) Radiation transport theory and applications;
f) Fluid flow and heat transfer phenomena related to reactor performance problems.

Nuclear engineers have many opportunities to apply their knowledge to topics that are at the forefront of technology. From studies of the safety of fission reactors through the development of future fusion energy devices, the field offers an exceptional set of interesting problems in research, design, and technical development.

This program is accredited by ABET.

Facilities

Special facilities available to nuclear engineering students include the following:

Reactor

2 megawatt open pool research reactor with pneumatic tube system
Neutron depth profiling facility
Single axis crystal neutron spectrometer and single rotor chopper

Required Program | **Sample Schedule**

Courses	*Hrs.*	*Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (57 hrs.)									
See under "Minimum Common Requirements," page 15, for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123, 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	18	-	6	4	3	-	3	2	-
Advanced Mathematics and Science (10 or 11 hrs.)									
Phys. 242, Gen. Phys. III	3	-	-	-	3	-	-	-	-
Math. 450, Adv. Math. for Eng. I	4	-	-	-	-	4	-	-	-
Math. 455, Boundary Value Probs. and Complex Var. or Math. 454	4-3	-	-	-	-	-	4	-	-
Related Technical Subjects (19 hrs.)									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials	3	-	-	-	-	3	-	-	-
Mech. Eng. 110, Statics *(NOTE)*	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mech.	3	-	-	3	-	-	-	-	-
Mech. Eng. 231, Classical & Stat. Thermodyn	4	-	-	-	4	-	-	-	-
EECS 314, Cct. Anal. and Electronics	3	-	-	-	-	3	-	-	-
EECS 315, Cct. Anal. and Electronics Lab	1	-	-	-	-	1	-	-	-
Mech. Eng. 325, Fluid Mechanics	3	-	-	-	-	3	-	-	-
Program Subjects (26 hrs.)									
Nuc. Eng. 311, Elements of Nuc. Eng. I	3	-	-	-	-	3	-	-	-
Nuc. Eng. 312, Elements of Nuc. Eng. II	3	-	-	-	-	-	3	-	-
Nuc. Eng. 315, Nuc. Instr. Lab	4	-	-	-	-	-	4	-	-
Nuc. Eng. 441, Fiss. Reactors and Power Plants I	4	-	-	-	-	-	-	4	-
Nuc. Eng. elective	9	-	-	-	-	-	-	3	6
Nuc. Eng. laboratory (above Nuc. Eng. 315)	3	-	-	-	-	-	-	-	3
**Technical Electives (8 hrs.)*	8	-	-	-	3	-	-	2	3
Free Electives (7 hrs.)	7	-	-	-	-	-	3	4	-
Total	**128**	**16**	**16**	**15**	**17**	**17**	**17**	**15**	**15**

NOTE: ME 211 and one credit hour of a technical elective can be substituted for ME 110 and ME 210.

*Electives should be carefully planned in consultation with a faculty adviser so that the complete program includes the equivalent of one term (16 hours) of engineering design.

Triple axis crystal neutron spectrometer
Hot laboratories and two hot caves with master slave manipulators
10,000 curie Cobalt-60 gamma source manipulators
Neutron radiography port
Neutron imaging facility
Helium profile spectrometer
Prompt gamma spectrometer

Michigan Ion Beam Laboratory
1.7 MV Tandem ion accelerator
2 MV Van de Graff ion accelerator for Rutherford backscattering
400 kV ion implanter
Dual source vacuum evaporator

Neutron Experimental Bay
150 kV Cockcroft-Walton accelerator used as 14 MeV neutron generator
Radiation spectroscopy equipment and fast neutron time-of-flight facility

Intense Energy Beam Interaction Laboratory
Michigan Electron Long Beam Accelerator (MELBA)
Intense relativistic electron-beam accelerators
TEA Co2 laser
Excimer laser
Ruby lasers
Duopigatron based ion-neutral beam accelerator
Holographic interferometry diagnostic
X-ray scintillator photomultiplier systems
z-pinch experiment
Laser-guided discharge experiment

Magnetic Mirror Laboratory
Michigan mirror machine (EECS)
High power microwave heating system
Super heterodyne microwave diagnostic

Radiation Detection
Measuring equipment including three microcomputer-based analysis systems
Photoneutron measurements laboratory with one-meter manganese bath calibration facility
Radiation imaging laboratory
Radiation solid state laboratory
Moessbauer spectrometer

Materials
Materials preparation laboratory including a single jet electropolisher and a metallograph
Stress corrosion cracking laboratory including a corrosion measurement system, two constant extension rate machines and static and dynamic autoclave systems

Computation
IBM 3090/400 vector supercomputer (U-M mainframe)
Direct access to University mainframe computers via UMnet
Seven Apollo domain workstations
Satellite access to Cray XMP/48 supercomputer at San Diego
IBM PC/XT personal computers
Intelligent terminals
Graphics and printing terminals
Apple Laserwriter printers
Part of Computer-Aided Engineering Network (CAEN) with 200 Apollo workstations

Requirements

Candidates for the degree Bachelor of Science in Engineering (Nuclear Engineering)—B.S.E. (N.E.)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Engineering Physics—Administered by Department of Nuclear Engineering

Program Adviser:
Professor R. M. Gilgenbach
145 Cooley Building
(313) 763-1261

Physics has been traditionally an integral part of the engineering curriculum, and all engineering students are required to take the introductory physics courses. However, in many areas of engineering the sophistication of a particular field, coupled with the tremendous rate of technological advances, has created a need for engineers with strong backgrounds in physics—people who can work in an engineering environment and who are capable of applying advanced concepts in physics to their particular tasks. For example, the development of the computer closely followed the invention of the transistor and is representative of a considerable number of recently discovered physical phenomena that have been successfully applied and utilized by engineers (consider lasers, nuclear reactors, particle accelerators, etc.). There is also a need to accommodate those students who desire to attend graduate school but who have not decided on a particular field of specialization. An advanced physics and mathematics background, coupled with conventional engineering courses, is an excellent preparation for many graduate engineering programs (e.g., nuclear engineering, electrical engineering) as well as a traditional physics or applied physics program.

Engineering Physics meets these needs by providing a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics. A unique feature of the curriculum is the elective sequence of engineering courses that the student must take in a narrow field of engineering design and analysis. This sequence of courses can be chosen by the student (with the adviser's agreement) in a field of particular interest, such as microprocessor design, plasma/nuclear fusion, computer methods, energy systems, and radiological science, to name a few.

Required Program

Required Program *Courses*	*Hrs.*	**Sample Schedule** *Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.) See under "Minimum Common Requirements" (page 15) for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engl. 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	3	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences	17	-	6	4	3	-	4	-	-
Technical Electives (9 hrs.)									
Mathematics	6	-	-	-	-	4	-	-	2
Engineering or Science	3	-	-	-	-	3	-	-	-
Related Technical Subjects (40 hrs.)									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials	3	-	-	-	3	-	-	-	-
Mech. Eng. 211, Intro. to Solid Mech. *(See Note)*	4	-	-	4	-	-	-	-	-
Mech. Eng. 324, Fluid Mech.	4	-	-	-	-	-	-	4	-
Mech. Eng. 371, Heat Transfer	4	-	-	-	-	-	-	-	4
EECS 314, Cct. Anal. & Electr.	3	-	-	-	3	-	-	-	-
EECS 315, Cct. Anal. & Electr. Lab	1	-	-	-	1	-	-	-	-
EECS 457, Instrumentation	3	-	-	-	-	-	3	-	-
Engineering Elective*	18	-	-	-	-	4	4	6	4
Program Subjects (23 hrs.)									
Phys. 242, Gen. Phys. III	3	-	-	-	3	-	-	-	-
Phys. 401, Int. Mech.	3	-	-	-	-	3	-	-	-
Phys. 405, Int. Elect. and Mag.	3	-	-	-	-	-	3	-	-
Phys. 406, Stat. and Thermal Phys.	3	-	-	-	-	-	3	-	-
Phys. 453, Atomic Phys. I	3	-	-	-	-	-	-	3	-
Phys. 463, Solid State Phys.	3	-	-	-	-	-	-	-	3
Phys. 409, Mod. Lab.	2	-	-	-	-	2	-	-	-
Phys. Elective	3	-	-	-	-	-	-	-	3
Total	**128**	**14**	**16**	**16**	**17**	**16**	**17**	**16**	**16**

Note: ME 110 and ME 210 can be substituted for ME 211.

*The engineering electives are to be chosen in consultation with the faculty adviser to form a coherent sequence that clearly defines professional goals for the student. Sample elective sequences for a number of different subject areas are available from the faculty advisers. Electives should be carefully planned in consultation with a faculty adviser so that the complete program includes the equivalent of one term (16 hours) of engineering design.

Requirements

Candidates for the degree Bachelor of Science (Engineering Physics)—B.S. (Eng. Physics)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Interdisciplinary Undergraduate Degree Program

Engineering
Program Adviser:
Professor J.C. Mathes
117A TIDAL
(313) 763-5395

Recent technological, economic, and social developments have significantly extended the range of problems to which engineering skills and methodologies must be applied. Problems in environmental quality, transportation systems, housing, and urban planning, among others, challenge students to develop programs combining technical knowledge with social and political awareness. In addition, the growing complexity of our technological society requires that some engineers have integrated studies in several technical areas.

To meet these needs, the Interdisciplinary Engineering Program—B.S. (Engineering)—allows students to combine studies in several engineering fields or to combine studies in engineering with studies in other fields. This program can prepare you for a wide variety of career and graduate school opportunities while providing you with a broad undergraduate education.

The program, however, is suited only for those students who have clearly defined career goals. Because the degree is undesignated (e.g., non-departmental), the program does not automatically provide the routine and typical career opportunities available to departmental programs.

Required Program

Courses	*Hrs.*	Sample Schedule — *Term Enrolled* 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.) See under "Variations" for alternatives									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engl. 125, Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 123 or 124, and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	2	3	3	3	3	3	-
Engineering Sciences (18-20 hrs.)*	18-20	-	-	3	6	6	3	-	-
Program Subjects (42-40 hrs.)									
Engineering Concentration**	22-20	-	-	-	3	4	6	6	3
Program Option Courses***	20	-	-	3	-	3	4	4	6
Free Electives (12 hrs.)	12	-	6	-	-	-	-	3	3
Total	**128**	**16**	**16**	**17**	**16**	**16**	**16**	**16**	**15**

The outline of studies demonstrates the well-rounded college education provided by the interdisciplinary engineering program. Few degree programs in any university allow such a balanced distribution of science, mathematics, social science, humanities, and technological studies.

*See guidelines for Engineering Science courses

**See guidelines for Engineering Concentration courses. The combined hours for Engineering Sciences and Engineering Concentration courses must total at least 40 hours.

***See guidelines for Program Option courses

Interdisciplinary Areas

Students with interdisciplinary goals devise a program option from the course offerings of two or three engineering departments, if the goals of such programs cannot be attained by pursuing one of the existing B.S.E. degrees. These programs will be one of the following types:

1) A pre-professional or pre-graduate program. The student chooses either a pre-law, pre-medicine, or pre-dentistry option or a pre-public administration, pre-business administration, pre-bioengineering, or pre-public systems engineering option. Most B.S. (Engineering) students have an option in one of these areas.

2) An interdepartmental College-wide program. The student crosses traditional boundaries in technical disciplines to study in new areas such as energy resources, integrated transportation systems, or technical communication. Before considering an option in one of the areas, students should investigate the possibilities in departmental programs.

3) An interdisciplinary University-wide program. The student combines studies in (a) the humanities, (b) the social sciences, (c) national and urban resources, (d) natural and environmental sciences, (e) business administration, (f) education, or (g) architecture and design with selected studies in technology and engineering. Many students pursue dual degrees when they choose an option in one of these areas.

Students are able to pursue these goals by choosing from many advanced courses in other fields and colleges as well as engineering.

Program Design

Each student is asked to define his or her own educational goals and to design a program with the advice of one of the program counselors. It is of primary importance that the student choose a purposeful sequence of advanced engineering concentration courses to complement an integrated sequence of program option courses. Together these form the student's "major."

Such a program, however, results from the student's own decisions. Since there is no structure of prerequisite and required courses in the junior and senior years, within the constraints explained below this program is flexible and allows the student considerable freedom to choose courses.

Requirements

Candidates for the degree Bachelor of Science (Engineering)—B.S. (Engineering)—must complete the required program. The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8½ or nine terms.

Program Option Courses

This group of courses is selected by students to provide a unified program of study oriented to their educational career goals. The program option can include courses from throughout the University. For most program options, these should be 300-, 400-, and 500-level courses.

Each student is encouraged to design a curriculum that reflects his or her individual goals. Some of the possible options have been identified below.

What Specific Options Do Students Choose?

Pre-Law. Students choose this option to prepare for law school to become practicing attorneys or to specialize in an area such as patent law where they can use their technical training.

Pre-Medicine. Many students choose this option, either to become physicians or to go into biomedical research where they can use their technical training. Some, however, find a degree in Chemical Engineering or Engineering Science to be a preferable pre-medicine path.

Pre-Dentistry. Many students plan to become dentists or to do dental materials research.

Pre-Bioengineering. An increasing number of engineers enter a graduate program in bio-engineering, a field related to medical research in which analytical methods are applied to problems in living systems and in design of new biological structures. An alternate path is provided by the Engineering Science program.

Pre-Business Administration or Business Administration. Many students earn an M.B.A. (Master of Business Administration) after completing a B.S. in engineering. Some students combine business courses with engineering courses to commence a career immediately. About half of all engineers who enter industry eventually assume managerial responsibilities. Students interested in this program option should consider whether or not a degree in Industrial and Operations Engineering would be more appropriate than the B.S. (Engineering) degree. Any engineering degree provides sound preparation for an M.B.A. program.

Technical Sales and Applications Engineering. Students combine engineering, communications, and business to prepare for positions in these fields.

Many companies require sales engineers in order to design and market their products to meet customer needs. These persons serve as liaison between their corporations' design and product engineers and the customers' engineers and managers.

Appropriate Technology. Students interested in alternative technologies design program options in appropriate technology, alternative energy resources, or environmental systems.

Urban Planning. An increasing number of engineers become planners and administrators in urban systems because they know sophisticated technology or are trained in problem-solving and systems design. Related options are in architecture, sociology, and transportation. This option primarily is a pre-graduate school option.

Technology Management.

In this field, engineers apply the systems approach to interrelated socio-technological systems, whether at the level of the organization, the community, the nation, or the world. For example, a student might study the planning, development, and management of energy resources at the regional level. This option primarily is a pre-graduate school option.

Technical and Professional Communication. Students choose this option either to enhance their qualifications for career as managers in industry, business, and government or to prepare themselves for careers as technical communicators. The option is distinctive among communication programs in the United States because its graduates combine engineering skills and communication skills, which never become obsolete.

The interdisciplinary engineering program allows the student to design a personalized program of studies. You can think of others in addition to those listed above and are encouraged to design your own.

Engineering Concentration Courses

The engineering concentration courses supplement or complement the program option courses. Each student elects a series of engineering courses that must have coherence with respect to subject matter and progression with respect to level of study. In environmental studies, for example, the student would supplement program option courses in the life sciences, natural resources, or geophysical sciences with courses from civil engineering, chemical engineering, aerospace engineering, and atmospheric and oceanic science. In business administration, the student would complement program option courses with systems, planning, management, operations, decision-making, and design courses from several engineering departments. These courses should be 300-, 400-, and 500-level courses.

Engineering Science Courses

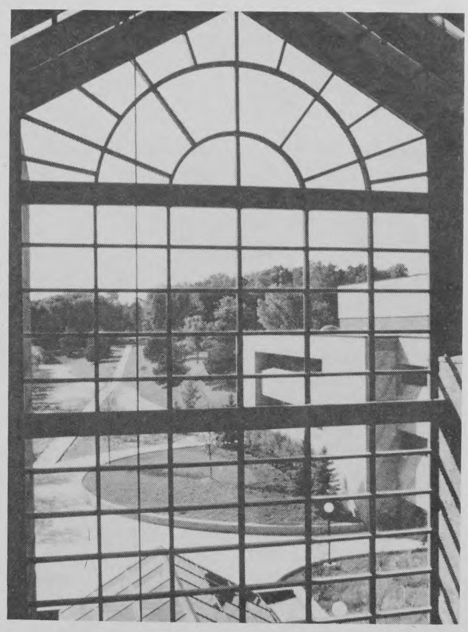
The engineering science courses provide science-based skills applicable to engineering problems. Most courses are at the 200- and 300-level (available to sophomores) and are prerequisites for many advanced engineering courses.

Each student in the program must select courses from this list in at least four of the six areas:

Area	Course
Electrical	EECS 216 (4) or EECS 314 (3), 315 (1) or EECS 213 (4), EECS 331 (4)
Materials	Mat. Sci. & Eng. 150 or 250 (3), Mech. Eng. 252 (3), Mech. Eng. 251 (3)
Mechanics	Mech. Eng. 110 (2), Mech. Eng. 210 (3), Mech. Eng. 211 (4), Mech. Eng. 240 (3), Aero. Eng. 314 (3), Mech. 325 (3) or Mech. Eng. 324 (4)
Nuclear	Nuc. Eng. 311 (3), Nuc. Eng. 312 (3)
Systems	I.&O.E. 310 (3) or Civ. Eng. 405 (3), I.&O.E. 315 (3), I.&O.E. 373 (4)
Thermodynamics	Mech. Eng. 231 (4) or Mech. Eng. 235 (3) or Chem. Eng. 230 (3)

A Unique Feature: Educational Goals Statement

For the interdisciplinary engineering program, the student is asked to write out a statement of educational goals and career objectives. The student then explains how his or her course selections contribute toward these goals. As the student progresses, of course, the goals may be modified. Finally, individuals are led to explore postgraduate opportunities and alternative career paths.



Military Officer Education Programs

The University in cooperation with the armed services of the United States provides an opportunity for all eligible male and female students to earn a commission in any of the three services (Army; Navy, including Marine Corps; and Air Force) upon completion of the degree requirements. This opportunity is available through enrollment in the Military Officer Education Program (MOEP), which is nationally known as the Reserve Officers Training Corps (ROTC).

All three officer educational programs (Army, Navy, and Air Force) offer four and two-year program options, financial benefits, and scholarship opportunities. Minor variations, however, do exist among the programs, and students should consult the specific information under the respective program.

Financial Benefits. All students enrolled in advanced (junior and senior year) officer education courses, whether or not on scholarship, receive a monthly stipend of $100 for the academic year. A uniform and the necessary books and equipment are furnished to all students. In addition, pay and travel allowances are provided for attendance at summer field training courses.

Scholarships. In addition to the financial benefits provided for all students enrolled in the advanced courses, a limited number of two, three, and four-year merit-based scholarships are awarded on a competitive basis by each of the Officer Education Programs. These scholarships provide full tuition, laboratory fees, full payment for required books, and a $100 monthly stipend.

Course Election by Non-Program Students. Officer education courses are also open to University students not enrolled in the program by permission of the instructor.

Air Force Officer Education Program

Program Office:
Room 154, North Hall
764-2403
Colonel Buley, Chairman; Captains Thomas, McGibney and Gaul.

Students who enroll as cadets in the Air Force Officer Education Program, successfully complete the program, and receive a University degree are commissioned as second lieutenants in the United States Air Force Reserve.

Career Opportunities. Men and women can serve in a wide range of technical fields such as meteorology, research and development, communications and electronics, engineering, transportation, logistics, and intelligence as well as in numerous managerial and training fields such as administrative services, accounting and finance, personnel, statistics, manpower management, education and training, investigation, and information services. There are also opportunities in the pilot, navigator, and missile career fields. Advanced education or technical training for these career areas may be obtained on active duty at Air Force expense.

Four-Year and Two-Year Programs. The four-year program consists of eight terms (16 hours) of course work. The first terms (freshman and sophomore years) comprise the General Military Course (GMC). No military obligation is incurred during the freshman year for AFROTC scholarship recipients and none during the freshman or sophomore years for non-scholarship AFROTC students. During the summer following the GMC, students are required to attend a four-week field training session. After completing field training, students enroll in the last four terms (junior and senior years) of AFROTC called the Professional Officer Course (POC). Once students attend the first POC class, they assume a contractual obligation to complete the program, accept a commission, and discharge the military service obligation.

The two-year program is for junior-level college students or graduate students with a two-year degree program who have not participated in the GMC but want to enter the POC. Application for the two-year program must be made by January 1 of the year in which students desire to enter the POC. Students must attend a six-week field training session prior to entering the POC. Once they attend the first class, these students incur the same obligation as four-year program students.

Financial Benefits and Scholarships. For a detailed description of the available financial benefits and scholarships, consult the appropriate sections in the general introduction to the Military Officer Education Programs.

Course of Study. Students enroll in one course in Aerospace Studies (AS) during each term of participation in the program for a total of 16 hours. In addition to the Aerospace Studies courses, students must satisfy certain supplemental course requirements. Distribution is indicated below:

Basic course sequence (first and second year): Aerospace Studies 101, 102, 201, 202 (4 hours), plus an approved course in English Composition (scholarship students only).

Advanced course sequence (third and fourth years): Aerospace Studies 310, 311, 410, 411 (12 hours), plus an approved course in Mathematical reasoning.

Scholarship students must, in addition, successfully complete one academic term (6 semester hours) of a major Indo-European or Asian language prior to commissioning.

This sequence of courses attempts to develop an understanding of the global mission and organization of the United States Air Force, of the historical development of air power and its support of national objectives, of concepts of leadership, management responsibilities and skills, of national defense policy, and of the role of the military officer in our society.

Flying Activities. Cadets who are physically and mentally qualified to become Air Force pilots receive dual and solo flight instruction under the supervision of an Air Force instructor pilot. The training is usually given between a cadet's junior and senior years at an Air Force pilot training base. Cadets holding FAA private pilot certificates or higher are exempt from this training.

Military Obligation. After being commissioned, graduates of the program will be called to active duty with the Air Force in a field usually related to their academic degree program. The period of service is four years for non-flying officers, five years for navigators after completion of navigator training, and eight years for pilots after completion of flight training.

Air Force Officer Education Courses (Aerospace Studies)

101. The Air Force Today. I. (1).
Examines the growth and development of the United States Air Force; covers Presidential, Secretary of Defense and JCS roles in the defense posture, and the national and U.S. military strategic concepts; studies the Air Force supporting forces. Compares the dynamics and interaction of all U.S. military forces in the General Purpose role and their cooperative efforts in the national security posture.

102. The Air Force Today. II. (1).
Continuation of AS 101.

201. U. S. Aviation History and Its Development into Air Power. I. (1).
Development of aviation from the 18th century, from balloons and dirigibles, to the present, and how technology has affected growth and development of air power; traces use and development of air power through WW's I and II, the Korean and Vietnamese conflicts, and employment in relief missions and civic action programs in the late 1960's.

202. U.S. Aviation History and Its Development into Air Power. II. (1).
Continuation of AS 201.

310. Concepts of Leadership Seminar. I. (3).
The concepts, principles, and techniques of leadership and human relations presented

within the framework of behavioral theories. Emphasis on the leader, group, and situation; their interaction as dynamic factors in an organizational environment with methodological implications for military and other professions. Practicum and laboratory centered on operational simulations and cadet corps activities.

311. Principles of Management Seminar. II. (3)
Historical overview of management theory development with particular consideration of behavioral science's impact on primary management function. Problem-solving will be incorporated into discussion of management functions, and analysis will be made of management principles as they apply to various combinations of political and power relations in the organizational setting. Exercises will simulate operational situations requiring the decision-making approach.

410. National Security Forces in Contemporary American Society Seminar. I. (3).
Focuses on the Armed Forces as an integral element of society. Provides examination of a broad range of american civil-military relations, and the environmental context in which defense policy is formulated. Special themes include: social attitudes toward the military; the role of the professional military leader-manager in a democratic society; the fundamental values and socialization processes associated with the Armed Services; the requisites for maintaining adequate national security forces; political, economic, and social constraints on the national defense structure; the impact of technological and international developments on strategic preparedness; the manifold variables involved in the formulation and implementation of national security policy.

411. National Security Forces in Contemporary American Society Seminar. II. (3).
Continuation of AS 410.

Note: A one hour of week Leadership Laboratory (0 credit) accompanies each of the above listed AS courses.

Army Officer Education Program

Room 131, North Hall
764-2400, 764-2401
Chairman: Lieutenant Colonel William Gregor; Assistant Chairmen: Major Eyle, Major Gallagher, Captain Runyon-Davis, Captain Hayes, and Captain O'Rourke.

Upon graduation and completion of program requirements, students receive a commission as second lieutenant in the United States Army Reserve or in the Regular Army.

Career Opportunities. Graduates may request active duty in the Army, or choose non-active duty service in the Army National Guard or Army Reserve in order to pursue a civilian career or graduate schooling. Others may apply for a Regular Army commission (same as West Point commission) and enter active duty for worldwide assignment. Service in the Army's 97 career specialties provides an opportunity to practice knowledge gained during university life. Business and industry leaders value the leadership and management experience of ex-Army officers.

Four-Year, Three-Year, and Two-Year Programs. Students may choose one of three program options as described in the general introduction to the Military Officer Education Programs. All programs include a six-week advanced summer camp at an Army post, which is taken as part of the advanced course sequence normally between the junior and senior years. The first two years of the four-year program can be taken without an obligation to the Army.

Students who intend to enroll in the two-year program should contact the chairman by February of their sophomore year in order to apply for attendance at a six-week summer basic camp before enrollment in the program the following fall term. Two-year candidates must have a total of two years of school remaining at the undergraduate and/or graduate level. Students with prior military service (or prior ROTC training) may enroll in the program with advanced standing at a level determined by the chairman and based on an evaluation of prior service or training.

Financial Benefits and Scholarships. Army ROTC scholarships are merit-based and provide partial to full tuition, partial book fees, and a $100/month stipend to help cover room and board. Engineering students may request an additional year of scholarship benefits if they are enrolled in a five-year program.

Army Fellowship Program. Each year the top 5% (based on GRE scores) of all students chosen for Regular Army commissions, are awarded Army ROTC Fellowships. This award permits the recipient to pursue a course of study, leading to a master's degree, at the Army's expense while receiving full pay and allowances as a commissioned officer.

Simultaneous Membership Program. Non-scholarship students can choose to join a Reserve or National Guard unit of their choice while enrolled at the University. The student trains as an officer trainee, gaining valuable leadership training as a member of the Reserve Forces and can collect over $1,100 per year in addition to the $100/month stipend previously mentioned.

Branch Assignments. In their last year, cadets are classified for branch assignments to one of the following 16 branches of the Army in accordance with their personal preference, aptitude, academic background, and the needs of the Army: Corps of Engineers, Signal Corps, Aviation, Armor, Field Artillery, Air Defense Artillery, Adjutant General's Corps, Military Intelligence, Finance Corps, Infantry, Medical Service Corps, Military Police Corps, Ordnance Crops, Quartermaster Corps, Transportation Corps, and Chemical Corps. Selected students may elect the Guaranteed Branch option at the beginning of the junior year.

Course of Study. Students enroll in one course in Military Science (MS) during each term of participation in the program for a total of 12 hours distributed as follows:

Basic Course sequence (first and second years): Military Science 101, 102, 201, 202 (4 hours total).

Advanced Course sequence (third and fourth years): Military Science 301, 302, 401, 402 (8 hours total).

The complete course of instruction includes: land navigation, Army orientation, professional ethics, military writing and speaking, principles of leadership and management, staff management principles, military justice, and tactics. In addition to the classroom courses, students participate in Leadership Laboratories (one 90 minute period per week). Training includes orienteering, rappelling, marksmanship, physical training, and other personal leadership development exercises. In addition, courses in human behavior, effective writing, and military history are required for completion of the program.

Military Obligation. Students may request non-active duty assignments in the Army Reserve or National Guard in order to pursue graduate schooling or civilian careers or a limited period of active duty. The period of military service depends on several factors, and can best be explained by visiting the AOEP office in North Hall.

Army Officer Education Courses (Military Science)

101. U.S. Army Today. (1).
The course examines the Army's role in our society, by presenting an overview of today's U.S. Army. The course also explores topics such as customs and traditions of the service, branches of the Army, roles of the commissioned and noncommissioned officer, organization of the Army, command and staff functions, and components of the U.S.

Army. Students who register for this course should also register for the 90-minute military skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

102. Basic Military Leadership. (1).
The course will focus on a study of the application of the principles and techniques of land navigation. The course will cover the art of using the techniques of terrain analysis, map reading, and compass employment to navigate over land from one point to another. Students who register for this course should also register for the 90-minute military skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

201. Basic Leadership and Management I. (1).
The course will include discussion of at least three leadership models, focusing on currently accepted leadership theory both in and outside the military. It will also include a discussion of current management theory, and how leadership and management interact in the achievement of organizational goals. Students who register for the course should also register for the 90-minute military skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

202. Basic Leadership and Management II. (1).
The course is a continuation of MS 201, Basic Leadership and Management I. It is specifically designed to enhance and develop a student's understanding of military leadership. It will capitalize upon previously learned leadership and management theory through practical application and discussion. Students who register for this course should also register for the 90-minute military skills laboratory which is conducted one a week. Laboratory sessions conentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

301. Advanced Leadership I. (2).
The course is a study and application of the principles and techniques of effective written and oral communications. The course will cover both theme writing and military correspondence, the military briefing, the after action report, the information/decision paper, and the conduct of meetings and conferences. Students who register for this course should also register for the 90-minute military skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

302. Advanced Leadership II. (2).
This course is designated to provide a basic knowledge of small unit tactics at the squad and platoon level. The material presented is intended to prepare the MS III cadet to successfully fulfill the requirements of squad and platoon leadership positions during Advance Camp. Additionally, the course is designated to develop the student's knowledge of the tactical utilization and organization for combat of the combined arms team from battalion to squad level. Students who register for this course should also register for the 90-minute laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

401. Military Justice. (2).
This course will consist of a series of discussions on the basic aspects of military justice and their application within the United States Military. Topics to be discussed include: military jurisdiction, the court-martial system, non-judicial punishment, non-punitive disciplinary measures, search and seizure, and evidence. A discussion of the Law of Land Warfare will be conducted emphasizing the Geneva and Hague Conventions. Students who register for this course should also register for the 90-minute skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

402. Military Management and Ethics. ***Prerequisite: permission of chairman.*** (2)
This course will focus on a discussion of current issues in military ethics and on those elements identifies as indigenous to the military as a profession. Contemporary leadership issues will be explored. Selected professional development topics will also be discussed to facilitate the transition from cadet to lieutenant and to help prepare the new officer to be effective in administrative and financial procedures as they relate to military service. Standards of Conduct governing Army personnel will be presented to inform cadets of expected and proper behavior while in the military service. Students who register for this course should also register for the 90-minute military skills laboratory which is conducted once a week. Laboratory sessions concentrate on the development of practical skills in the areas of rappelling, land navigation, first aid, rifle marksmanship, tactics, drill and ceremonies, and leadership.

Navy Officer Education Program

Room 103. North Hall
764-1498
Capt. Maier, USN, Chairman; CDR Boucher, Lieutenants Hutchens, Litzenberger, Stevens, and Dinoble; Capt. Gasapo, USMC.

Students enrolled as midshipmen in the Navy Officer Education Program who successfully complete the program and receive a university degree are commissioned as officers in the United States Navy or Marine Corps, or in the Naval or Marine Corps Reserve.

Career Opportunities. Graduates of the program have a wide range of job and career opportunities as commissioned officers in the Navy or Marine Corps. Navy officers may choose duty in surface ships, aviation, and submarines and in subspecialties such as nuclear propulsion. Marine Corps officers may choose aviation, infantry, armor, or artillery specialties. After graduation, all commissioned officers receive additional training in their chosen specialties.

Four-Year and Two-Year Programs. The four-year program includes eight terms of course work. A military obligation is incurred at the beginning of the sophomore year for scholarship students.

The two-year program includes six weeks of training at the Naval Science Institute in Newport, Rhode Island, during the summer before a student's junior year. This is followed by enrollment in the same junior and senior level courses taken by four-year program students. A military obligation is incurred by two-year program students upon enrolling in junior level classes.

Financial Benefits and Scholarships. For a detailed description of the available financial benefits and scholarships, consult the appropriate sections in the general introduction to the Military Officer Education Programs. Each year the Navy awards scholarships for study at The University of Michigan to students chosen on the basis of selections made by a national committee. Criteria for eligibility vary between the several programs offered. Details are available from the program chairman.

Course of Study. Students enroll in Naval Science (NS) courses during each term of participation in the program. In addition, all students are required to elect college course work in calculus, physics, foreign languages, and other Navy required courses. Students also participate in a four- to six-week summer training exercise during the periods between academic years.

Military Obligation. Depending upon the program in which they are enrolled, graduates have a three or four year active duty service obligation. Those who are selected for postgraduate education may incur an additional service obligation upon completion of that training.

Navy Officer Education Program Courses

Note: The courses listed herein are offered primarily for the students participating in the program; however, they are open to and may be taken by any University enrolled student with prior permission of the course instructor.

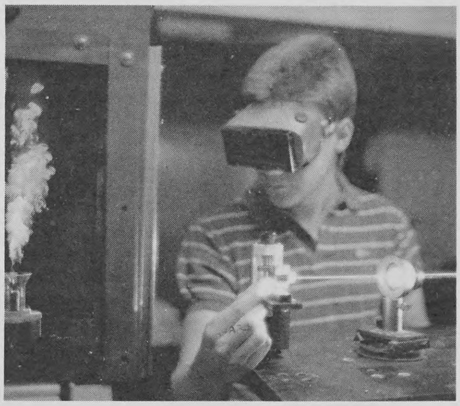
101. Introduction to Naval Science. 1. (2).
An introduction to the structure and principles of naval organization and management. Practices and the concepts lying behind naval organization and management are examined within the context of American social and industrial organization and practice.

102. (Nav. Arch 102). Naval Ship Systems II. (3).
Types, structures, and purposes of ships. Ship compartmentation, propulsion systems, auxiliary power systems, interior communications, and ship control. Elements of ship design to achieve safe operations, and ship stability characteristics.

201. (EECS 250). Electronic Sensing Systems. (3).
Prerequisite: preceded or accompanied by Physics 240. I.

Introduction to properties and behavior of electromagnetic energy as it pertains to naval applications of communication, radar, and electro-optics. Additional topics include sound navigation and ranging (SONAR), tracking and guidance systems, and computer controlled systems.

202. Seapower in American History. II. (3).
This course focuses on the role of seapower in American history, with emphasis on the U.S. Navy. The course includes discussions of: the development of U.S. naval power and its application as an instrument of foreign policy; the historical relationship of the navy and the domestic political and economic environment; the historical relationship of the navy and the American Merchant Marine;



and the rise of the United States as a maritime power.

301. (Astron. 261). Navigation. I. (3).
Theory, principles, and procedures of ship navigation including piloting, dead reckoning, celestial methods, and modern electronic navigation; practical sextant work, plotting on charts, and use of navigational publications.

302. Naval Operations. II. (2).
Principles of shiphandling and fleet operations from the point of view of Officer of the Deck, including study of relative motion, communications, tracking, and rules of the road.

310. Evolution of Warfare. (3).
Basic study of the art of war, concepts of warfare, and evolution of warfare from beginning of recorded history to present. Special emphasis is placed on technological, tactical, and organizational innovations. Conceptual base is developed in the student by study of selective battles that have had major political, military, and social significance.

401. Leadership and Management I. I. (2).
Study of leadership and management theory, structure of organizations, decision theory, communications, authority, chain of command and behavioral science and the manager with emphasis on U.S. Navy Application.

402. Leadership and Management II. II. (2).
Study of organizational administration, human goals, race relations, equal opportunity, drug awareness, and human resources management with emphasis on U. S. Navy application.

410. Amphibious Warfare. (3).
History, development, and techniques of amphibious tactics. Course examines in detail significant amphibious operations of twentieth century from Gallipoli to present.

Graduate Studies

The undergraduate program in engineering offers only limited opportunities for advanced or special studies. Many students find continued study for at least one additional year a decided advantage. It offers an attractive opportunity to pursue their special interests and to acquire a more thorough preparation for their first employment. The University of Michigan has always maintained a leading position in postgraduate engineering education and provides excellent facilities in many fields.

All students who are candidates for graduate degrees are enrolled in the Horace H. Rackham School of Graduate Studies. Its *Bulletin* should be consulted for complete information.

Anyone contemplating graduate work should consult with the program adviser or the advisory committee for the desired program. The College is offering a variety of graduate level courses via closed circuit television into the greater Detroit area for credit. The remote student participates directly in the on-campus classroom presentations.

Electing courses approved for graduate credit. Credit, not to exceed 15 hours (limited to 10 hours for a graduate student in Civil Engineering), earned with a grade of B or better in graduate level (400 or 500) courses while enrolled as an undergraduate with senior standing, and not used to meet bachelor's degree requirements, may be used to partially satisfy the requirements for a degree in the School of Graduate Studies. The student should consult the Graduate School for the regulation pertaining to the transfer of this pre-graduate credit.

Master's Degrees

Master of Science in Engineering. A candidate for the degree M.S.E.—Master of Science in Engineering—must meet the requirements for the degree Bachelor of Science in Engineering at the University in the student's field of specialization, or essentially the equivalent of these requirements, with sufficient evidence that the scholastic requirements of study can be met at an advanced level.

Master of Science. Qualified students who have attained an undergraduate degree in mathematics or an appropriate field of physical science are offered opportunities by the faculty of the College of Engineering in several instances to pursue their studies that will lead to an M.S. degree—Master of Science.

Admission Requirements. In general, an applicant must have earned a B average in undergraduate work to be accepted by the School of Graduate Studies into a master's degree program. If the preparation of an otherwise acceptable candidate is not adequate, the candidate will be required to take the necessary preparatory courses without graduate credit.

Degree Requirements. The requirements for a master's degree include the completion of at least 30 credit hours of graduate work approved by the adviser or advisory committee for the program elected, with an average grade of at least B covering all courses elected as a graduate student.

It is required that a student take at least two graduate-level cognate courses for a minimum of two hours of credit each in a department other than the department of the student's specialization, selected with the approval of the adviser.

A 400-level course listed in the *Bulletin* of the School of Graduate Studies may be elected for graduate credit when approved by the student's adviser.

A superior student who is well prepared may complete the requirements for a master's degree in two terms. The degrees offered are designated in the headings to the several descriptions that follow.

M.S.E. in Aerospace Engineering and M.S. in Aerospace Science

Advisory Committee:
Consult departmental office

Because of the broad nature of study in Aerospace Engineering, a B.S.E. in a variety of engineering fields is suitable preparation for entrance to the M.S.E. program. Admission and setting of degree requirements is approved by the departmental graduate committee. Normally, a candidate for the M.S.E. degree will include in his or her program three to five advanced courses in aerospace engineering, two or three courses in mathematics beyond advanced calculus, and possibly, several selected courses in other fields. Up to four credit hours of non-technical studies and up to five credit hours of directed study may be elected. The courses in aerospace engineering may be selected to emphasize one or more of the following technical areas: gasdynamics (aerodynamics and propulsion), flight dynamics and control systems, and structural mechanics.

A candidate for the M.S. degree in aerospace science must present substantially the equivalent of the four-year program in physics or mathematics at the University and must complete a program of 30 credit hours to be determined in consultation with the departmental graduate committee. Normally, this program will include selected courses in mathematics and physics and several courses in aerospace engineering. Up to four credit hours of nontechnical studies and up to five credit hours of directed study may be elected.

The courses in aerospace engineering may be selected to emphasize one or more of the following technical areas: gasdynamics, flight dynamics and controls systems, and structural mechanics.

M.S.E. in Applied Mechanics

Adviser:
Professor Noboru Kikuchi,
3005B EECS, (313) 764-3387

Students starting graduate study in applied mechanics normally should have preparation that is substantially the equivalent of the requirements for a bachelor's degree specializing in applied mechanics at The University of Michigan. This includes studies in mathematics and mechanics beyond the introductory level. In many cases, applicants will have done their previous study in other branches of engineering or science. Generally, students from any of the usual undergraduate engineering degree programs and from non-engineering programs such as mathematics and physics will have had all or most of the desired preparation. If deficiencies exist, they may be made up in a manner prescribed by the departmental graduate program committee.

A total of 30 hours of graduate study is required for the master's degree. These must include 18 hours of graduate credit applied mechanics courses, Applied Mech. 422, 440, 511 or their equivalent; at least six hours from graduate courses concerned with advanced mathematics. A master's thesis, subject to departmental approval, may be substituted in place of six credits of the 12 credit hours, which are not specific course requirements.

M.S. in Atmospheric Science; M.S. in Oceanic Science

Advisers:
Professor Sushil Atreya and
Professor Stanley Jacobs

Candidates for the M.S. in atmospheric or oceanic science must present the substantial equivalent of a bachelor's degree in engineering, physics, mathematics, or some other scientific area, including the equivalent of Math. 404 and Physics 240 and 241. Each candidate will follow a special program arranged in conference with an adviser and may be required to make up deficiencies. A total of 30 hours is required, including 15 hours of atmospheric and oceanic science, and six hours of mathematics, or three hours of mathematics and three hours of physical science. Interdisciplinary programs may be arranged.

Thesis or Research Essay: A student will select a research topic in conjunction with an appropriate faculty member who will guide the student in preparation of both the research and the thesis or research essay. Satisfactory completion of the thesis or research essay will normally count for six credit hours of the total 30 required for the master's degree. A minimum of six credit hours of course work may be substituted with the approval of the graduate adviser.

M.S. in Bioengineering

Advisory Committee:
Professors Daniel Green (EECS)
Thomas Armstrong (I&OE)
Albert Nuttall (OTO)
Steven Goldstein (Surgery)
Henry Wang (CE)
and Spencer BeMent (EECS)

The Bioengineering Program at The University of Michigan is a graduate program in the School of Graduate Studies granting the M.S. and Ph.D. degrees in Bioengineering. The Program is jointly supported by the College of Engineering and the Medical School.

The Program is interdisciplinary. A student may plan a widely diversified educational program to advance the student's personal goals under the guidance and counsel of faculty associated with the Program. Research opportunities are as diversified as the range of activities conducted by the University units supporting the Program.

Entrance requirements for the Bioengineering Program. Those students with a Bachelor of Science in Engineering or Physics degree should present a minimum background of:
■ One course in organic chemistry
■ One course in either basic biology or introductory physiology that has laboratory experience
■ One course in a generally related area of the biological sciences such as anatomy, experimental psychology, microbiology, physiology, pharmacology, etc.

Those students with a Bachelor of Science or Bachelor of Arts degree and majors in related bioengineering areas such as experimental psychology, physiology, zoology, microbiology, and biochemistry, must complete the above requirements plus the following:
■ Two terms of college physics;
■ Mathematics through differential equations;
■ One course in basic electronic circuits;
■ At least one term (three credit hours) in two of the following: mechanics, fluid mechanics, and thermodynamics.

Students may enter the Bioengineering Program prior to meeting all the prerequisites if approved by the admissions committee. These students must plan to complete the prerequisites during their enrollment in the Program in addition to the stipulated requirements for the Master of Science or Doctor of Philosophy degree in Bioengineering.

The requirements for degrees follow.

Master of Science Degree in Bioengineering. In order to obtain the master's degree in bioengineering, students must complete at least 30 credit hours of graduate study beyond the bachelor's degree. Within this requirement, a group of core courses or their equivalents in the biological sciences, and several graduate level engineering and physical science courses must be completed. Directed research work is required to familiarize the student with the unique problems associated with biological systems research.

The course requirements or their equivalent total 12-23 hours as follows:
Human Physiology (4 hours)
Introductory Biological Chemistry (3-5 hours)
Bioinstrumentation (4 hours)
Statistics (3-4 hours)
Directed Research (2 hours)
Advanced Math (3-4 hours)

Students who have completed courses equivalent to any of the core courses prior to entering the master's degree program may take graduate level biological science or engineering courses in their place. The remainder of the students' programs will include a minimum of eight hours of coursework in advanced engineering and physical sciences. A grade of B or better must be attained in each course used toward the master's degree.

Directed Research and Thesis Research Opportunities. The University of Michigan Bioengineering Program provides a wide range of research opportunities and thereby affords students a variety of choices. The major thrust of the Program is in the use of engineering analysis, science, mathematics, and instrumentation to formulate a basis for understanding or predicting the performance of living systems. The environment of the clinic and the research laboratory is particularly important to students in this program. The conception and development of new instrumentation and advanced data systems frequently moves hand-in-hand with research investigations.

The following are examples of the types of research efforts in which Bioengineering students are participating:

The engineering analysis of the performance of different parts of the nervous system. This work includes dynamic analysis and modeling of receptor systems, determination of skeletal muscle transfer characteristics, signal analysis of the electromyogram and of a compound action potentials, and modeling of signal transmission and coding in neurons. Improved bioelectric electrodes are being developed to facilitate some of the above work. Studies of neurosensory systems include the neurophysiology of the auditory and vestibular systems, the electrical biophysics of the peripheral auditory system, and detailed characterization of the electroretinogram, and quantitative studies of the somatosensory system.

The properties of biological tissues and materials used to replace and repair natural tissue are a significant consideration in many engineering analyses of biological problems. Tissue studies include the mechanical properties of bone, and the factors involved in fracture and healing of bone. Studies of artificial materials used as implants include mechanical property analysis and biocompatibility under various conditions of material-tissue interaction. The results of these fundamental studies are being applied directly to practical problems such as traction treatment of spinal curvature, improved protection of automotive vehicle occupants, and the design of prosthetic devices such as total knee replacements.

Several research activities have as their goals the application of engineering principles to the solution of clinical problems. The work may be in the form of instrumentation development to enable new measurements to be made, or in the utilization of the techniques of systems analysis and optimization theory for better diagnosis and treatment. Examples of instrument development include smaller and more responsive electrodes for blood gas measurement, a device for continuous monitoring of the degree of cervical dilation during labor, and an ultrasonic particle measuring instrument. Growth and physical development of children are being assessed more accurately through improved measuring devices and computer controlled anthropometry.

Diagnostic applications of signal processing and parameter estimation techniques include the early detection of lung disease, quantitation of the degree of arteriovenous shunting in patients with congenital hear defects, and prediction and prevention of complications in heart attack patients. Examples of therapeutic applications of engineering systems theory are the optimization of therapy with drugs such as anticoagulants, determination of the proper timing and amount of blood transfusion or intravenous infusion, and computer control of treatment with the artificial kidney to reduce the incidence of low blood pressure reactions. These projects rely on the results of other investigations involving fundamental research on pharmacokinetics, transport of materials across natural and artificial membranes, and the mechanisms of cardiovascular control.

The facilities available for student research include well-equipped laboratories in the Medical School and the Engineering College, the clinical facilities of the University of Michigan Hospitals, and Ann Arbor Veteran's Administration Hospital. Students working in the laboratories and clinics have access to modern on-line data acquisition equipment and the flexibility of both large and small scale computational capacity. A medium scale computer system housed in the Electrical Engineering and Computer Science Department is devoted to a large extent to medical imaging problems. This machine is part of a network which links several systems in the medical school and other campus locations.

The student's education in the laboratory or clinic of his or her choice is enhanced by seminars, clinical conferences, and informal discussion with faculty members.

M.S.E. in Chemical Engineering

Adviser:
Professor Brice Carnahan
Program Office
3074C H. H. Dow Building

The minimum requirement for the M.S.E. degree is 30 graduate credit hours with an average grade of B. A master's thesis is required for fellowship recipients; however, a thesis is not required for those students who are on their own funds or outside funds. The course work must include at least 21 hours in chemical engineering (courses with a Chem. Eng. prefix) of which up to six credit hours of research are accepted (Chem. Eng. 695); and at least two courses outside the chemical engineering program. The required course is Chem. Eng. 595 (research survey). Each student is encouraged to develop a program to fit his or her professional objectives and should consult with the graduate adviser concerning a plan of study.

A full range of courses is available in several special fields, particularly: applied mathematics and computation (Chem. Eng. 507, 509, 607, 608); colloids and surfaces (Chem. Eng. 470); biochemical engineering (Chem. Eng. 417, 516); electrochemical processes (Chem. Eng. 548, 573); kinetics and catalysis (Chem. Eng. 525, 528, 628); optimization and control (Chem. Eng. 566, 588); polymers (Chem. Eng. 451, 511); process design (Chem. Eng. 587, 687); thermodynamics (Chem. Eng. 537, 538); and transport phenomena and fluid mechanics (Chem. Eng. 526, 527, 529, 542). A booklet describing the facilities, faculty, and graduate program is available from the adviser.

A student wishing to pursue a combination of the M.S.E. and B.S.E. program in the senior year should contact the undergraduate program adviser.

A student wishing to pursue a combination of the M.S.E. and B.S.E. program in the senior year should contact the undergraduate program adviser.

M.S.E. in Civil Engineering

Advisory Committee:
Professors Linda Abriola
Robert Carr
Donald Gray, Subhash Goel (Chairman)
Egon Tons, and Walter Weber.

A candidate for the M.S.E. degree must present the equivalent of the undergraduate civil engineering program as preparation and in addition must complete at least 30 credit hours of graduate work approved by the adviser, of which 15 or more hours must be in civil engineering courses. Graduate study programs leading to this degree may be arranged in the following special areas: construction, environmental, geotechnical, highway, hydraulic and hydrological, municipal, structural, and transportation engineering.

M.S.E. in Construction Engineering and Management

Adviser:
Professor Robert Carr

This program is available to students interested in construction who meet the requirements for admission to master's degree work in engineering. The requirement for this degree is successful completion of at least 30 credit hours of graduate work, of which 12 credit hours must be in courses emphasizing construction. The remainder of the program will be selected in conference with the adviser along lines designed to best complement the student's ultimate objective.

M.S.E. in Public Works Administration

Adviser:
Professor Eugene Glysson

The program in municipal engineering and public works administration is available to those students who meet the requirements for admission to master's degree work in Civil Engineering. The requirement for this degree is the successful completion of at least 30 hours of graduate work of which at least 15 must be in civil engineering courses related to public works engineering. The remainder of the program will be selected from such areas as: urban planning, theory of management, system analysis, and political science, in conference with the adviser so as to best complement the student's ultimate objective.

M.S.E. in Environmental Engineering; M.S. in Water Resources Sciences; and M.S. in Water Resources Management

Advisers:
Professor Walter Weber (Environmental Engineering and Water Resources Sciences), Professor Jonathan Bulkley (Water Resources Management)

Interdisciplinary programs of advanced study in water resources in the College of Engineering are centered in the Department of Civil Engineering. These include degree programs in Environmental Engineering, Water Resources Sciences, and Water Resources Management.

The program leading to the degree M.S.E. in Environmental Engineering is open to qualified candidates with a Bachelor of Science degree in any of the generally recognized fields of engineering. Program emphasis is placed on development of both technological and socio-economic concepts required for solution of a variety of environmental and water resources problems. Candidates for the degree M.S.E. must complete a minimum of 30 hours of graduate work, planned in consultation with the program adviser, constituting an integrated program. A typical program normally includes courses in: hydrology and water quantity management; water quality and water pollution control; water, wastewater, and hazardous waste treatment, water pollution control; water, wastewater, and hazardous waste treatment, water chemistry and limnology; air pollution and solid wastes control; systems analysis, operations research techniques, and computer applications; political and institutional factors in environmental and water resource systems.

The degree M.S. in Water Resources Sciences, under the general administrative direction of the University Water Resources committee, is intended primarily for: (1) chemists who wish to specialize in Water Chemistry; (2) biologists or bacteriologists who wish to specialize in Aquatic Biology; and (3) mathematicians who wish to specialize in Water Resources Systems Analysis and Design. Each candidate for the degree M.S. in Water Resources Sciences will plan a program in consultation with program adviser. A minimum of 36 hours of graduate credit is required to qualify for a degree. This will normally consist of six hours in courses designed to orient the student to the broad field of water resources, 15 hours in core courses in a scientific specialization, nine hours of science electives to meet the student's special needs, and six hours of laboratory or field research. No thesis is required but the student will prepare a written scientific report covering a research problem.

The objective of the program in Water Resources Management is to provide a working knowledge of the problems and approaches to managing the use and development of water resources and to provide specialization in one of several major aspects of water management approved by the Water Resources Committee. The curriculum is designed to integrate technical, economic, social, and institutional aspects involved in various types of public water management enterprises. A minimum of 48 hours of graduate credit is required to qualify for the degree of Master of Science in Water Resources Management. Of the total credit hours required, approximately 30 should be in courses which emphasize both the physical attributes of water and the policy issues associated with water resources management. Each student must choose 15 elective credits which will reinforce the individual area of specialization. Normally, six credit hours in the field of specialization will be earned in research or in supervised field experience.

M.S.E. and M.S. in Computer Science and Engineering

Entrance Requirements: A student desiring to pursue graduate work in Computer Science and Engineering should have completed a bachelor's degree or equivalent in computer science, computer engineering, or in a related area. The undergraduate program should have included courses equivalent to the prerequisites of the Computer Science and Engineering "kernel" (see below). Students who show exceptional promise, but who do not satisfy the normal admission requirements, may be considered and are encouraged to apply.

Applicants must submit the results of the Graduate Record Examination (GRE) General Test, consisting of quantitative, analytical, and verbal scores. Three letters of recommendation are required. Admission decisions are generally made within two months after the application and all supporting materials are received. International applicants must also submit the results of the Test of English Language (TOEFL).

Requirements for all Divisions of Electrical Engineering and Computer Science

1. A student must satisfy both the general master's degree requirements of the Rackham School of Graduate Studies, as specified in Section 7:1 of the Rackham *Bulletin*, and the College of Engineering regulations as specified in the College of Engineering *Bulletin*. The Rackham cognate requirement (at least two graduate level courses for a minimum of two credit hours each) must be satisfied. In addition, the student must satisfy the requirements listed below.
2. 30 credit hours of graduate level courses must be completed.
3. At least 24 credit hours in technical coursework must be earned.
4. At least 12 credit hours of EECS coursework at the 500 level or higher must be earned. Credit hours earned in other departments or universities and credit hours earned in individual study, research, or seminar courses cannot be counted towards this requirement.
5. A maximum of six (6) credit hours of individual study, research and seminar courses (EECS 598, EECS 699 and similar courses) will be accepted toward the master's degree.
6. The course grade must be B- or better for the credit hours received in any course to be counted towards any master's requirement (including the 30 total credit hours).
7. The Grade-Point-Average in EECS coursework must be at least 5.0, based on Rackham's 9.0 scale. (In addition Rackham requires the overall GPA among all courses applied to the master's degree to be at least 5.0)
8. Courses of insufficiently advanced level, or which substantially duplicate in level and content courses already completed by the student, may not be counted as meeting any master's requirement..

Degree Specific Requirements to Computer Science and Engineering

The Computer Science and Engineering masters degree program requires students to complete "kernel" course requirements, mandated electives, and free electives, for the total of 30 credits. A research-oriented directed study or Master's Thesis is also required. The purpose of the kernel is to give the student training in the major areas of computer science and engineering. Students who enter without an undergraduate engineering degree receive a M.S. degree. Students who enter with an engineering degree have a choice of either the M.S. or M.S.E. degrees.

Computer Science and Engineering kernel requirements:

1. *Software:* EECS 482, Computer Operating Systems (Prerequisite: EECS 380 and 381) *or* EECS 483, Compiler Construction (Prerequisite: EECS 480 or EECS 380)
2. *Hardware:* EECS 478, Switching and Sequential Systems (Prerequisite EECS 303, and senior or graduate standing) *or* EECS 570, Logical Design of Digital Computers (Prerequisite: EECS 470 or EECS 370 and 478)

3. *Theory:* EECS 574, Theoretical Computer Science I (Prerequisite: EECS 476) *or* EECS 586, Analysis of Algorithms (Prerequisite: EECS 480)
4. *Intelligent Systems:* EECS 492, Introduction to Artificial Intelligence (Prerequisite: EECS 380 and 303)

Courses taken at another university or department that are equivalent in level and content may fulfill one or more of these requirements. Such "equivalency" is granted by the graduate chairman. Moreover, equivalency does not fulfill any other degree requirements; in particular credit hour requirements.

Computer Science and Engineering directed study requirement:

A research-orented directed study of at least three credit hours must be completed. (It is possible to replace this directed study with a Master's Thesis.)

Computer Science and Engineering mathematical cognate requirement:

One of the two cognate courses required by the Rackham graduate school must be a mathematics course. A list of courses is maintained by the CSE division from which this course must be selected.

M.S.E. and M.S. in Electrical Engineering (Systems)

Program Chairman:
Professor Frederick Beutler

The Graduate Program in Electrical Engineering (Systems) is identified with the disciplines of communications, control, signal and image processing, systems theory, stochastic systems, information theory, estimation and detection, robotics, bioelectrical science, and other disciplines in which the emphasis is on the design and analysis of systems of interacting components or devices, rather than on the physical components of devices themselves. The Program is administered by the Systems Science and Engineering Division of the Electrical Engineering and Computer Science Department (EECS).

The M.S.E. and M.S. degree programs are identical except for admissions requirements. Students desiring admission to the M.S.E. program must have an earned bachelor's degree in Electrical Engineering, or the equivalent of the undergraduate Electrical Engineering Program at The University of Michigan. Students desiring admission to the M.S. program should have an earned bachelor's degree in engineering, physical sciences, or mathematics. Application procedures are described in a departmental brochure containing information for prospective students. The principal requirements for the M.S.E. and M.S. degrees are listed below. (A more complete statement on master's degree requirements is available from the EECS department.) A student must earn at least 30 credit hours of graduate level coursework of which at least 24 credit hours must be in technical courses, at least 12 credit hours must be EECS course work at the 500 level or higher (excluding credit hours earned in individual study, research or seminar courses) and at least three (3) credit hours must be in mathematics. The student must also choose a major and minor area, and complete a "kernel" of courses in each. The major area must be communication, control systems, or signal processing. The minor area must be different from the major and must be chosen from either the previous list or bioelectrical sciences, circuits and electronics, computers, electromagnetics and electrodynamics, electro-optics, or solid state. At least nine (9) credit hours must be earned from the kernel of the major area, with at least six (6) of these at the 500 level or higher. At least six (6) credit hours must be earned from the kernel of the minor area, with at least three (3) of these at the 500 level or higher and satisfactory completion of the EECS Introductory Seminar course in the first fall term. Course grades must be B- or better in order to be counted towards any requirements. A master's thesis is optional. Up to six (6) credit hours may be transferred if the department grants approval. The student must also satisfy the regulations of the School of Graduate Studies and the College of Engineering.

M.S.E. and M.S. in Electrical Engineering

Program Chairman:
Professor Ronald Lomax

The Graduate Program in Electrical Engineering covers topics such as circuits, electronics, electrodynamics, electromagnetics, energy conversion, electro-optics, and solid state materials, devices and integrated circuits. The Program is administered by the Electrical Science and Engineering Division of the Electrical Engineering and Computer Science Department (EECS).

The M.S.E. and M.S. degree programs are identical except for admission requirements. Students desiring admission to the M.S.E. program must have an earned bachelor's degree in Electrical Engineering, or the equivalent of the undergraduate Electrical Engineering Program at The University of Michigan. Students desiring admission to the M.S. program should have an earned bachelor's degree in engineering, physical sciences, or mathematics. Application procedures are described in a departmental brochure containing information for prospective students. The principal requirements for the M.S.E. and M.S. degrees are listed below. (A more complete statement on master's degree requirements is available from the EECS department.)

A student must earn at least 30 credit hours of graduate level coursework, of which at least 24 credit hours must be in technical courses, at least 12 credit hours must be EECS course work at the 500 level or higher, excluding credit hours earned in individual study, research, or seminar courses, and at least three (3) credit hours must be in mathematics. EECS 590, "EECS Introductory Seminar," must be taken in the first fall term of graduate studies. The student must also choose a major and minor area, and satisfy a requirement in each. The major area must be circuits and electronics, electromagnetics and electrodynamics, electro-optics, or solid state. The minor area must be different from the major and must be chosen from either the previous list or bioelectrical sciences, communications, computers, control systems, or signal processing. For each designated major and minor area there is a set of courses called the "kernel." As specified below, the major and minor requirements are to be satisfied by taking courses from the respective kernels. Specifically, at least nine (9) credit hours must be earned from the kernel of the major area, with at least six (6) of these at the 500 level or higher. At least six (6) credit hours must be earned from the kernel of the minor area, with at least three (3) of these at the 500 level or higher. A grade point average of B or higher is required overall and also in EECS course work. Course grades must be B- or higher to earn credit toward the master's degree. A master's thesis is optional. Up to six (6) credit hours may be transferred if the department grants approval. The student must also satisfy the regulations of the School of Graduate Studies and the College of Engineering.

M.S.E. and M.S. in Industrial and Operations Engineering

Adviser:
Professor John R. Birge, 244 Industrial and Operations Engineering Building

The degree of Master of Science in Engineering, in Industrial and Operations Engineering, is available to students who complete the M.S.E. course requirements and have a bachelor's degree from a recognized program in engineering. The degree Master of Science, in Industrial and Operations Engineering, is available to students with a bachelor's degree from a recognized program in physics, mathematics, or other field related to engineering. Students who hold bachelor's degrees from other fields and who wish to receive an M.S. in Industrial and Operations Engineering should consult with the program adviser as specialized programs (usually involving additional credit hours over basic requirements) can be provided.

The basic requirements include 30 credit hours of approved graduate level courses, of which: at least 18 hours must be in I.&O.E. courses; at least four courses must be at a 500 (or higher) level, of which at least three must be from I.&O.E. (independent study courses, I.&O.E. 590, do not count towards this requirement); no more than four credit hours of independent study. At least two courses, four credit hours, must be from outside the I.&O.E. department. Students are required to make up deficiencies in their preparation in probability, statistics, and computer programming. An overall grade point average of B or higher, in graduate courses taken in the program, is required.

Special options, for which sequences of courses have been defined, include Manufacturing Systems Engineering, Occupational Health and Safety Engineering, and Public Systems Analysis. Material describing these options and other details of the graduate programs are available from the graduate program secretary, Room 240 I. & O.E. Building.

Joint MBA/MS(IOE) Degree Program

The School of Business Administration and the Department of Industrial and Operations Engineering offer a joint degree program enabling a student to pursue concurrent work in business administration and industrial and operations engineering leading to the MBA and MS(IOE) degrees. The program is arranged so that all requirements for both degrees are completed in two and one-half years of enrollment (65 credit hours will be necessary.

Students interested in the MBA/MS(IOE) combined program must apply to and be admitted by both schools, using their respective application forms and indicating that application is being made to the joint program. Only one application fee is necessary, however. Students are expected to meet the prerequisites for each program. In particular the statistics requirement for the IOE program should be discussed with an advisor prior to commencing either program. This combined program is not open to students who have earned either the MBA or MS(IOE) degrees. However, students registered in the first year of either program may apply.

Students admitted to this joint program must satisfy the following degree requirements:

(1) The 30-credit hour MBA core
(2) 15 elective hours in business administration (12 of the 15 hours must be approved by IOE)
(3) 18 credit hours in graduate level IOE courses (at least nine of which must be in courses numbered 500 or above)
(4) A 2 credit independent study in IOE or the Business School which would lead to a paper integrating business and IOE perspectives on a particular area of interest.

The joint program can begin with studies in either school. However, because of the sequences nature of the core course in the MBA program, most students will find it advantageous to start the first year in the Business School. Students who wish to begin with Industrial and Operations Engineering should consult a counselor in the Business School to work out an appropriate plan of study.

Masters in Hospital Administration and Industrial Engineering

A 60 credit hour interdepartmental master's degree program administered jointly by the IOE department and the Department of Hospital Administration in the School of Public Health. This program prepares graduates for engineering and administrative positions in hospitals and other health organizations. The degree provides a comprehensive program in health administration and engineering.

Areas of study include hospital administration and hospital systems engineering, management information systems, computer aided systems, and operations analysis.

M.S.E. in Materials Science and Engineering

Adviser:
Professor J. Wayne Jones, 2168 Dow Building

A minimum of 30 credit hours of graduate-level work must be passed. Of the 30 hours at least 19 hours must be formal class work and must include Mat. Sci. & Eng. 590 (1). Individual research is required. Up to 11 hours of Mat. Sci. & Eng. 690 or M.S. thesis may be used as part of the 30-hour requirement. At least six hours should be in courses outside of materials science and engineering.

All students are encouraged to design their programs to satisfy their individual interests. A booklet describing the graduate program in more detail is available from the secretary in the graduate committee office, 2168 Dow Building.

M.S.E. in Mechanical Engineering

Adviser:
Professor A. G. Ulsoy, 2236 G.G. Brown, (313) 936-0331

The requirement for this degree is 30 credit hours of approved graduate work. At least 18 hours must be taken in mechanical engineering and at least two cognate subjects, totaling five or more credit hours, must be taken in departments other than mechanical engineering. Up to six credit hours of research or nine credit hours of thesis can be taken as part of a 30 credit-hour requirement. Details of course requirements and fields of specialization will be furnished by the department upon request.

Students majoring in mechanical engineering will not be given graduate credit for courses equivalent to any that they have been required to take for the bachelor's degree or for courses required in the undergraduate curriculum of this department.

M.S. and M.S.E. in Naval Architecture and Marine Engineering

Adviser:
Professor Michael M. Bernitsas, 204 Naval Architecture and Marine Engineering Building

The applicant should have a bachelor's degree in naval architecture and marine engineering or its equivalent. Applicants with bachelor's degrees in other engineering disciplines will have to take extra courses beyond the 30 credit-hour minimum.

A minimum of 30 credit hours is required for the degree of which at least 15 hours are taken in naval architecture and marine engineering. Half of the program must consist of 500-level (or higher) courses. Five or more hours must be in graduate-level mathematics courses. Two courses of at least two credit hours each must be taken outside the department.

Students will specialize in one or more of the following areas: ship hydrodynamics, ship strength and vibration, marine engineering, ocean engineering, marine systems, ship production, or computer-aided marine design. Within each of these areas of specialization students are required to take several core courses, with the remainder chosen to meet individuals' goals and objectives.

Refer to the booklet titled, "Graduate Programs in Naval Architecture and Marine Engineering," available from the departmental office, for a more detailed description of the graduate program in naval architecture and marine engineering.

M.S.E. in Nuclear Engineering and M.S. in Nuclear Science

Adviser:
Professor Terry Kammash

Students entering the program in nuclear engineering must have a bachelor's degree from an accredited engineering program. The nuclear science program is available to those with bachelor's degrees from recognized programs in physics, chemistry, or mathematics who wish to work on nuclear energy development.

Students planning to enter the M.S. degree program who do not have an undergraduate degree in Nuclear Engineering should take courses in atomic and nuclear physics and in advanced mathematics for engineers (Math. 450 or equivalent). Students without these prerequisites will be requested to make up the deficiencies in addition to the 30 hours required for the M.S. degree. An upper-level course in electronic circuits (Elec. Eng. and Comp. Sci. 313, 314, or 315, Physics 455, or equivalent), a course in fluid mechanics (Mech. Eng. 325, or equivalent), a course in electromagnetic fields (Physics 405 or equivalent), and a course in digital computer programming (Eng. 103, Elec. Eng. and Comp. Sci. 283, or equivalent) are recommended as desirable preparation.

The requirements for the master's degree are 30 hours of course work at the graduate level, including 20 hours from nuclear engineering and two courses outside the department. At least four of the nuclear engineering courses, excluding Nuc. Eng. 599 and 799, must be at the 500 level or higher. A student must elect a laboratory course in nuclear engineering or show equivalent experience. The student, with approval of the program adviser, may substitute a master's project report for two to six credit hours of graduate course work, with the Nuc. Eng. 599 credits not to exceed 3 credit hours per full term. In this case, the student will be required to make a seminar presentation of the master's project, in addition to a written final report. Additional courses are selected with the help of the program adviser from courses in nuclear engineering, cognate fields of engineering, mathematics, physics, chemistry, and others. Where the entering student presents evidence of satisfactory completion of work equivalent to any of the nuclear engineering courses, substitution of other courses will be arranged by the program adviser.

Professional Degrees

The following programs lead to professional degrees:
Aerospace Engineer - Aerospace E.
Applied Mechanics Engineer - App. M.E.
Chemical Engineer- Ch.E.
Civil Engineer- C.E.
Electrical Engineer - E.E.
Industrial and Operations Engineer - I.&O.E.
Marine Engineer - Mar.E.
Mechanical Engineer - M.E.
Metallurgical Engineer - Met.E.
Naval Architect - Nav. Arch.
Nuclear Engineer - Nuc.E.

The professional degree programs require a minimum of 30 credit hours of work beyond the Master of Science in Engineering level or its equivalent, taken at this University with a grade average of B or better. Successful completion of a qualifying examination for admission to candidacy is required.

The total graduate program shall include:
1) At least 24 hours in the area of the department or program cited in the degree. The department or program advisers may specify these hours in greater detail.
2) At least six hours devoted to a research, design, or development problem, including a written report covering the work. A committee of faculty members will supervise the work, approve the report, and conduct a final oral examination on this work.
3) At least three courses in cognate fields other than mathematics.
4) At least nine hours in mathematics beyond the Bachelor of Science in Engineering mathematics requirements of the department cited in the degree.

Doctor's Degree

Doctor of Philosophy—Ph.D.

The doctor's degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly announced graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in some subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. No assurance is given that the student may become a candidate for the doctorate until evidence of superior scholarship and ability as an original investigator has been shown.

There is no general course or credit requirement for the doctorate. In most areas, a student must pass a comprehensive examination in a major field of specialization, be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

Requirements regarding foreign language and nontechnical courses are left to individual departments or programs and to the Graduate School. A prospective doctoral student should consult the program adviser regarding specific details.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office upon request.

Description of Courses

The courses offered by the College of Engineering, and by certain closely associated departments of other units of the University, are listed with a brief description of each. Time schedules are issued giving hours and room assignments for the courses and sections offered each term.

Designations. The Roman numeral in boldface type, following the course number and title, indicates the position of the course in a sequence of courses on the same subject. Prerequisites appear in italics. When they appear, Roman numerals in light-face type indicate the times at which the department concerned plans to offer the course: I, fall; II winter; III, spring-summer; III*a*, spring, half; III*b*, summer, half. (see under Term for definitions relating to the several terms). The italic number in parentheses indicates the hours of credit for the course; for example, *(3)* denotes three credit hours, or, *(to be arranged)* denote credit to be arranged.

What the Course Number Indicates. The number of each course is designated to indicate the general level of maturity and prior training expected.

100: Freshman level courses
200: Sophomore level courses
300: Junior level courses
*400: Senior level courses
500: Predominantly Graduate level courses
600 and above: Graduate level courses

Unless a phrase such as "Junior Standing," "Senior Standing," or "Graduate Standing" is part of the list of prerequisites for a course, a student may elect an advanced level course relative to his or her current status if the other prerequisites are satisfied. If the difference in standing level is greater than one academic year, it is usually not wise to elect an advanced level course without first consulting the department or the instructor offering the course.

Prerequisites for Engineering Courses

In general, the prerequisites listed for a course designate specific subject materials and/or skills expected to have been mastered before electing the course (or, in some cases, concurrent with).

Course Equivalence. Unless otherwise stated, the phrase "or equivalent" may be considered an implicit part of the prerequisite for any course. When a student has satisfactorily completed a course that is not listed but is believed to be substantially equivalent to one specified as a prerequisite for a course that the student wants to elect, the individual may consult the program adviser and upon determining if equivalency has been satisfied, election may be approved.

Permission of Instructor. The phrase "or permission of instructor (or department)" may be considered an implicit part of the statement of prerequisites for any course. When permission is a stated requirement, or when a student does not have the stated prerequisite for a course but can give evidence of background, training, maturity, or high academic record, the student should present to the program adviser a note of approval from the instructor or department concerned.

*A 400 level course listed in the *Bulletin* of the Horace H. Rackham School of Graduate Studies may be elected for graduate credit when approved by the student's graduate program adviser.

Aerospace Engineering

Department Office:
302 Aerospace Engineering Building
phone 764-3310

Faculty

Thomas C. Adamson, Jr., Ph.D., Professor of Aerospace Engineering and Chairman of the Department Aerospace Engineering

William J. Anderson, Ph.D., Professor of Aerospace Engineering

Frederick L. Bartman, Ph.D., Professor of Aerospace Engineering

Frederick J. Beutler, Ph.D., Professor of Information and Control Engineering, Department of Aerospace Engineering and Chairman of the Graduate Program in Computer, Information and Control Engineering

Harm Buning, M. S. E., Arthur F. Thurnau Professor and Professor of Aerospace Engineering and Associate Chairman of the Department of Aerospace Engineering

Joe G. Eisley, Ph.D., Professor of Aerospace Engineering

Gerard M. Faeth, Ph.D., Professor of Aerospace Engineering

Elmer G. Gilbert, Ph.D., Professor of Aerospace Engineering

Donald T. Greenwood, Ph.D., Professor of Aerospace Engineering

Paul B. Hays, Ph.D., Professor of Aerospace Engineering

Robert M. Howe, Ph.D., Professor of Aerospace Engineering

Jack R. Lousma, Eng. Degree, Adjunct Professor of Aerospace Engineering

N. Harris McClamroch, Ph.D., Professor of Aerospace Engineering

Arthur F. Messiter, Jr., Ph.D., Professor of Aerospace Engineering

William F. Powers, Ph.D., Adjunct Professor of Aerospace Engineering

Martin Sichel, Ph.D. Professor of Aerospace Engineering

John E. Taylor, Ph.D., Professor of Aerospace Engineering

Bram van Leer, Ph.D., Professor of Aerospace Engineering

Nguyen X. Vinh, Ph.D., Professor of Aerospace Engineering

William W. Wilmarth, Ph.D., Professor of Aerospace Engineering

Arnold M. Kuethe, Ph.D., Professor Emeritus of Aerospace Engineering

Edgar J. Lesher, M.S.E., Professor Emeritus of Aerospace Engineering

Vi-Cheng Liu, Ph.D., Professor Emeritus of Aerospace Engineering

James A. Nicholls, Ph.D., Professor Emeritus of Aerospace Engineering

Richard L. Phillips, Ph.D., Professor Emeritus of Aerospace Engineering

William L. Root, Ph.D., Professor Emeritus of Aerospace Engineering

Pauline M. Sherman, M.S., Professor Emeritus of Aerospace Engineering

James F. Driscoll, Ph.D., Associate Professor of Aerospace Engineering

C. William Kauffman, Ph.D., Associate Professor of Aerospace Engineering

Nicolas Triantafyllidis, Ph.D., Associate Professor of Aerospace Engineering

Luis P. Bernal, Ph.D., Assistant Professor of Aerospace Engineering

Werner J. A. Dahm, Ph.D., Assistant Professor of Aerospace Engineering

Pierre T. Kabamba, Ph.D., Assistant Professor of Aerospace Engineering

Kenneth G. Powell, Ph.D., Assistant Professor of Aerospace Engineering

Anthony M. Waas, Ph.D., Assistant Professor of Aerospace Engineering

Donald E. Geister, M.S.E., Lecturer of Aerospace Engineering

100. Introduction to Flight. (2).
An introduction to the physical principles of flight within the atmosphere and in space, to the major historical developments in the conquest of air and space, and to the current state of aerospace developments and their role in national and world affairs.

200. General Aeronautics and Astronautics. ***Prerequisite: Physics 140, preceded or accompanied by Eng. 103. I and II.*** (2).
Introduction to aerospace engineering. Elementary problems designed to orient the student in the program of aerospace engineering, together with a discussion of the current state of aerospace developments and the role of the engineer. Recitations and demonstrations.

300. Elements of Space Science and Technology. ***Prerequisite: Math. 216; Physics 240.*** (3).
Scientific and technological aspects of current space flights, mission goals, the space environment, vehicle characteristics, performance, and flight paths. Mission support: communications, power, computers, etc. Open to all University students.

301. Laboratory I. ***Prerequisite: preceded or accompanied by EECS 314. I and II.*** (2).
Comprehensive series of lectures and experiments designated to introduce the student to basic principles of electronics, circuit analysis, transducers, modern laboratory instrumentation, experimental methods, and data analysis. Experiments involve simple measurement and instrumentation problems.

302. Laboratory II. ***Prerequisite: Aero. Eng. 301. I and II.*** (2).
Continuation of the material in Aero. Eng. 301.

314. Structural Mechanics I. ***Prerequisite: Mech. Eng. 211. I and II.*** (3).
Review of plane states of stress and strain; basic equations of plane elasticity and selected problems; failure criteria and applications; energy principles of structural theory; thin-walled beam theory.

320. Compressible Flow and Propulsion I. ***Prerequisite: Mech. Eng. 235. I and II.*** (3).
First part of an aerodynamics sequence designated to study the fundamental principles and their applications; physical nature of fluids, conservation laws; nozzles and diffusers; shock waves; applications to jet propulsion, and other problems.

330. Aerodynamics II. ***Prerequisite: Aero. Eng. 320 or introductory course in fluid mechanics. I and II.*** (3).
Second part of an aerodynamics sequence designed to study the fundamental principles and their applications; viscous effects in laminar and turbulent flows; boundary layer theory; concepts of instability and transition to turbulent flow; flows under the influence of gravitational and electromagnetic forces.

340. Mechanics of Flight. ***Prerequisite: Aero. Eng. 200, Mech. Eng. 240. I and II.*** (3).
Mechanics of a particle applied to the analysis of vehicle flight paths. Rigid body mechanics applied to translational and rotational vehicle motion. Analysis of vehicle motion and static and dynamic stability using perturbation theory.

350 (Math. 350). Aerospace Engineering Analysis. ***Prerequisite: Math. 216. I and II.*** (3).
Formulation and solution of some of the elementary initial- and boundary-value problems relevant to aerospace engineering. Application of Fourier series, separation of variables, and vector analysis to problems of forced oscillations, wave motion, diffusion, elasticity, and perfect-fluid theory.

380. Undergraduate Seminar. ***Prerequisite: junior standing.*** (1).
A series of seminars by noted outside speakers designed to acquaint undergraduates with both current problems and state of the art aerospace industry. Will involve a short term project or paper pertinent to one of the seminar topics.

390. Directed Study. ***(To be arranged).***
Individual study of specialized aspects of aerospace engineering.

411. (Appl. Mech. 411) (Civ. Eng. 411) (Nav. Arch. 411). Finite Element Applications. ***Prerequisite: Eng. 103, Mech. Eng. 211. I*** (3).
The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and interpret results. A short introduction to the underlying theory is also presented.

414. (Appl. Mech. 414). Structural Mechanics II. ***Prerequisite: Aero. Eng. 314. I and II.*** (3).
Introduction to plate theory. Stability of structural elements; columns and beam columns; plate in compression and shear; secondary instability of columns. Introduction to matrix methods of deformation analysis; structural dynamics.

416. Theory of Plates and Shells. ***Prerequisite: Mech. Eng. 211, Math. 450 or Aero Eng. 350.*** (3).
Linear elastic plates, linear theory of membranes. Bending of axisymmetric and non-axisymmetric linear shells, vibrations of shells, finite element techniques for solving plates and shell problems.

420. Aerodynamics III. ***Prerequisite: Aero. Eng. 320, and Aero. Eng. 350 or Math. 450; preceded or accompanied by Aero. Eng. 330. I and II.*** (3).
Third part of an aerodynamic sequence designed to study the fundamental principles and their applications; inviscid flows and fundamentals of field theory; generation of airfoil lift; thin airfoil theory; induced drag and finite wings; wave kinematics; two dimensional compressible flow.

423. Aero-Acoustics. ***Prerequisite: Aero. Eng. 320 or a course in compressible flow.*** (3).
Principles of generation, perception, and abatement of sound generated by fluid flows; Elementary acoustics; acoustical response of the human ear. Theory and results of measurement of sound generated by explosions, sonic booms, jets, boundary layers, and flow excited structural vibrations. Qualitative assessment of techniques and effectiveness of noise abatement procedures.

424. Applied Aerodynamics. ***Prerequisite: Aero. Eng. 420.*** (3).
Topics related to flow about aircraft wings and bodies and the resulting aerodynamic forces at subsonic, transonic and supersonic speeds. Potential flows, boundary layers, shock waves, separation, transition, turbulence, effects of Mach and Reynolds numbers. Discussion and explanation of analytical methods, numerical methods, and experimental results. Selected other applications.

430. Propulsion II. ***Prerequisite: Aero Eng. 320. I and II.*** (3).
Performance and analysis of flight-propulsion systems including the reciprocating engine-propeller, turbojet, turboprop, ramjet, and rocket.

439. Aircraft Propulsion Laboratory. ***Prerequisite: Aero. Eng. 320.*** (2).
Series of experiments designed to illustrate the general principles of propulsion and to introduce the student to certain experimental techniques in the study of actual propulsive devices, using full-scale or reduced models of the pulsejet, turbojet, ramjet, and rocket motors.

440. Vehicle Systems Performance. ***Prerequisite: junior standing.*** (3).
Role of performance in systems analysis; mathematical modeling; identification of constraints, performance parameters, and performance indices. The aircraft performance problem: flight envelope, aerodynamic approximations, available propulsion systems; takeoff, landing, climb, and range performance. Modern performance optimization techniques. Applications to automobile, high-speed train, and space vehicle performance analysis.

447. Flight Testing. ***Prerequisite: Aero. Eng. 340.*** (2).
Theory and practice of obtaining flight-test data on performance and stability of airplanes from actual flight tests. No laboratory fee will be charged, but a deposit covering student insurance and operating expense of the airplane will be required.

452. (EECS 401). Probabilistic Methods in Engineering. ***Prerequisite: EECS 300 or Math. 448. I and II.*** (3).
Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions, averages, independence. Introduction to discrete and continuous random processes: wide sense stationarity, correlation, spectral density. C.I.C.E. students may not receive graduate credit for both EECS 401 and 501.

455. (EECS 488). Computer Graphics Application. ***Prerequisite: EECS 280 or I.&O.E. 473 or EECS 383.*** (3).
Application of several software packages and display devices for engineering problem solving and production of computer animated films. Use of Computek, Tektronix, and PDP graphics terminals for electrical circuit design, interactive data smoothing, production of engineering graphs, etc. POLYGRAPHICS and BEFLIX computer animation packages and their use in MTS. Production of two or three films using graphics terminals.

464. (A.&O.S. 464). Upper Atmospheric Science. ***Prerequisite: senior or graduate standing in a physical science or engineering. I.*** (3).
An introduction to physical processes in the upper atmosphere; density, temperature, composition, and winds; atmospheric radiation transfer processes and heat balance; the ionosphere; rocket and satellite measurement techniques.

471. Automatic Control Systems. ***Prerequisite: Aero. Eng. 340. I, II and IIIA.*** (3).
Automatic control problems; solution approach using feedback. Transfer function and state space description of linear control systems. Control design criteria; stability, sensitivity, time response. Use of Routh-Hurwitz, root-locus, Nyquist, Bode methods for control design. Application to design of automatic control systems for flight vehicles.

472. (EECS 460). Fundamentals of Control Systems. ***Prerequisite: Mech. Eng. 240, EECS 310 or EECS 360, and senior standing. I and II.*** (3).
Concept and importance of control systems. Control system descriptions: stability, sensitivity, transfer function representations. System performance and design criteria: stability, sensitivity, time response. Concept of feedback. Time response of linear control systems. Use of Hurwitz, root-locus, Nyquist and Bode methods for analysis and synthesis of linear control systems. Not open to students with credit for Aero. Eng. 471.

473. (EECS 461). Control Systems Laboratory. ***Prerequisite: EECS 460 or Aero. Eng. 471.*** (2).
Introduction to control system simulation and design. Experiments with physical systems. Illustration of basic control principles. Design examples and the use of computer design aids.

481. Airplane Design. ***Prerequisite: senior standing. I.*** (4).
Power-required and power-available characteristics of aircraft on a comparative basis, calculation of preliminary performance, stability, and control characteristics. Design procedure, including layouts and preliminary structural design. Subsonic and supersonic designs. Emphasis on design techniques and systems approach. Lectures and laboratory.

482. Design of Rocket- and Air-Borne Remote Sensing Probes. ***Prerequisite: senior standing.*** (4).
Design techniques and projects for geophysical, environmental, and earth resources surveys. Aircraft, sounding rocket, and balloon instruments and payloads as well as vehicle characteristics, and performance are considered. Student projects bring together in a unified concept components for sensing (remote and *in situ*), telemetering, tracking, performance, safety, and data processing.

483. Aerospace System Design. ***Prerequisite: senior standing. II.*** (4).
Aerospace system design, analysis and integration. Consideration of launch facilities, booster systems, spacecraft systems, communications, data processing, and project management. Lectures and laboratory.

484. Computer Aided Design. ***Prerequisite: Aero. Eng. 414 and senior standing. I.*** (4).
Computer generation of geometric models. Calculation of design parameters. Finite element modeling and analysis. Each student will complete a structural component design project using industry standard applications software.

490. Directed Study. ***(To be arranged).***
Individual study of specialized aspects of aerospace engineering. Primarily for undergraduates.

510. (Appl. Mech. 510). Finite Elements in Mechanical and Structural Analysis I. ***Prerequisite: Aero. Eng. 414 (Appl. Mech. 414) or Appl. Mech. 413. I.*** (3).
Introductory level. Development of the linear finite element displacement method. Virtual work. Application to trusses, beams, plates, shells, and solids. Stress, displacement, strain energy. Computer laboratory based on a general purpose finite element code. Term project.

514. Foundations of Solid Mechanics. ***Prerequisite: Aero. Eng. 414 or equivalent. I.*** (3).
Introduction to nonlinear continuum and structural mechanics. Elements of tensor calculus, basic kinematics, conservation laws (mass, linear and angular momentum, energy, etc.), constitutive equations in continua applications in hyperelastic solids, numerical (f.e.m.) methods for the corresponding nonlinear boundary value problems, derivation of non-linear shell theories from 3-D considerations.

515. Mechanics of Composite and Microstructured Media. ***Prerequisite: Aero. Eng. 514 or equivalent. I.*** (3).
An introduction to the mechanics of composite (more than one phase) solids with an emphasis on the derivation of macroscopical constitutive laws based on the microstructure. Eshelby transformation theory, self consistent methods, homogenization theory for periodic media, bounding properties for effective moduli of composites. Applications of aerospace interest.

518. (Appl. Mech. 518). Theory of Elastic Stability I. ***Prerequisite: Appl. Mech. 511. I.*** (3).
Elastic and inelastic buckling of bars and frameworks; variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

520. Gasdynamics I. ***Prerequisite: Aero Eng. 420.*** (3).
Gasdynamics at an intermediate level: Thermodynamics; the conservation equations; vorticity theorems; unsteady one-dimensional flow; the method of characteristics; stationary and moving shock waves; two-dimensional steady flow including method of small perturbations.

521. Experimental Gasdynamics. ***Prerequisite: Aero. Eng. 330 and 420.*** (3).
Experimental methods in modern gasdynamics; physical principles and interpretation. Shop practice and theory of instrument design: mechanics, electronics, and optics. Measurement of velocity, pressure, density, temperature, composition, energy and mass transfer in fluids and plasmas. Transducers and laboratory instrumentation in gasdynamic research.

522. Gasdynamics II. ***Prerequisite: Aero. Eng. 520.*** (3).
The Navier-Stokes equations, including elementary discussion of tensors; exact solutions. Laminar boundary-layer theory; asymptotic concepts; solutions for incompressible boundary layers. Compressible boundary layers; special solutions; transformation of equations; heat transfer in forced and free convection. Introduction to the mechanics of turbulence; Reynolds stresses; turbulent boundary layers.

523. Numerical Methods in Fluid Dynamics I. ***Prerequisite: Aero. Eng. 420 or equivalent. I.*** (3).
Basic mathematical ideas needed for computational fluid dynamics, finite-difference approximations to partial differential equations, applications to model equations for fluid dynamics.

529. Introduction to Energy Transfer. ***Prerequisite: Aero. Eng. 330.*** (3).
A survey of energy transfer processes including unsteady heat conduction, convection in non-reactive and reactive flows, and radiation. Aerospace applications, including re-entry heating, ablation, rocket nozzle cooling, radiative transfer, satellite heating, convection in dissociated flows.

530. Propulsion III. ***Prerequisite: Aero Eng. 430.*** (3).
Continuation of Aero. Eng. 430. Further treatment of aircraft engine performance, including off-design operation, and study of selected problems in the field of propulsion.

532. Introduction to Gaskinetics and Real Gas Effects. ***Prerequisite: Aero. Eng. 420.*** (3).
A study of some modern topics of flow problems not covered in the traditional gasdynamics of ideal gases: concepts of gaskinetics, aerodynamics of free molecules, shock transition layer, real gas effect, high temperature effects, multicomponent flows, etc.

533. Combustion Processes. ***Prerequisite: Aero. Eng. 320.*** (3).
This course covers the fundamentals of combustion systems, and fire and explosion phenomena. Topics covered include thermochemistry, chemical kinetics, laminar flame propagation, detonations and explosions, flammability and ignition, spray combustion, and the use of computer techniques in combustion problems.

535. Rocket Propulsion. ***Prerequisite: Aero. Eng. 430.*** (3).
Analysis and performance of liquid and solid propellant rocket powerplants; propellant thermochemistry, heat transfer, system considerations, advanced rocket propulsion techniques.

540. Intermediate Dynamics. ***Prerequisite: Mech. Eng. 240. I.*** (4).
Kinematics of motion, particle dynamics, Lagrange's equations. Rigid body dynamics including Euler's equations, the Poinsot construction, spin stabilization, the rotation matrix. Vibrations of coupled systems, orthogonality relationships, generalized co-ordinates and generalized system parameters.

541. Computational Dynamics. ***Prerequisite: Aero. Eng. 540. I.*** (3).
Formulation of dynamics problems for computer solution. Kinematic preliminaries. Matrix and dyadic notation. Constraints, generalized coordinates, and quasi-coordinates. Generalized speeds. Rigid and flexible multibody dynamics. Computational efficiency.

542. Astrodynamics I. ***Prerequisite: Aero. Eng. 340. I.*** (3).
The study of motion of aircraft in a vacuum and in the atmosphere with emphasis on preliminary mission planning. Analysis of trajectories in suborbital, orbital, lunar, and interplanetary operations. Aerodynamic forces and heating characteristics and their effect on the selection of flight paths during entry into planetary atmospheres.

543. Structural Dynamics. ***Prerequisite: Aero. Eng. 414 or 540.*** (3).
Natural frequencies and mode shapes of elastic bodies. Nonconservative elastic systems. Structural and viscous damping. Influence coefficient methods for typical flight structures. Response of structures to random and shock loads. Lab demonstration.

544. Aeroelasticity. ***Prerequisite: Aero. Eng. 414 or 540.*** (3).
Introduction to aeroelasticity. Vibration and flutter of elastic bodies exposed to fluid flow. Static divergence and flutter of airplane wings. Flutter of flat plates and thin walled cylinders at supersonic speeds. Oscillations of structures due to vortex shedding.

545. Principles of Vertical Take-Off and Landing Aircraft. ***Prerequisite: preceded or accompanied by Aero. Eng. 420.*** (3).
Introduction to helicopter performance, aerodynamics, stability and control, vibration and flutter. Other V/STOL concepts of current interest.

546. Advanced Dynamics. ***Prerequisite: Aero. Eng. 540 or Appl. Mech. 443 or Mech. 443. II*** (3).
Hamilton's equations, canonical transformations, and Hamilton-Jacobi theory. Applications to orbital problems. General perturbation theory. Introduction to special relativity.

548. Astrodynamics II. ***Prerequisite: Aero. Eng. 542.*** (3).
Orbit determination. Systems of canonical equations. Perturbation theory with applications to the motion of an artificial satellite. Lunar and planetary theories.

549. (Appl. Mech. 549) (Mech. Eng. 549). Random Vibrations of Mechanical Systems. ***Prerequisite: Mech. Eng. 240.*** (3).
Random mechanical inputs; wind buffeting; earthquakes; surface irregularities. Engineering applications include response of linear spring-mass system and an elastic beam to single and multiple random loading. Failure theories. Necessary concepts such as ensemble averages, correlation functions, stationary and ergodic random processes, power spectra, are developed heuristically.

550. (EECS 560). Linear Systems Theory. ***Prerequisite: graduate standing. I and II.*** (3).
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.

551. (EECS 562). Non-linear Dynamical Systems. ***Prerequisite: graduate standing. II.*** (3).
Introduction to and analysis of phenomena which occur in non-linear dynamical systems. Topics include: equilibria, limit cycles, second order systems and phase plane analysis, bifurcations and chaos, Liapunov and input-output stability theory, asymptotic analysis including averaging theory and singular perturbations, numerical techniques.

552. (EECS 501). Probability and Random Processes. ***Prerequisite: EECS 401 or graduate standing. I and II.*** (4).
Introduction to probability and random processes. Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, poisson and wiener processes, stationary processes, auto correlation, spectral density, effects of filtering, linear least - squares estimation, and convergence of random sequences.

553. (EECS 502). Continuous State Stochastic Processes. ***Prerequisite: EECS 501. II.*** (3).
Gaussian processes. correlation functions. Stationary processes; ergodic properties and spectral theory. Response of linear systems to stochastic inputs. Introduction to spectral estimation. Least mean square error linear filtering, estimation and prediction. Recursive filtering. Examples and applications in control and communications.

565. (Appl. Mech. 565). Optimal Structural Design. ***Prerequisite: Aero. Eng. 414 and 350. I.*** (3).
Optimal design of structural elements (bars, trusses, frames, plates, sheets) and systems; variational formulation for discrete and distributed parameter structures; sensitivity analysis; optimal material distribution and layout; design for criteria of stiffness, strength, buckling, and dynamic response.

570. Guidance and Navigation of Aerospace Vehicles. ***Prerequisite: a course in feedback control. I.*** (3).
Principles of space vehicle, homing and ballistic missiles guidance systems in two and three dimensions. Explicit, linear perturbation, and velocity-to-be gained guidance modes. Mechanization by inertial and other means, including strapped-down and stable-platform inertial systems. Celestial navigation procedures with determination and redundant measurements. Application of Kalman filtering to recursive navigation theory.

571. (EECS 561). Digital Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 471/ Mech. Eng. 461. I.*** (3).
Sampling and data reconstruction in computer control systems, z-transforms and state equations to describe discrete and mixed data systems. Analysis of digital feedback systems using root locus, Nyquist and Jury tests. Design of digital feedback systems using frequency domain techniques and state space techniques. Non-linear digital feedback systems.

572. (EECS 566). Non-linear Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 461/Mech. Eng. 471 and EECS 562/Aero. Eng. 572. I.*** (3).
Methods of analysis and design of non-linear control systems. Topics include: stabilizing controllers, absolute stability theory, describing function methods, input-output stability of feedback systems. Control techniques for non-linear systems: dither, vibrational control, variable structure systems and sliding mode control, linearization by nonlinear feedback.

573. Real-Time Simulation of Dynamic Systems. ***Prerequisite: permission of instructor. II.*** (3).
High-speed simulation of systems described by ordinary differential equations with emphasis on real-time applications and hardware-in-the-loop. Error analysis of numerical integration methods, use of multiple frame rates, treatment of discontinuous non-linearities, performance of D-A and A-D converters. Examples include control systems, flexible structures, and aerospace vehicles.

574. Control of Aircraft, Missiles, and Space Vehicles. ***Prerequisite: a course in feedback control. I.*** (3).
Analysis and synthesis of autopilots for aircraft. Design of thrust-vector control systems including effects of elastic structures and fuel sloshing. Attitude control systems for space vehicles; mechanization using jet thrusters and inertia wheels; gravity gradient moments.

575. Optimization of Space Trajectories. ***Prerequisite: permission of instructor. I.*** (3).
Introduction to optimal control. Switching theory. Applications to aerospace trajectories: orbital transfer and rendezvous, atmospheric reentry, aero-assisted transfer.

576. (EECS 563). Optimal Control. ***Prerequisite: EECS 560/Aero. Eng. 550. II.*** (3).
Definition of optimal control problems. Formulation of discrete time optimal control problems as constrained mathematical programming problems. Formulation of continuous time optimal control problems as variational problems. The Pontryagin necessary condition. Application to a variety of specific optimal control problems from diverse disciplines. Introduction to computational methods in optimal control.

577. (EECS 505) (I.&O.E. 511) (Math. 562). Continuous Optimization Methods. ***Prerequisite: Math. 417 or Math. 419. I and II.*** (3).
Survey of continuous optimization problems. Unconstrained optimization problems: unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.

578. (EECS 564). Estimation, Filtering, and Detection. ***Prerequisite: EECS 501, 560. II.*** (3).
Principles of estimation, linear filtering and detection. Estimation: linear and non-linear minimum mean squared error estimation, and other strategies. Linear filtering: Wiener and Kalman filtering. Detection: simple, composite, binary and multiple hypotheses. Neyman-Pearson and Bayesian approaches.

579. Control of Aerospace Structures. ***Prerequisite: Aero. Eng. 471, Aero. Eng. 414, and Aero. Eng. 550. II.*** (3).
Equations of motion of controlled elastic structures; modal and finite element formulations; shape control; active damping using feedback; application to control of flexible aircraft and flexible space structures.

580. (EECS 565). Linear Feedback Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461 and EECS 560/ Aero. Eng. 550. II.*** (3).
Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design tradeoffs. Design formulations using both frequency domain and state space descriptions. Pole placement/ observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems.

590. Directed Study. ***(To be arranged).***
Individual study of specialized aspects of aerospace engineering. Primarily for graduates.

596. Aurora and Airglow. ***Prerequisite: permission of instructor. II.*** (3).
Morphology and physics of the aurora and airglow. Emission spectra in the aurora and their atomic and molecular origin; proton aurora; mesastable excitation; calculation of emission profiles. Night-and day-glow; predawn and post-twilight enhancements; mid-latitude red arc; excitation mechanisms.

597. (A.O. & S.S. 597). Fundamentals of Space Plasma Physics. ***Prerequisite: Senior level statistical physics course. II.*** (3).
Basic plasma concepts, boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wind. Collisionless shocks, propagating and planetary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading.

610. (Appl. Mech. 610). Finite Element Methods in Mechanics II. ***Prerequisite: Aero. Eng. 510 (Appl. Mech. 510) (Mech. Eng. 557). II.*** (3).
Advanced topics in finite element theory. Plates, shells, large deflections, stability, plasticity, dynamics. Iterative methods for non-linear problems. Solution of field problems for fluid flow and electric potential. Survey of software available.

618. (Appl. Mech. 618). Theory of Elastic Stability II. ***Prerequisite: Aero. Eng. 518 or equivalent and graduate standing. II.*** (3).
Koiter's theory for buckling, post-buckling, mode interaction and imperfection sensitivity behavior in non-linear solids. Applications to thin-walled beams, cylindrical and spherical shells as well as to 3-D hyperelastic solids. Loss of ellipticity in finitely strained solids. Hill's theory on bifurcation, uniqueness and post-bifurcation analysis in elastic-plastic solids with applications.

620. Dynamics of Viscous Fluids. ***Prerequisite: Aero. Eng. 520.*** (3).
Navier-Stokes equations; low Reynolds number flows; incompressible and compressible laminar boundary layers; boundary layer stability and transition to turbulence; turbulent boundary layers, wakes, and jets.

621. Dynamics of Compressible Fluids. ***Prerequisite: Aero. Eng. 520.*** (3).
Theory of characteristics; shock-wave phenomena; interaction problems; hodograph transformation; transonic flow.

623. Numerical Methods in Fluids Dynamics II. ***Prerequisite: Aero. Eng. 523 or equivalent preceded or accompanied by Aero. Eng. 520 and Aero. Eng. 522. II.*** (3).
Techniques for numerical calculation of boundary-layer flows, transonic potential flows, and compressible rotational flows. Solution of the Navier-Stokes equations. Other topics such as grid generation, turbulence modeling, etc.

627. Continuum Theory of Fluids. ***Prerequisite: Aero. Eng. 520.*** (3).
Physical concepts underlying the flow of fluids acted upon by stresses arising from viscosity and from electromagnetic and gravity fields. Invariant analysis of stress-strain relations. Maxwell's equations, analysis of electromagnetic stresses and energy dissipation in moving media, the equations of motion in energy in a moving fluid, and some solutions of the complete equations.

628. Statistical Theory of Fluids. ***Prerequisite: Aero. Eng. 532. II.*** (3).
Statistical theory of flow from the viewpoint of the Boltzmann equation. The Chapman-Enskog solution for the transport phenomena. Rarefied gas dynamics. Studies of the random fluctuation phenomena by means of the Fokker-Planck equation, the generalized harmonic analysis of Weiner-Khintchine. Brownian motion, turbulent diffusion, etc. Irreversible thermodynamics and Onsager's reciprocal relation.

632. Gas Flows with Chemical Reactions. ***Prerequisite: Aero. Eng. 532, and 620.*** (3).
Thermodynamics of gas mixtures, chemical kinetics, conservation equations for multi-component reacting gas mixtures. Deflagration and detonation waves. Nozzle flows and boundary layers with reaction and diffusion.

651. (EECS 600). Function Space Methods in System Theory. ***Prerequisite: EECS 400. II.*** (3).
Introduction to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert spaces, resolution spaces. Emphasis on using these concepts in systems problems.

652. (EECS 602). Theory of Stochastic Processes. ***Prerequisite: EECS 502.*** (3).
Measure theoretic treatment of stochastic processes. Analysis and representation of various stochastic processes using function analytic concepts. Wiener processes, martingales, diffusion processes. Stochastic integrals, introduction to stochastic differential equations and stochastic calculus.

653. (EECS 603). Estimation Theory. ***Prerequisite: EECS 553. II.*** (3).
Representations of stochastic processes for statistical estimations. Least squares and linear unbiased minimum variance estimators. Bayes, min-max, maximum likelihood of posteriori and maximum likelihood estimators. Recursive filtering, prediction, and interpolation. Applications to control and communications.

673. (EECS 617) (Nuc. Eng. 673). Topics in Theoretical Plasma Physics. ***Prerequisite: Nuc. Eng. 571 or EECS 517 or Aero. Eng. 726. I and II*** (3).
An advanced course in theoretical plasma physics covering topics of current research interest. Specific content will vary from year to year. Representative topics include: studies of weakly ionized plasmas with applications to gas lasers; space plasmas; laser fusion plasmas; and non-linear plasma dynamics and plasma turbulence.

676. (EECS 663). Theory of Optimal Control ***Prerequisite: EECS 563 or Aero. Eng. 575.*** (3).
General theoretical questions in optimal control: existence of optimal controls, derivation of necessary and sufficient conditions for optimality. Selected special topics: singular control, state constraints, min-max criteria, systems described by partial differential equations, the second variation. Examples and applications of the theory.

721. Turbulence. ***Prerequisite: Aero. Eng. 620.*** (3).
Physical and mathematical description of turbulence in boundary layers, wakes, jets, and behind grids, turbulent fields; theories for turbulent mass, momentum, heat, and particle diffusion.

726. Introduction to Plasma Dynamics. ***Prerequisite: permission of instructor.*** (3).
Physical properties of a plasma; particle orbit theory; collective phenomena in a plasma; kinetic equations for a plasma; instabilities; transport phenomena and derivation of the magnetohydrodynamic equations.

729. Special Topics in Gasdynamics. ***Prerequisite: permission of instructor. (To be arranged).***
Advanced topics of current interest.

740. Special Topics in Flight Dynamics and Control Systems. ***(To be arranged).***

800. Seminar. ***(To be arranged).***

810. Seminar in Structures. ***(To be arranged).***

820. Seminar in Aerodynamics. ***(To be arranged).***

830. Seminar in Propulsion. ***(To be arranged).***

840. Seminar in Flight Dynamics and Control Systems. ***(To be arranged).***

880. Seminar in Space Technology. ***Prerequisite: permission of instructor. (To be arranged).***

990. Dissertation/Pre-Candidate. I and II (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination must be held under a full-term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I and II*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination must be held under a full-term candidacy enrollment.

Applied Mechanics —

Administered by the Department of Mechanical Engineering and Applied Mechanics

Department Office:
2250 G.G. Brown
phone (313) 764-2694
See Page 60 for statement on Course Equivalence.

402. Experimental Stress Analysis. ***Prerequisite: Mech. Eng. 210 or 211 and Math. 216. I.*** (3).
Review of plane stress-strain relationships; fundamentals of photoelastic method of stress determination using transmission polariscope and methods of separating principal stresses; theory and application of brittle coatings; fundamentals of moiré fringe method of strain analysis; techniques of mechanical, optical, and electrical resistance strain gages and related circuitry. Lectures and laboratory experiments.

403. Experimental Mechanics. ***Prerequisite: Mech. Eng. 210 or 211 and 240. II*** (2).
Theory and practice in the design and execution of experiments in engineering. Modeling theory. Probability and elementary statistics applied to data treatment; analysis, design, and use of instruments for static or dynamic conditions, including measurement of strain, pressure, temperature, and viscosity. One-hour lecture and two-hour laboratory, with assigned experiments.

404. (Mech. Eng. 404). Coherent Optical Measurement Techniques. ***Prerequisite: senior or graduate standing. II.*** (3).
Modern optical techniques using lasers in measurements of mechanical phenomena. Introduction to the nature of laser light and Fourier optics; use of holograph and laser speckle as measurement techniques; laser doppler velocimetry.

407. Theory of a Continuous Medium. ***Prerequisite: Mech. Eng. 210 or 211; Mech. Eng. 325 or Mech. Eng. 324; Mech. Eng. 235; Math. 450. I.*** (3).
The general theory of a continuous medium. Kinematics of large motions and deformations; stress tensors; conservation of mass, momentum and energy; discontinuity requirements; restrictions on constitutive equations from thermodynamics; invariance requirements; constitutive equations for elasticity, viscoelasticity, plasticity, and fluids; applications for special deformations with emphasis on viscoelastic fluid flow.

411. (Aero. Eng. 411) (Civ. Eng. 412) (Nav. Arch. 411). Finite Element Applications. ***Prerequisite: Eng. 103, and Mech. Eng. 210 or 211. I.*** (3).
The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, chells, etc., and displaying the solutions graphically. Students learn to prepare input data and interpret results. A short introduction to the underlying theory is also presented.

412. Advanced Strength of Materials. ***Prerequisite: Mech. Eng. 311. I.*** (3).
Review of energy methods, Betti's reciprocal theorem; elastic, thermoelastic and

elastoplastic analysis of axisymmetric thick cylinders and rotating discs; bending of rectangular and circular plates, including asymmetric problems; beams on elastic foundations; axisymmetric bending of cylindrical shells; torsion of prismatic bars.

414. (Aero. Eng. 414). Structural Mechanics II. ***Prerequisite: Aero. Eng. 314. I and II.*** (3).
Introduction to plate theory. Stability of structural elements; columns and beam columns; plates in compression and shear; secondary instability of columns. Introduction to matrix methods of deformation analysis; structural dynamics.

422. Intermediate Mechanics of Fluids. ***Prerequisite: Mech. Eng. 325, preceded or accompanied by Appl. Mech. 501. I.*** (3).
Fundamental concepts of theoretical fluid mechanics. Development and applications of continuity, stream functions, vorticity. Euler and Bernoulli equations, irrotational flows. Laplace equation, conformal mapping, numeral methods. Hydrodynamic forces and moments. Navier-Stokes equations and solutions. Elements of boundary layers, jets, wakes.

443. (Mech. Eng. 443). Intermediate Dynamics. ***Prerequisite: Mech. Eng. 240. II.*** (3).
Vector Kinematics in 3D, rotating coordinate systems. Systems of particles. Rigid body inertial properties. Rigid body dynamics: Euler equations, direct and inverse dynamic problems, bearing reactions, tops and gyroscopes.

450. Mechanics of Composite Materials. ***Prerequisite: Mech. Eng. 210 or 211 and 240. II.*** (3).
Classification and characterization of composite materials. Behavior in the elastic range. Stress-strain relations for anisotropic media. Orthotropic laminae. Plane problems. Theory of anisotropic plates. Bending, buckling and vibrations of laminated plates.

490. Special Topics in Applied Mechanics. ***Prerequisite: permission of instructor. I, II, III, IIIa and IIIb. (Credit to be arranged).***
Selected topics pertinent to research and study in applied mechanics.

495. (Bioeng. 495). Introduction to Bioengineering. ***Prerequisite: permission of instructor. I.*** (1).
Definition of scope, challenge, and requirements of bioengineering field. Faculty members review engineering-life sciences interdisciplinary activities as currently pursued in the College of Engineering and Medical School. P/F credit only.

501. Analytical Methods in Mechanics I. ***Prerequisite: Mech. Eng. 210 or 211, Mech. Eng. 240 and Math. 216. II.*** (3).
An introduction to the notation and techniques of vectors, tensors, and matrices as they apply to mechanics. Emphasis is on physical motivation of definitions and operations, and on their application to problems in mechanics. Extensive use is made of examples from mechanics.

502. Methods of Differential Equations in Mechanics. ***Prerequisite: Math 454. II.*** (3).
Applications of differential equation methods of particular use in mechanics. Boundary value and eigenvalue problems are particularly stressed for linear and nonlinear elasticity, analytical dynamics, vibration of structures, wave propagation, fluid mechanics, and other applied mechanic topics.

505. (Mech. Eng. 505). Finite Element Methods in Mechanical Engineering and Applied Mechanics. ***Prerequisite: graduate standing. I and II.*** (3).
Theoretical and computational aspects of finite element methods. Examples from areas of thermal diffusion, potential/irrotational flows, lubrication, structural mechanics, design of machine components, linear elasticity, and Navier-Stokes flows problems. Program development and modification are expected as well as learning the use of existing codes.

510. (Aero. Eng. 510). Finite Elements in Mechanical and Structural Analysis I. ***Prerequisite: Aero. Eng. 414(Appl. Mech. 414) or Appl. Mech. 412. I.*** (3).
Introductory level. Development of the linear finite element displacement method. Virtual work. Application to trusses, beams, plates, shells and solids. Stress displacement, strain energy. Computer laboratory based on a general purpose finite element code. Term project.

511. Intermediate Mechanics of Solids. ***Prerequisite: Mech. Eng. 210 or 211, preceded or accompanied by Appl. Mech. 501. I.*** (3).
Analysis of stress strain, generalized Hooke's law. St. Venant's torsion and flexure problems. Plane stress and plane strain problems. Introduction to elastic structural approximations and inelastic behavior.

512. Theory of Elasticity. ***Prerequisite: Appl. Mech. 511. II.*** (3).
Basic equations of three dimensional elasticity. Variational principles, the plane problem, and torsion and bending of prismatic beams, with application of complex function theory.

513. (Civ. Eng. 513). Fracture Analysis. ***Prerequisite: senior standing. I.*** (3).
Self-contained introduction to linear elastic fracture mechanics including elements of plane elasticity. Topics: Airy stress function, Green's functions, dislocation solutions, crack tip asymptotics, stress intensity factors, interface cracks, numerical solutions based on singular integral equations.

514. Nonlinear Fracture Mechanics. II. (3). ***Prerequisite: Appl. Mech. 412.***
Elements of solid mechanics, historical development of fracture mechanics, energy release rate of cracked solids, linear elastic fracture mechanics, elastic-plastic fracture mechanics.

516. Theory of Shells I. ***Prerequisite: Appl. Mech. 511. I and II.*** (3).
General theory for deformation of thin shells with small deflections; various approximate theories, including the membrane theory. Application to various shell configurations.

517. Theory of Linear Viscoelasticity I. ***Prerequisite: Appl. Mech. 511. I.*** (3).
Viscoelastic stress-strain relations; generalized creep and relaxation models, operational approach. Correspondence between viscoelastic and elastic solutions of boundary value problems. Three-dimensional theory of linear viscoelastic media. Quasi-static problems; sinusoidal oscillation problems; use of complex modulus and compliance; dynamic problems, impact.

518. (Aero. Eng. 518). Theory of Elastic Stability I. ***Prerequisite: Appl. Mech. 511. I.*** (3).
Elastic and inelastic buckling of bars and frameworks; variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

519. Theory of Plasticity I. ***Prerequisite: Appl. Mech. 511. I.*** (3).
Fundamentals of plasticity; stress-strain relations, yield criteria and the general behavior of metals and nonmetals beyond proportional limit in the light of experimental evidence. Various approximate theories with emphasis on the theory of plastic flow. Applications to problems of bending, torsion, plane strain and plane stress; technological problems.

521. Dynamics of Nonhomogenous Fluids. ***Prerequisite: Appl. Mech. 422. I and II.*** (3).
Theory of large-amplitude motion of fluids and variable density and entropy in a gravitational field, including the phenomenon of blocking and selective withdrawal of water; waves of small and of finite amplitudes in stratified fluids, including waves in the lee of mountains; stability of stratified flows; flow

of nonhomogeneous fluids in porous media. Analogy with rotating fluids.

522. Mechanics of Inviscid Fluids I. ***Prerequisite: Appl. Mech. 422. II.*** (3).
Theory of inviscid flows. Forces. moments, and the added mass tensor; application of conformal mapping; free streamline theory; flows with concentrated and distributed vorticity; linear wave theory; flow past slender bodies and wings; holograph and Karman-Tsien methods for subsonic flows; method of characteristics; perturbation methods in high-speed flows.

523. Mechanics of Viscous Fluids I. ***Prerequisite: Appl. Mech. 422. II.*** (3).
Theory of viscous flows. Exact solutions of the Navier-Stokes equations; slow motion solutions; boundary layers; jets and wakes; forced and free convection flows; heat transfer and compressible boundary layers; hydrodynamic stability; statistical theories of turbulence; rotating flows; surface tension effects.

524. Wave Motion in Fluids. ***Prerequisite: Appl Mech. 422. II.*** (3).
Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to, a moving body; Korteweg-deVries equation; conoidal and solitary waves in water; wave reflection and diffraction; shallow-water waves by the method of characteristics; statistical approach and spectral analysis; wave generation.

525. Non-Newtonian Fluid Mechanics. ***Prerequisite: Mech. Eng. 325 or Chem. Eng. 341.*** (3).
Non-Newtonian continuous media; flow classifications, stress-strain, rate-of-strain, laminar shear flow models for developed and boundary layer flows, stability compared to Newtonian case, turbulent flows. Flows of nonhomogenenous systems; non-Newtonian fluids vs. non-Newtonian behavior of particulate and multiphase media, laminar and turbulent shear flow models, rigid particle suspensions, flexible particle suspensions, gas-liquid flows. Momentum and energy transport and relation to boundary shear and other problems.

526. (Mech. Eng. 526). Computational Fluid Mechanics. ***Prerequisite: Appl. Mech. 422 or Mech. Eng. 521. I.*** (3).
Application of finite differences and other numerical techniques to current problems in fluid mechanics, including high speed flow, boundary layer and separated flows. Problems in aerodynamics, combustion, and turbulent flow. Random choice, vortex, and panel methods. Visual presentation of numerical simulations.

529. Advanced Laboratory in Mechanics of Fluids. ***Prerequisite: Appl. Mech. 422. II.*** (2).
Laboratory experiments designed to give the student an insight into the physical behavior of fluids and the role of experimentation in research. Experimental results are compared with existing theory whenever possible. Experiments include fundamental studies of free streamline flows, drag forces and moments, pressure distributions, thermal instability, slow-motion flows, and the Prandtl-Meyer flows.

540. (Aero. Eng. 540). Intermediate Dynamics. ***Prerequisite: Mech. Eng. 240. I.*** (4).
Kinematics of motion, particle dynamics, Lagrange's equations. Rigid body dynamics including Euler's equations, the Poinsot construction, spin stabilization, the rotation matrix. Vibrations of coupled systems, orthogonality relationships, generalized co-ordinates, and generalized system parameters.

541. (Mech. Eng. 541). Mechanical Vibrations. ***Prerequisite: Mech. Eng. 440. I.*** (3).
Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete non-conservative systems. Vibration of multi-degree-of-freedom systems. Small oscillation theory. Free vibration eigenvalue problem. Undamped system response. Viscously damped systems. Vibration of continuous systems. Modes of vibration of bars, beams, membranes, plates.

545. Wave Motion in Solids. ***Prerequisite: Appl. Mech. 460 and Mech. Eng. 314. II.*** (3).
Rayleigh, Love, and Stoneley waves. Harmonic and transient waves in wave guides. Cagniard's method. Approximate theories. Introduction to characteristics and anelastic waves.

546. (Bioeng. 546). Biomechanics. ***Prerequisite: Mech. Eng. 210 or 211, and Mech. Eng. 240. II.*** (3).
Definition of biological tissue behaviors, including elastic, viscoelastic, and plastic properties, with emphasis on bone; dynamics of gait; impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

548. Nonlinear Oscillations and Dynamic Stability of Mechanical Systems. ***Prerequisite: Appl Mech. 443/Mech. 443 or 540. II.*** (3).
Large-amplitude vibrations of mechanical systems; dynamic instability theory of rods, plates, and shells; methods of Liapunov; asymptotic approaches of Krylov, Bogoliubov, and Mitropolsky; perturbation methods; Floquet theory.

549. (Aero. Eng. 549) (Mech Eng. 549). Random Vibrations of Mechanical Systems. ***Prerequisite: Mech. Eng. 240.*** (3).
Random mechanical inputs: wind buffeting; earthquakes; surface irregularities. Engineering applications include response of linear spring-mass system and an elastic beam to single and multiple random loading. Failure theories. Necessary concepts such as ensemble averages, correlation function, stationary and ergodic random processes, power spectra, are developed heuristically.

565. (Aero. Eng. 565). Optimal Structural Design. ***Prerequisite: Aero. Eng. 435 or 414. II.*** (3)
Optimal design of structural elements (bars, trusses, frames, plates, sheets) and systems; variational formulation for discrete and distributed parameter structures; sensitivity analysis; optimal material distribution and layout; design for criteria of stiffness, strength, buckling, and dynamic response.

590. Engineering Practice and Problem Solving in Applied Mechanics. ***Prerequisite: graduate standing. I, II, IIIa, IIIb, and III.*** (3).
An individual study course designed for the master's degree candidate. Student and individual faculty members will select a problem of mutual interest and appropriate depth and complexity. The course is designed to develop the ability to do background research, to select analytical and computational models, and to utilize experimental evidence.

605. (Mech. Eng. 605). Advanced Finite Element Methods in Mechanics. ***Prerequisite: Mech. Eng. 505/Appl Mech. 505. II.*** (3).
Recent developments in finite element methods: mixed, hybrid, mixed-hybrid, reduced integration penalty, singular, boundary integral elements. Emphasis on the methodology for developing elements by using calculus of variations. Applications selected from various branches of solid and fluid mechanics.

610. (Aero. Eng. 610). Finite Element Methods in Mechanics II. ***Prerequisite: Aero. Eng. 510 (Appl Mech. 510). I.*** (3).
Advanced topics in finite element theory. Plates, shells, large reflections, stability, plasticity, dynamics. Iterative methods for nonlinear problems. Solution of field problems for fluid flow and electric potential. Survey of software available.

618. (Aero. Eng. 618). Theory of Elastic Stability II. ***Prerequisite: Aero. Eng. 518 or equivalent and graduate standing. II.*** (3).
Koiter's theory for buckling, post-buckling, mode interaction and imperfection sensitivity behavior in nonlinear solids. Applications to thin-walled beams, cylindrical and spherical shells as well as to 3-D hyperelastic solids. Loss of ellipticity in finitely strained solids. Hill's theory on bifurcation, uniqueness and post-bifurcation analysis in elastic-plastic solids with applications.

623. Theory of Hydrodynamic Stability. ***Prerequisite: Appl. Mech. 422. I.*** (3).
Treatment of hydrodynamic equations in general co-ordinates by tensorial methods; gravitational, hydromagnetic, and surface-tension instabilities; instability of rotating fluids and of flow in porous media. Tollmien-Schlichting waves; instability of free-surface flows.

626. (Mech. Eng. 626). Singular-Perturbation and Approximate Methods in the Mechanics of Fluids I. ***Prerequisite: Appl. Mech. 422 or Mech. Eng. 521. II.*** (3).
Application of asymptotic methods to fluid mechanics, with special emphasis on the method of matched expansions. Regular perturbation solutions; suppression of secular terms; method of multiple times; boundary layer and low Reynolds number flows by inner and outer expansions; phenomena in rotating flows; asymptotic solutions of the Orr-Sommerfeld equation.

640. The Principles and Applications of Variational Methods. ***Prerequisite: Appl. Mech. 443/Mech. Eng. 443 or Mech. Eng. 540.*** (3).
Fundamental processes of the calculus of variations; derivation of the Euler-Lagrange equations; proof of the fundamental lemma; applications of the direct method; Lagrange multipliers; "natural" boundary conditions; variable end points; Hamilton's canonical equation of motion; Hamilton-Jacobi equations. Descriptions of fields by variational principles. Applications to mechanics. Approximate methods.

641. (Mech. Eng.641) Advanced Vibrations of Structures. ***Prerequisite: Appl. Mech. 541/Mech. Eng. 541. II.*** (3)
Energy formulation for nonconservative gyroscopic systems. Spectral methods for free and forced vibrations. Eigenvalue and boundary value problems. Non self-adjoint systems. Variational methods of approximation: Bubnov-Galerkin. Perturbation theory for the eigenvalue problem. Dynamics of rotating systems. Dynamics of constrained dynamical systems.

680. Numerical Methods in Mechanics. ***Prerequisite: one 500 level course in mechanics. I.*** (3).
Matrix methods applied to the stiffness matrix, vibration analysis, and hydrodynamic stability. Solution of integral equations by collocation, variational methods, successive approximations; applications to elasticity, plates, slow viscous flow, and inviscid flow. Finite difference and finite increment methods; application to wave propagation, structural stability, plasticity, free-surface flows and wakes.

716. Theory of Shells II. ***Prerequisite: Appl. Mech. 516.*** (3).
Refinements in classical shell theory to account for anisotropy, shear deformation, thick shells. Nonlinear shell theory with particular reference to stability; plastic deformation of shells; dynamics of shells.

719. Theory of Plasticity II. ***Prerequisite: Appl. Mech. 519. II.*** (3).
Plastic theory for materials with isotropic hardening, kinematic hardening, and time dependence. Theories based on crystal slip; variational theorems; range of validity of total deformation theories. Theory of generalized stresses applied to circular plates; behavior at finite deflection; limit analysis of shells. Plane stress, plane strain, and axial symmetry. Plastic response to impact loads. Minimum weight design.

801. Seminar in Applied Mechanics. ***Prerequisite: permission. I.*** (1 or 2).
A series of weekly seminars. Students who contribute may elect one or two hours credit.

911. Research in Mechanics of Solids. I, II, IIIa. ***(To be arranged).***
Research in theory of elasticity, plasticity, photoelasticity, structures, and materials. Special problems involving application of theory and experimental investigation.

921. Research in Mechanics of Fluids. I, II, IIIa. ***(To be arranged).***
Analytical or experimental investigation of special problems in fluid flow, or intensive study of a special subject in fluid mechanics.

941. Research in Dynamics. I, II, IIIa. ***(To be arranged).***
Original investigation in the fields of body motions such as vibrations of mechanical systems, control problems, and other fundamental problems in the mechanics of rigid body motion.

990. Dissertation/Pre-Candidate. I and II (2-8); IIIa and IIIb. (1-4).
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I and II*** (8); ***IIIa and IIIb.*** (4).
Dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

Applied Physics*,** (Division 320)

Department Office:
1036 Randall
phone (313) 936-0635

*College of Literature, Science and the Arts.
**College of Engineering.

Professor Roy Clarke, Director; Professors Allen, Ben-Jacob, Bhattacharya, Gilgenback, Merlin, Orr, Rand, Sander, Srolovitz, Steel, Uher, Zorn.

514. Applied Physics Seminar. ***Prerequisite: graduate studies. I and II.*** (3).
Graduate seminars are required each term to familiarize students with current research and problems. Given by a mix of faculty, external lecturers and the students themselves to acquaint students with the scope of research activity and opportunities, the goal of the seminar structure is to promote a strong interaction with the work being done in Applied Physics.

518. (EECS 518, Physics 518). Microcomputers in Experimental Research. ***Prerequisite: graduate research. I.*** (3).
A graduate-level laboratory course in the application of microcomputers to experimental research, this course is designed to give students hands-on experience of modern techniques of data acquisition, data handling and analysis, and graphical presentation of results, using microcomputers. A number of experiments will be carried out which illustrate how to interface modern research instrumentation in a variety of commonly encountered experimental situations.

530. (EECS 530). Electromagnetic Theory. ***Prerequisite: EECS 331. I.*** (3).
Maxwell's equations. Electrostatics, magneto-statics and electrodynamics applied to waveguides, antennas, propagation and diffraction. Boundary conditions, uniqueness of solutions, Green's functions, potentials and multipole expansions, integral representations and other expansions for fields. Reciprocity, equivalence, induction, reaction and Babinet's theorem.

531. (EECS 630). Advanced Electromagnetics. ***Prerequisite: EECS 530. I.*** (3).
Propagation in anisotropic media (crystals, ionosphere) and near conducting surfaces. Special relativity, Lienard-Wiechert potentials, radiation by moving charges (synchrotron, Cerenkov, Bremsstrahlung radiation), multipole radiation. Cross sections and scattering from electrons, atoms, inhomogeneities, dynamic density fluctuations and spheres. Coherent and incoherent scattering and an introduction to nonlinear matter-field interactions.

540. (EECS 540). Applied Quantum Mechanics I. ***Prerequisite: EECS 300 or Math. 404, Physics 242. I.*** (3).
Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics; one dimensional quantum problems including the quantum wells, WKB approximation, tunneling and the harmonic oscillator; introduction to angular momentum; the hydrogen atom; molecular orbitals; the rigid rotator and diatomic molecules; spin and identical particles, and time independent perturbation theory.

541. (EECS 541). Applied Quantum Mechanics II. ***Prerequisite: Appl. Phys. 540 or EECS 540. I.*** (3).
Advanced theory of angular momentum, time dependent perturbation theory, quantization of fields, the second quantization for bosons and fermions, scattering theory, the density matrix, reservoir theory.

550. (EECS 538). Lasers and Electro-Optics I. ***Prerequisite: EECS 434. I.*** (3).
Propagation of laser beam: Gaussian wave optics and the ABCD law. Crystal properties and the dielectric tensor; electro-optic effects and devices; acousto-optic diffraction and devices. Introduction to nonlinear optics: coupled mode theory and second harmonic generation; phase matching.

551. (EECS 539). Lasers and Electro-Optics II. ***Prerequisite: Appl. Phys. 550 or EECS 538. I.*** (3).
Laser resonators, eigenmodes, and stability analysis; rate equation analysis; homogeneous and inhomogeneous broadening mechanism; laser gain and gain saturation; Q-switching and mode locking. Special topics: laser pulse compression; Raman and Brillouin scattering; phase conjugation.

715. Individual Projects.

990. Dissertation/Precandidate.

995. Dissertation/Candidate.

Atmospheric, Oceanic, and Space Sciences

Department Office:
2233 Space Research Building
phone (313) 764-3335
See Page 60 for statement of Course Equivalence.

Faculty

William R. Kuhn, Ph.D., Professor of Atmospheric Science and Chairman of the Department of Atmospheric, Oceanic and Space Sciences

Sushil K. Atreya, Ph.D., Professor of Atmospheric Science

John R. Barker, Ph.D., Professor of Atmospheric Science

Frederick L. W. Bartman, Ph.D., Professor of Atmospheric Science

Alfred M. Beeton, Ph.D., Adjunct Professor of Oceanic Science

John P Boyd, Ph.D., Professor of Atmospheric Science

George R. Carignan, Adjunct Professor of Atmospheric Science and Associate Chairman of the Department of Atmospheric Oceanic and Space Sciences

Thomas M. Donahue, Ph.D., Edward H. White II Distinguished University Professor of Planetary Science

S. Roland Drayson, Ph.D., Professor of Atmospheric Science

Paul B. Hays, Ph.D., Professor of Atmospheric Science

Stanley J. Jacobs, Ph.D., Professor of Oceanic Science

Andrew F. Nagy, Ph.D., Professor of Atmospheric Science

Donald J. Portman, Ph.D., Professor of Atmospheric Science

James C. G. Walker, Ph.D., Professor of Atmospheric Science

Albert Nelson Dingle, Sc.D., Professor Emeritus of Atmospheric Science

Gerald C. Gill, M.A., Professor Emeritus of Atmospheric Science

Dennis G. Baker, Ph.D., Associate Professor of Atmospheric Science

Thomas I. Gombosi, Associate Professor of Atmospheric Science

Timothy L. Killeen, Associate Professor of Atmospheric Science

Perry J. Samson, Ph.D., Associate Professor of Atmospheric Science

Guy A. Meadows, Ph.D., Associate Professor of Oceanic Science

John T. Clarke, Assistant Professor of Atmospheric Science

Steven L. Mullen, Ph.D., Assistant Professor of Atmospheric Science

Lee H. Somers, Ph.D., Lecturer in Oceanic Science

111. Underwater Methods for Engineering and Sciences. ***Prerequisite: permission of instructor (to establish physical and swimming abilities). I and II.*** (3).
Principles and practices of conducting engineering and research operations underwater: human performance, use of diving equipment; underwater safety; underwater engineering and research techniques; preparation of students to organize and conduct their own underwater operations. Lecture and laboratory.

202. The Atmosphere. I and II. (3).
Elementary description of the atmosphere: its characteristics and behavior, its changes over generations and hours, its destructive capability, and its response to human activity.

203. The Oceans. I and II. (3).
Elementary descriptions of the oceans, their characteristics and behaviors; the sea as a world resource and as an influence on civilizations.

204. Introduction to Planetary and Space Science. I. (3).
Development of space exploration is presented with an emphasis on the exploration of the solar system, comparative atmospheric phenomena and the impact that these studies have had on understanding our own (terrestrial) environment. The course is intended for nonscience majors with a background in high school math and science.

212. Introduction to Weather Forecasting. ***Prerequisite: Previous or concurrent with A.O. & S.S. I and II.*** (3).
This laboratory supplements A.O. & S.S. 202, The atmosphere, with an introduction to weather forecasting. Participants will learn how to read and draw weather maps, how to make weather observations and measurements, and how to assimilate this information into their own weather forecasts.

304. Atmospheric, Oceanic and Space Sciences I. ***Prerequisite: Physics 140, Math. 116, Chem. 112 or 114. I and II.*** (3).
The various aspects of meteorology and oceanography. Emphasis is placed on the geophysical and geochemical origins, composition, structure, and motions of the atmosphere oceans.

305. Atmospheric, Oceanic and Space Sciences II. ***Prerequisite: A.O. & S.S. 304, Math. 215. I and II.*** (3).
A continuation of A.O. & S..S. 304, with emphasis on the description and physical basis of geophysical fluid wave motions and other physical and biological processes, introducing the student to various aspects of aeronomy, meteorology, and oceanography.

308. Laboratory in Oceanographic Data. ***Prerequisite: preceded or accompanied by A.O.& S.S. 304. I.*** (2).
Field and laboratory methods for collection and analysis of oceanographic data. Field trips, lecture-demonstrations, and laboratory work in biological, chemical, physical, and geologic aspects of the marine and lake environments.

310. Synoptic Laboratory I. ***Prerequisite: preceded or accompanied by A.O. & S.S. 304. I.*** (1).
An introduction to atmospheric data and their practical treatment; methods of observation of different elements.

311. Synoptic Laboratory II. ***Prerequisite: A.O.& S.S. 310 and preceded or accompanied by A.O & S.S. 305. II.*** (2).
Analysis of meteorological data in space and time; vertical distribution of different elements in the atmosphere; weather forecasting.

312. Climatology. ***Prerequisite: A.O. & S.S. 305 and preceded or accompanied by Math. 216. II.*** (3).
Climatic classification schemes; the physical basis of climates in terms of long-term equilibria of the earth-atmosphere-ocean systems; the global distribution of energy balance components; the influence of atmospheric and oceanic circulation on climate.

330. Thermodynamics of Atmosphere. ***Prerequisite: preceded or accompanied by Math. 216. II.*** (3).
Physical principles of thermodynamics with emphasis on atmospheric applications. Topics include: equation of state; first and second laws of thermodynamics, adiabatic processes; energy conservation laws; thermodynamics of water phases; heat transfer, molecular and eddy diffusion of heat; thermodynamic diagrams; vertical stability.

332. Radiative Processes in the Atmosphere. ***Prerequisite: A.O & S.S. 305, Physics 240, Math. 215. II.*** (3).
The nature of radiation, solar and terrestrial radiation, scattering, atmospheric visibility, satellite measurements of solar and terrestrial radiation.

350. (Nav. Arch. 350). Ocean Engineering. ***Prerequisite: Civ. Eng. 325 (Mech. Eng. 325). II.*** (3).
Engineering analyses of work systems for operation in and on the oceans. Offshore drilling platforms, submersibles and semi-submersibles, cables, and moorings. Buoy systems, pipe laying, salvage and rescue systems, ocean lining. Selected aspects of physical oceanography underwater acoustics and instrumentation.

401. Geophysical Fluid Dynamics. ***Prerequisite: Math. 216, Physics 240. I.*** (3).
Dynamics of the oceans and atmosphere. Equations of motion, wave properties, quasi-geostrophic approximation, dissipative processes, introduction to stability theory.

408. Environmental Problem Solving with Computers. ***Prerequisite: Eng. 103, Math. 216. I.*** (3).
Solution of meteorological, oceanographic, and general environmental problems using computers. Applications of numerical analysis, statistics, and data handling to geophysics and environmental numerical output in terms of observed phenomena.

411. Cloud and Precipitation Processes. ***Prerequisite: A.O.& S.S. 330 and Chem. 365. I.*** (3).
The special nature of water substance; nucleation of phase changes in the free atmosphere; the structure and content of clouds; the development of physical characteristics of precipitation; air cleansing by rain; rain chemistry; and the dynamics of rain systems.

412. Dynamics of Climate. ***Prerequisite: A.O. & S.S. 312. I.*** (3).
Climatic fluctuations and change; paleo and historical climates; construction of climatic models; and the climatic implications of human activity.

417. (Geol. 417). Geology of the Great Lakes. ***Prerequisite: permission of the instructor. I.*** (2).
Geologic history of the late-glacial and post-glacial Great Lakes of North America, with emphasis on evaluation of evidence. Related topics such as bedrock setting, engineering problems, and physical environment of sedimentation.

422. Micrometeorology I. ***Prerequisite: Physics 240 or Math. 215. I.*** (3).
Physical processes responsible for the thermal and moisture conditions in the air layer near the ground. Components of net radiation exchange, heat transfer in soil, wind structure and turbulence near the ground, turbulent transfer of sensible heat and water vapor, evapotranspiration; forest climatology, transitional microclimates.

423. (Nat. Res. 423). Biological Oceanography. ***Prerequisite: Nat. Res. 211. II.*** (3).
The interrelationships of organisms and the marine environment, with emphasis on the structure and function of coastal ecosystems.

424. Mesometeorology. ***Prerequisite: A.O. & S.S. 454. II.*** (3).
An introduction to mesometeorological phenomena including organized convection, thunderstorms, tornadoes, foehns, lee waves, orographic blocking, sea breezes, urban heat islands, and effects from the Great Lakes.

425. (Nav. Arch. 425). Physics of the Oceans. ***Prerequisite: A.O. & S.S. 305 or permission of instructor. I.*** (4).
Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on thermodynamics and equations of state of sea water, optical and acoustical properties of sea water, currents, tides, waves, and turbulent phenomena.

429. (Nat. Res. 429). Great Lakes Limnology. ***Prerequisite: Nat Res. 311 or Zool. 443, or A.O. & S.S. 423 (Nat. Res. 423). II.*** (2).
Lectures on the physics, chemistry, and biology of the Great Lakes ecosystems are presented by instructors and invited outside speakers. Each student is required to research a topic mentioned in the introductory lectures, prepare an abstract and list of references, and make an oral presentation as the basis for a class discussion.

435. (Nav. Arch. 435). Analysis of Geophysical Data. ***Prerequisite: A.O. & S.S. 401. I.*** (3).
Methods of geophysical data analysis with emphasis on atmospheric and oceanographic applications. Power spectral analysis, optimal estimation theory, digital signal processing and time/space domain techniques for time series analysis.

440. Coastal Dynamics and Sedimentation. ***Prerequisite: A.O. & S.S. 335, Math. 216, Physics 240. II.*** (3).
Fundamentals of shallow water wave motions are investigated in terms of near-shore processes, water waves (generation, propagation, refraction, and breaking); tides and long term sea level changes; longshore current generation and prediction and sediment transport. The response of the beach and coastal structures to these processes will be examined.

442. Oceanic Dynamics I. ***Prerequisite: A.O. & S.S. 401. II.*** (3).
Wave motions; group velocity and dispersion. Gravity waves, wave statistics and prediction methods; long period waves; the tides. Steady state circulation, including theories of boundary currents and the thermocline.

450. (Nav. Arch. 450). Coastal and Offshore Engineering. ***Prerequisite: Nav. Arch. 340 or A.O. & S.S. 335. I.*** (3).
Dynamics of ocean waves. Deep and shallow water waves. Mechanics of sediment movement due to waves and currents. Effect of sediment transport on offshore structures. Loading and motions of offshore structures. Morison's equation. Current and wind loads. Wave loading. Absolute and relative motions and buoys and platforms in head seas.

451. Atmospheric Dynamics I. ***Prerequisite: A.O. & S.S. 401. II.*** (4).
Quasi-geostrophic energetics; fronts; the mean circulation; planetary and equatorial waves: overview of the dynamics of the middle atmosphere; wave-mean flow interaction; spectral methods; and tropical meteorology.

454. Weather Analysis and Forecasting Laboratory. ***Prerequisite: A.O. & S.S. 401. I.*** (3).
Principles of meteorological analysis. Structure of wave cyclones and fronts; vorticity, divergence, and vertical velocity; quasi-geostrophic theory and diagnostics; cyclogenesis and frontogenesis. Description of operational numerical forecast models and facsimile products. Daily weather discussion and forecasting. Lectures and laboratory exercises.

460. Satellite Meteorology. ***Prerequisite: permission of instructor. I.*** (3).
Topics selected from: characteristics of meteorological satellite orbits and of instruments used for the measurement of meteorological parameters using visible, infrared, and microwave radiation. Application of satellite measurements to Earth's radiation balance and albedo, surface temperature, atmospheric temperature structure, cloud heights and types, minor atmospheric constituents, aerosols and precipitation, winds, and circulation.

461. Meteorological Instrumentation for Air Pollution Studies. ***Prerequisite: permission of instructor. II.*** (2).
Analysis of meteorological factors that affect dispersion directly and indirectly. Guidelines in selecting wind speed, wind direction, turbulence, temperature, and humidity measuring instruments. Significance of rate of response of sensors. Methods of measuring these parameters above the heights of towers. Methods of measuring diffusion by tracer experiments, both visible and invisibie. Wind tunnel modeling of urban problems.

462. Meteorological Instrumentation. ***Prerequisite: A.O. & S.S. 330 or 332. I.*** (3).
Principles of meteorological instruments; methods of measurement of ground level pressure, temperature, humidity, precipitation, wind, and radiation; methods of measurement of upper air conditions. Elementary analysis of response characteristics of single instruments and of instrument systems. Lectures, laboratory, and field trips.

463. Air Pollution Meteorology. ***Prerequisite: permission of instructor. II.*** (3).
Weather and motion systems of the atmosphere; topographic influences on winds, atmospheric stability and inversions; atmospheric diffusion; natural cleansing processes; meteorological factors in plant location, design, and operation.

464. (Aero. Eng. 464). Upper Atmospheric Science. ***Prerequisite: senior or graduate standing in a physical science or engineering. I.*** (3).
An introduction to physical processes in the upper atmosphere; density, temperature, composition, and winds; atmospheric radiation transfer processes and heat balance; the ionosphere; rocket and satellite measurement techniques.

469. (Nav. Arch. 469). Underwater Operations. ***Prerequisite: permission of instructor. II.*** (3).
Survey of manned undersea activities in oceanography and ocean engineering. The tools of underwater operations: decompression chambers, habitats, submarines, diving apparatus; pertinent design criteria and applications as based on human hyperbaric physiology and performance. Topics in research diving for engineering and oceanographic studies.

472. (Geol. 472). Experimental Marine and Mineral Geochemistry. ***Prerequisite: A.O. & S.S. 478 or Geol. 461. II.*** (2).
Laboratory and field experiments with solution chemistry of natural carbonate minerals. Determination of Eh-pH and other phase diagrams for common hydrogeochemical phases. The study of surface phenomena using common geochemical phases.

479. Atmospheric Chemistry. ***Prerequisite: Chem. 126, Math. 216. I.*** (3).
Thermochemistry, photochemistry, and chemical kinetics of the atmosphere; geochemical cycles, generation of atmospheric layers and effects of pollutants are discussed.

480. (Geol. Sci. 480). The Planets: Composition, Structure, and Evolution. ***Prerequisite: Math. 216, Physics 240, Chem. 126. I.*** (3).
Origin of the solar system, composition and radial distribution of material in planets and satellites; relationship of gravity fields to shape and density distribution; magnetism; origin and significance of topography; structure of planetary atmospheres; energetics and dynamics of interiors and atmospheres, thermal histories and evolution of interiors, devolatization, origin, and evolution of atmospheres.

495. Thermosphere and Ionosphere. ***Prerequisite: senior standing in engineering or physical science. II.*** (4).
Basic physical processes significant to the structure and characteristics of the upper atmosphere; photochemistry, diffusion, ionization, distribution of neutral and charged particles; thermal structure of the upper atmosphere; atmospheric motions, geomagnetic storms.

499. Directed Study for Undergraduate Students. ***Prerequisite: permission of instructor. I, II, III, IIIa and IIIb. (To be arranged).***
Directed reading, research, or special study for advanced undergraduate students.

501. Seminars in Limnology and Oceanography. ***Prerequisite: graduate standing. I and II.*** (1).
Current research efforts will be presented by graduate students and faculty dealing with all phases of limnology and oceanography.

524. General Circulation. ***Prerequisite: previous or concurrent with A.O. & S.S. 401. I (odd years).*** (2).
Processes that maintain the general circulation of the Earth's atmosphere; the observed general circulation; energetics; balance requirements; low-frequency fluctuations, teleconnections, blocking, and wave-mean flow interaction. Comparison of observations with simple theories and results from general circulation model simulations. Lectures, discussions, and assigned readings.

528. (Nav. Arch. 528). Remote Sensing of Ocean Dynamics. ***Prerequisite: A.O. & S.S. (Nav. Arch.) 335 or permission of instructor. II.*** (3).
The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means.

532. Radiative Transfer-Thermal Processes. ***Prerequisite: A.O. & S.S. 332. II.*** (3).
Fundamental principles of molecular radiative transfer applicable to planetary atmospheres; macroscopic and microscopic forms of the transfer equation for both grey and non-grey cases; line broadening mechanisms; band models; non-local thermodynamic equilibrium source functions; applications to, and results from climate studies.

533. Radiative Transfer-Scattering. ***Prerequisite: A.O. & S.S. 332. II.*** (3).
Theory of atmospheric scattering. Single scattering, Rayleigh scattering, introduction to the Mie Theory; multiple scattering in planetary atmospheres, scattering by clouds and aerosols, optical phenomena, approximate methods of solution of radiative transfer equations.

550. (Nav. Arch. 550). Offshore Engineering Analysis. ***Prerequisite: Nav. Arch. 410, 420, 440, and 450 (A.O. & S.S. 450). II.*** (3).
Prediction of hydrodynamic loading of large offshore structures. Three dimensional source-sink distribution methods. Calculation of drift forces due to waves and currents. Empirical analysis of viscous forces on structural members. Morison's equation. Static and dynamic analysis and design or risers, cables and pipelines. Spectral fatigue analysis of offshore structures.

551. Advanced Geophysical Fluid Dynamics. ***Prerequisite: A.O. & S.S. 451. I.*** (3).
Advanced topics in dynamic meteorology and oceanography including frontogenesis, stability and instability, dynamics of the equatorial ocean, CISK and hurricanes, modons and Gulf Stream rings, strange attractors.

554. Advanced Synoptic Meteorology: Middle Latitude Weather Systems. ***Prerequisite: A.O. & S.S. 401 (which may be taken concurrently) or A.O. & S.S. 454. I.*** (3).
Review of governing equations. Extratropical Cyclenes and Cyclogenesis; jet streams and upper waves in the westerlies; fronts and frontogenesis. Diagnosis of vertical velocity. Quasi-geostrophics and semi-geostrophic theory. Diabatic effects. Lectures, map discussions, and laboratory exercises.

555. Spectral Methods. ***Prerequisite: Math. 216 and Eng. 103 or knowledge of FORTRAN. II.*** (4).
An introduction to numerical methods based on Fourier Series, Chebyshev polynomials, and other orthogonal expansions. Although the necessary theory is developed, the emphasis is on algorithms and practical applications in geophysics and engineering, especially fluid mechanics. Many homework assignments will be actual problem-solving on the computer.

563. Air Pollution Dispersion Modeling. ***Prerequisite: A.O. & S.S. 463. I.*** (3).
Principles of modeling air pollution transport and dispersion. Discussion of models for line sources, area sources and point sources. Analysis of individual model data requirements, founding assumptions, and inherent limitations. Practical experience using currently operational models.

564. The Stratosphere and Mesosphere. ***Prerequisite: A.O. & S.S. 464. I, odd years.*** (3).
The physical, chemical, and dynamical properties of the atmosphere between the tropopause and the turbopause. Among the topics covered are the heat and radiation budgets, atmospheric ozone, stratospheric warmings, the biennial stratospheric oscillation, airglow.

572.(Geol. 572). Marine Geochemistry. ***Prerequisite: A.O. & S.S. 478 or Geol. 461. I.*** (3).
Geochemistry of low temperature and pressure liquid-solid reactions and their influences on marine chemistry. Topics covered are carbonate geochemistry, geochemical removal of elements from sea water, pelagic sediments, and marine radiochemistry.

565. Planetary Atmospheres. ***Prerequisite: graduate standing. II, odd years.*** (3).
Radiative, photochemical, thermodynamic, and aeronomical processes in the atmospheres of the planets and satellites, with the objective of understanding the composition, structure, origin, and evolution of the atmospheres; theoretical and empirical results, including planetary observations by space probes.

578. (E.I.H. 666). Air Pollution Chemistry (Environ. Health 666). ***Prerequisite: A.O. & S.S. 479, or Chem. 365. II.*** (3).
Tropospheric and stratospheric air pollution are discussed following a review of thermochemistry, photochemistry, and chemical kinetics. Gaseous and particulate air pollutants are considered in terms of their origins and transformations.

589. (Geol. Sci. 589). Global Geochemical Cycles and Fluxes. ***Prerequisite: permission of instructor. II.*** (2).
Investigation of the processes that control the composition of the lithosphere, hydrosphere, and atmosphere. Estimation of the budgets of major constituents and of isotopes. Quantitative modeling of possible changes with time in the compositions of oceans, sedimentary rocks, and atmosphere. The carbon cycle, oceanic cations, redox balance, sulfur budget, isotopes of carbon, sulfur, oxygen and strontium. Global productivity, and the impact of life. Climatic consequences of geochemical change.

595. Magnetosphere and Solar Wind (Elec.-Comp. Eng. 518). ***Prerequisite: graduate standing. I, even years.*** (3).
General principles of magnetohydrodynamics; theory of the expanding atmosphere; properties of solar wind, interaction of solar wind with the magnetosphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.

597. Fundamentals of Space Plasma Physics. ***Prerequisite: Senior level statistical physics. II.*** (3).
Basic plasma concepts, Boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wing. Collisionless shocks, propagating and plantary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading.

605. Current Topics in Atmospheric and Oceanic Science. ***Prerequisite: permission of instructor. I and II.*** (3).
Advances in specific fields of atmospheric and oceanic sciences, as revealed by recent research. Lectures, discussion, and assigned reading.

606. Computer Applications to Geo-Fluid Problems. ***Prerequisite: A.O. & S.S. 442 or 451, and Eng. 103 and Math 450. II.*** (3-4).
Solution of geo-fluid problems by numerical techniques using a digital computer. Lectures, laboratory, exercises using the digital computer.

651. Dynamics of Planetary Atmospheres and the Upper Atmosphere. ***Prerequisite: A.O. & S.S. 451. I.*** (3).
Dynamic meteorology of other planets (Mars, Venus, Jupiter, and Titan), the Earth's middle atmosphere, and thermosphere. Tides, solitary waves, quasi-geostrophic turbulence, and dynamics and chemistry are among the phenomena discussed.

701. Special Problems in Meteorology and Oceanography. ***Prerequisite: permission of instructor. I and II. (To be arranged).***
Supervised analysis of selected problems in various areas of meteorology and oceanography.

990. Dissertation/Pre-Candidate. I, II, and III (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Bioengineering

Office:
4230 EECS Building
phone (313) 764-9588
See Page 60 for statement on Course Equivalence.

401. (Anatomy 401). The Human Body: Its Structure and Function. I. (4).
A lecture-oriented, multi-media course that highlights the basic fabric of the human body as a functioning biological organism. A blend of gross anatomy, histology, developmental anatomy and neuroanatomy that takes the human body from conception to death while dealing with organization at all levels from cells to systems, system interrelations, and key features of select anatomical regions.

410. (Mat. Sci. & Eng. 410). Biomedical Materials Considerations. ***Prerequisite: Mat. Sci. & Eng. 250 or permission.*** (2).
Interactions of materials implanted in the body. Histological and hematological considerations including general foreign body reactions, inflammation and reparation, carcinogenicity, thrombosis, hemolysis, protein and cellular issues, immunogenic and toxic properties. Basic discussion of implants vs. transplants and relevant biological components. Tours of relevant university facilities.

417. (EECS 417). Electrical Biophysics. ***Prerequisite: EECS 210 or 213 or 314 or 416 and preceded or accompanied by EECS 300 or Math. 448. I.*** (3).
Electrical biophysics of muscle, nerve, and synapse; electrical conduction in excitable tissue; models for nerve, muscle, and sensory receptors, including the Hodgkin-Huxley equations; biopotential mapping, cardiac electrophysiology, and biological noise.

432. (EECS 432). Fundamentals of Ultrasonics with Medical Applications. ***Prerequisite: EECS 331. II.*** (3).
Basic principles; waves, propagation, impedance, reflection, transmission, attenuation, power levels. Generation of ultrasonic waves; transducers, focusing, Fraunhofer and Fresnel zones. Instrumentation; display methods, Doppler techniques, signal processing. Medical applications will be emphasized.

434. (Chem. Eng. 434) (Civ. Eng. 580) (Microb. 434). Microbiology for Engineers. ***Prerequisite: Chem. 225. I and II.*** (4).
Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

458. (EECS 458). Biomedical Instrumentation and Design. ***Prerequisite: permission of instructor. I and II.*** (4).
Measurement and analysis of biopotentials and biomedical transducer characteristics; electrical safety; applications of FET's, integrated circuits, operational amplifiers for signal processing and computer interfacing; signal analysis and display on the laboratory minicomputer. Lectures and laboratory.

476. (Mech. Eng. 476). Thermal-Fluid Sciences in Bioengineering. ***Not open to Mech. Eng. majors. I.*** (3).
Fluid dynamics, thermodynamics, and heat transfer at micro- and macro-level. Systemic circulation, microcirculation, simulation of flow regulation, artificial flow-regulating devices. First and second laws of thermodynamics. Conduction, metabolic heat generation, convection, radiation, regulation of body temperature, clothing, micro heat transfer, hyperthermia, hypothermia and cryogenic applications.

481. (Nuc. Eng. 481). Engineering Aspects of Radiology and Nuclear Medicine. II. (2).
An introduction to the physical principles, instrument systems, and analytical method of importance in radiation-related medical procedures. Topics are drawn from research and clinical activities in diagnostic radiology, nuclear medicine, and radiation therapy.

495. (Appl. Mech. 495). Introduction to Bioengineering. ***Prerequisite: permission of instructor. II.*** (1).
Definition of scope, challenge, and requirements of the bioengineering field. Faculty members review engineering-life sciences interdisciplinary activities as currently pursued in the College of Engineering and Medical School.

516. (Chem. Eng. 516). Dynamics of Biochemical Systems. Prerequisite: a course in physical chemistry, a course in biology. (3).
Colloidal phenomena in biological systems, mechanisms of transport through membranes, physical chemistry properties of biological materials, kinetics of growth processes, enzyme catalysis, natural control mechanisms, engineering applications of biochemical phenomena.

519. (Physiol 519). Bioengineering Physiology. ***Prerequisite: Biol. 105 or 112 or equivalent, and permission of instructor.*** (4).
Quantitative description of the structure and function of mammalian systems, including the neuromuscular, cardiovascular, respiratory, renal and endocrine systems. Mathematical models are used to describe system performance where applicable. Lectures, laboratories, and problem sessions.

525. (Microb. 525). Systems Analysis of the Microbial Cell. ***Prerequisite: Biol. 105 or 112 and Math. 215. II.*** (3).
This course is designed to equip the student with appropriate concepts and techniques for the quantitative analysis of the integrated behavior of complex biochemical systems. A general approach is developed from the basic postulates of enzyme catalysis and is illustrated with numerous specific examples, primarily from the microbial cell.

534. (I.&O.E. 534). Biomechanics and Physiology of Work. ***Prerequisite: I.&O.E. 333 and I.&O.E. 334, or I.&O.E. 433.*** (3).
New techniques to predict the anatomical and physiological basis for human performance in various man-machine systems. Models to 1) muscle contraction speed, strength, and endurance, 2) skeletal strength and movement, 3) human metabolism and cardiopulmonary system responses to work stress, and 4) motor system control functions. Biomechanical and physiological monitoring systems, and applications to the design of man-machine systems.

535. (I.&O.E. 535). Laboratory in Biomechanics and Physiology of Work. ***Prerequisite: I.&O.E. 534 (Bioeng. 534). II.*** (2).
This laboratory is offered in conjunction with the Biomechanics and Physiology of Work course to allow students to experimentally determine 1) musculoskeletal reactions to volitional acts, 2) how EMG is used in muscle actions and fatigue evaluation, and 3) how the cardiopulmonary systems respond to various work stressors.

546. (Appl. Mech. 546) (Mech. Eng. 546). Biomechanics. ***Prerequisite: Mech. Eng. 211, 240. II.*** (3).
Definition of biological tissue behaviors, including elastic, viscoelastic, an plastic properties, with emphasis on bone; dynamics of gait, impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

569. (EECS 569). Introduction to Neurophysiological Systems. ***Prerequisite: EECS 360 or EECS 460. II.*** (3).
Application of systems theory to neurophysiology; a theoretical and experimental

study of the application of linear and nonlinear theory, state-space concepts, and stability criteria to several neurophysiological systems; neuromuscular systems, pupillary control, eye tracking, temperature regulation, and central nervous system function.

590. Directed Research. ***(Credit to be arranged).***
Provides opportunity for bioengineering students to participate in the work of laboratories devoted to living systems studies.

690. (Physiol. 690) (Zool. 691) (Anat. 690) (Psych. 690) (Pharmacol. 690) (Neurol. 690). Neuroscience. ***Prerequisite: graduate standing and permission of instructor. I.*** (3).
Study of nervous system including comparative aspects, structure, function, chemistry, behavior, and pathology.

691. (Physiol. 691) (Zool. 691) (Anat. 691) (Neurol. 691). Neuroscience Laboratory. ***Prerequisite: Physiol. 690 and permission of instructor. I.*** (3).
Laboratory exercises and demonstrations in neurobiology.

890. Bioengineering Seminar. (1).

990. Dissertation/Pre-Candidate. I, II, and III. (2-8); IIIa and IIIb. (1-4).
Election for dissertation work by doctoral students not yet admitted to status as candidates. Defense of dissertations, that is, final oral examinations, must be held under full-term candidacy enrollments.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III. (8); IIIa and IIIb.*** (4).
Election for dissertation work by doctoral students who have been admitted to status as candidates. The defense of dissertations, that is, final oral examinations, must be held under full-term candidacy enrollments.

Business Administration —

Administered by the School of Business Administration

Office:
1235 Business Administration
phone (313) 763-5796

Engineering undergraduate students interested in pursuing the Master of Business Administration degree, following the completion of their Bachelor's degree in Engineering, are encouraged to consult with counselors in the Office of Admissions and Student Services, 1235 Business Administration. Undergraduate engineering study is a particularly good preparation for the MBA degree program and excellent career opportunities exist for engineers who earn the MBA degree.

The business courses below are of special interest to students enrolled in the undergraduate engineering curriculum. In the election of such courses, attention is called to the administrative rules of the School of Business Administration, which affect elections as follows:

1) No student shall elect courses in the School of Business Administration who does not have at least third-year standing (55 credit hours). This does not apply to Accounting 271 and 272, which are listed as sophomore-level courses in the Economic Department of the College of Literature, Science, and the Arts, and the Accounting area of the School of Business Administration.

2) Juniors may elect courses numbered 300 to 399 inclusive, and seniors may elect any courses numbered 300 to 499 inclusive, provided they have satisfied particular course prerequisites.

3) Courses numbered 500 or above may be elected only by properly qualified graduate students and are not open to undergraduate students.

For descriptions of the following and other courses in Business Administration, see the undergraduate *Bulletin* of the School of Business Administration:

Accounting and Information Analysis
A 271. Principals of Accounting (3).
A 272. Principals of Accounting (3).

Business Economics and Public Policy
BE 300. Economics of Enterprise (3).

Computer and Information Systems.
CIS 301. Information Systems and Data Processing (3).

Finance
F 300. Financial Management (3).

Law, History, and Communication
LHC 305. Business Law (3).
LHC 306. Business Law (3).

Marketing
M 300. Marketing Management (3).

Organizational Behavior and Industrial Relations
OB 300. Behavioral Theory in Management (3).
OB 315. Management of Personnel (3).
OB 322. Management-Union Relations (3).

Operations Management
OM 311. Operations Management (3).

Statistics and Management Science
SMS 301. Introductory Probability and Statistics (3).

Chemical Engineering

Department Office:
3074 Dow Building
phone (313) 764-2383
See Page 60 for statement on Course Equivalence.

Faculty

Hugh Scott Fogler, Ph.D., P.E., Vennema Professor of Chemical Engineering and Chairman of the Department of Chemical Engineering

Dale E. Briggs, Ph.D., P.E., Professor of Chemical Engineering

Brice Carnahan, Ph.D., P.E., Professor of Chemical Engineering

Rane L. Curl, Sc.D., Professor of Chemical Engineering

Francis M. Donahue, Ph.D., Professor of Chemical Engineering

Erdogan Gulari, Ph.D., Professor of Chemical Engineering

Robert H. Kadlec, Ph.D., P.E., Professor of Chemical Engineering

James Oscroft Wilkes, Ph.D., Professor of Chemical Engineering

Gregory S. Y. Yeh, Ph.D., Professor of Materials Engineering

Edwin Harold Young, M.S.E., P.E. Professor of Chemical and Metallurgical Engineering

Howard Klee, Jr., Sc.D., Adjunct Professor of Chemical Engineering

Donald LaVerne Katz, Ph.D., P.E., Alfred Holmes White Professor Emeritus of Chemical Engineering

Lloyd L. Kempe, Ph.D., P.E., Professor Emeritus of Chemical Engineering and of Microbiology, Medical School

John E. Powers, Ph.D., Professor Emeritus of Chemical Engineering

Maurice J. Sinnott, Sc.D., Professor Emeritus of Chemical and Metallurgical Engineering

Mehmet Rasin Tek, Ph.D., P.E., Professor Emeritus of Chemical Engineering

George Brymer Williams, Ph.D., P.E., Professor Emeritus of Chemical and Metallurgical Engineering

Johannes W. Schwank, Ph.D., Associate Professor of Chemical Engineering

Henry Y. Wang, M.S., Ph.D., Associate Professor of Chemical Engineering

James R. Falender, Ph.D., Adjunct Associate Professor of Chemical Engineering

Stacy G. Bike, Ph.D., Assistant Professor of Chemical Engineering

Costas Kravaris, Ph.D., Assistant Professor of Chemical Engineering

Jennifer J. Linderman, Ph.D., Assistant Professor of Chemical Engineering

Bernhard O. Palsson, Ph.D., Assistant Professor of Chemical Engineering

Anastasios C. Papanastasiou, Ph.D., Assistant Professor of Chemical Engineering

Phillip E. Savage, Ph.D., Assistant Professor of Chemical Engineering

Levi T. Thompson, Jr. Ph.D., Assistant Professor of Chemical Engineering

Robert Ziff, Ph.D., Assistant Professor of Chemical Engineering

Laboratory fees are required to be paid in advance for each course involving laboratory work.

134. Experimentation in Biochemical Engineering. ***Prerequisite: for students with freshman or sophomore standing only.*** (3).
Introduction to methods of generating and analyzing data related to the kinetics and stoichiometry of biochemical systems. Two lectures, and one three-hour laboratory. On some occasions some students may be required to return in the evening to complete experiments.

151. (Eng. 151). Plastics. ***Prerequisite: high-school chemistry.*** (3).
Plastics such as nylon, lucite, and polystyrene will be synthesized, analyzed, molded, and tested mechanically by the students. The instructor will demonstrate advanced methods of characterization and processing. Lecture followed by a three-hour laboratory. Local plant visits.

230. (Mat. Sci. & Eng. 230). Thermodynamics I. ***Prerequisite: Eng. 103, Chem. 126, Math. 116. I.*** (4).
An introduction to applications of the first law of thermodynamics. Steady and unsteady state material and energy balances, the equilibrium concept. Properties of fluids. Engineering systems.

330. Thermodynamics II. ***Prerequisite: Chem. Eng. 230 (Mat. Sci. & Eng. 230). II.*** (4).
Development of fundamental thermodynamic property relations and complete energy and entropy balances. Analysis of heat pumps and engines, and use of combined energy-entropy balance in flow devices. Calculation and application of total and partial properties in physical and chemical equilibria. Prediction and correlation of physical/chemical properties of various states and aggregates.

340. Dynamics of Chemical and Physical Change. ***Prerequisite: Chem. 126. II.*** (4).
Principles of stoichiometry, phase behavior, chemical equilibria, reaction kinetics, and transport phenomena applied to chemical reactions and separations in environmental, biochemical, and engineering systems. Not open to chemical engineering students.

341. Fluid Mechanics. ***Prerequisite: preceded or accompanied by Chem. Eng. 230. II.*** (3).
A study of fluid mechanics for Chemical Engineering. Mass, energy, and momentum balances on finite and differential systems. Laminar and turbulent flow in pipes, porous media, and equipment. Boundary-layer and potential flow.

342. Heat and Mass Transfer. ***Prerequisite: Chem. Eng. 230 and 341; Math. 216. I.*** (3).
Theories and applications of heat and mass transport phenomena, emphasizing their analogies and contrasts. Fourier's law. Steady and unsteady thermal conduction. Heat transfer coefficients. Heat exchangers. Condensation and boiling. Radiation, Kirchoff's law and view factors. Fick's law. Steady and unsteady diffusion. Mass transfer coefficients. Absorbers. Simultaneous heat and mass transfer.

343. Separation Processes. ***Prerequisite: Chem. Eng. 230 (Mat. Sci, & Eng. 230). I.*** (3).
Introduction and survey of separations based on physical properties, phase equilibria, and rate processes. Emphasis on analysis and modeling of separation processes. Staged and countercurrent operations.

344. Reaction Engineering and Design. ***Prerequisite: Chem. Eng. 330, preceded or accompanied by Chem. Eng. 342. II.*** (3).
Fundamentals of chemical reaction engineering. Rate laws, kinetics, and mechanisms of homogeneous and heterogeneous reactions. Analysis of rate data. Diffusion limitations. Design of industrial reactors.

360. Chemical Engineering Laboratory I. ***Prerequisite: Chem. Eng. 342. II.*** (3).
Experimentation in thermodynamics and heat, mass, and momentum transport on a bench scale. Measurement error estimation and analysis. Lecture laboratory, conferences, and reports.

417. Biochemical Technology. ***Prerequisite: organic chemistry. II.*** (3).
Concepts necessary in the adaptation of biological and biochemical principles to industrial processes and technology of the biochemical engineering industries. Lectures, problems, and library study will be used to develop the ideas presented.

434. (Bioeng. 434) (Civ. Eng. 580) (Microb. 434). Microbiology for Engineers. ***Prerequisite: Chem. 225. I.*** (4).
Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

446. Chemical Engineering of Water. ***Prerequisite: Chem. 225, and Chem. Eng. 342 or 340. I.*** (3).
Development and modification of chemical and metallurgical process and plant designs as dictated by raw water and effluent disposal requirements.

449. Air Pollution Control. ***Prerequisite: Chem. Eng. 340 or 342 or Mech. Eng. 371. II.*** (3).
Sources of air pollution are identified. Principles and techniques are discussed to eliminate or control gaseous and particulate pollutants to within required legal limits.

451. (Mat. Sci. & Eng. 451). Introduction to Polymers. ***Prerequisite: junior standing in engineering or science. I.*** (4).
Preparation, properties, and utilization of polymeric materials. Lectures, recitation, and laboratory.

452. (Mat. Sci. & Eng. 452) (Macro. Sci. 452). Applied Polymer Processing. (3).
Theory and practice of polymer melt processing. Non-Newtonian flow; extrusion, injection and molding operations; fiber, film, and rubber processing; kinetics of solidification; mechanical orientation; product characterization; structure-property relations.

457. (Mat. Sci, & Eng. 457). Fundamentals of Polymeric Materials. ***Prerequisite: Mat. Sci. & Eng. 250. I.*** (3).
Basic preparation, characterization, identification of bulk polymers and polymer molecules including the amorphous, glassy, and crystalline states; basics of forming and processing techniques, engineering and design properties including tensile behavior, creep and stress relaxation, fracture, fatigue.

460. Chemical Engineering Laboratory II. ***Prerequisite: Chem. Eng. 343. I and II.*** (3).
Experimentation in rate and separation processes on a scale which tests process models. Introduction to the use of instrumental analysis and process control. Laboratory, conferences, and reports.

466. Process Dynamics and Control. ***Prerequisite: Chem. Eng. 343 and 344. I.*** (3).
Introduction and process control in chemical engineering. Application of Laplace transforms and frequency domain theory to the analysis of open-loop and closed-loop process dynamics. Stability analysis and gain/

phase margins. Controller modes and settings. Applications to the control of level, flow, heat exchangers, reactors, and elementary multivariable systems.

470. Colloids and Interfaces. ***Prerequisite: Chem. Eng. 343 and 344. I.*** (3).
This is a first course in colloid and interface science. The repulsive forces and attractive forces at interfaces are described along with the dynamics of the interfaces. Topics include the stability of macroemulsions, the formulation and properties of microemulsions, and surface metal-support interactions of catalysts.

485. Biochemical Engineering Process Design. ***Prerequisite: Chem. 225 and preceded or accompanied by Chem. Eng. 340 or Chem. Eng. 343. II.*** (3).
Selection and design of processes and equipment for the industrial manufacture of biochemical including foods, pharmaceuticals, and potable water, and for industrial waste treatment. Recitation and calculation periods.

486. Chemical Process Simulation and Design I. ***Prerequisite: preceded or accompanied by Chem. Eng. 342, 343. I.*** (3).
Economic evaluation of chemical processes. Strategies for decision making, trouble shooting faults, potential problem analysis, plant safety and failure analysis. The selection and specification of engineering materials for use in the chemical, petrochemical, and petroleum industries.

487. Chemical Process Simulation and Design II. ***Prerequisite: Chem Eng. 344, 486, preceded or accompanied by Chem. Eng. 466. I and II.*** (4).
Process synthesis and design. Process simulation with computer assistance. Process and corporate economics. Design project with technical report.

488. Practice of Chemical Engineering Design. ***Prerequisite: Chem. Eng. 487*** (3).
Practice of process design; dynamics and control of processes; economics of processes, principles of capital budgeting and cost effectiveness. Three lecture hours per week plus one afternoon calculational and tutorial workshop.

490. Directed Study, Research and Special Problems. ***(To be arranged).***
Laboratory and/or conferences. Provides an opportunity for undergraduate students to work in research or areas of special interest such as design problems and economic studies. Where the subject covers some aspect of plant work, as in summer employment in industry, arrangements should be made in advance. Not open to graduate students.

507. Mathematical Modeling in Chemical Engineering. ***Prerequisite: Chem. Eng. 344 and Eng. 303. I.*** (3).
Formulation of deterministic models from conservation laws, population balances; transport and reaction rates. Formulation of boundary and initial conditions. Dimensional analysis, analytical and numerical methods.

508. Applied Numerical Methods I. ***Prerequisite: Eng. 103.*** (3).
Numerical approximation, integration, and differentiation. Single and simultaneous linear and nonlinear equations. Initial-value methods for ordinary differential equations. Finite-difference methods for parabolic and elliptic partial differential equations. Implementation of numerical methods on the digital computer, with applications to fluid flow, heat transfer, reactor engineering, and related areas.

509. Statistical Analysis of Engineering Experiments. (3).
The use of statistical methods in analyzing and interpreting experimental data and in planning experimental programs. Probability, distributions, parameter estimation, test of hypotheses, control charts, regression and an introduction to analysis of variance.

511. (Mat. Sci. & Eng. 511). Rheology of Polymeric Materials. ***Prerequisite: a course in fluid mechanics or permission of instructor.*** (3).
An introduction to the relationships between the chemical structure of polymer chains and the rheological behavior. The course will make frequent reference to synthesis, processing, characterization, and use of polymers for high technology applications.

512. (Mat. Sci. & Eng. 512). Physical Polymers. ***Prerequisite: senior or graduate standing in engineering or physical science.*** (3).
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress-relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation, and morphology.

516. (Bioeng. 516). Dynamics of Biochemical Systems. ***Prerequisite: a course in physical chemistry, and a course in biology.*** (3).
Colloidal phenomena in biological systems, mechanisms of transport through membranes, physical chemical properties of biological materials, kinetics of growth processes, enzyme catalysis, natural control mechanisms, engineering applications of biochemical phenomena.

525. Catalysis, Kinetics, and Research Reactors. ***Prerequisite: two physical chemistry courses.*** (3).
The course covers topics in heterogeneous catalytic reactions and research reactor kinetics. It emphasizes basic principles of heterogeneous catalysis, surface effects, reaction kinetics, and design of research reactors.

526. Heat Transfer. ***Prerequisite: Chem. Eng. 342.*** (3).
Principles of conduction, convection, and radiation. Application to processes in the chemical and petroleum industries. Selected topics such as heat transfer effects in two-phase flow, condensation of multicomponent vapors, extended surfaces, and radiation from gases and flames.

527. Fluid Flow. ***Prerequisite: Chem. Eng. 341.*** (3).
Applications of fluid dynamics to chemical engineering systems. Theory and practice of laminar and turbulent flow of Newtonian and non-Newtonian fluids in conduits and other equipment. Multiphase flow. Introduction to the dynamics of suspended particles, drops, bubbles, foams, and froth. Selected topics relevant to chemical and other engineering disciplines.

528. Chemical Reactor Engineering. ***Prerequisite: Chem. Eng. 344.*** (3).
Analysis of kinetic, thermal, diffusive, and flow factors on reactor performance. Topics include batch, plug flow, backmix reactors, empirical rate expressions, residence time analysis, catalytic reactions, stability, and optimization.

529. Mass Transfer. ***Prerequisite: Chem. Eng. 342.*** (3).
Formulation of diffusional mass balances; diffusion in solids, liquids, and gases; Fick's first and second laws; convective mass transfer, modeling of mass transfer systems.

537. Thermodynamic Relations and Applications. ***Prerequisite: Chem. Eng. 330.*** (3).
The fundamental property relation and its application to physical and chemical equilibria in homogeneous and heterogeneous systems. Magnetic, electric, surface, and stress effects. Fugacities and activities of the constituents of multicomponent mixtures are determined through analyses of experimental PVT, concentration, and electrochemical potential data.

538. Statistical and Irreversible Thermodynamics. ***Prerequisite: Chem. Eng. 330.*** (3).
The laws of probability and statistics are applied to microscopic matter to yield properties of macroscopic systems. Relations

between classical and statistical thermodynamics are developed. Coupling of irreversible processes is treated through the entropy balance and microscopic reversibility.

541. Fluid Mechanics and Heat Transfer. ***Prerequisite: Chem. Eng. 342.*** (3).
An integrated study of fluid mechanics and heat transfer. Differential mass, momentum, and energy balances. Inviscid, viscous, and turbulent flow; dimensional analysis. Motion of bubbles; two-phase flow and fluidization. Conduction, convection; radiation from surfaces and gases. Application to problems in the chemical and petroleum industries.

542. Intermediate Transport Phenomena. ***Prerequisite: Graduate Standing.*** (3)
Foundations of transport phenomena. Heat and mass transfer with chemical reaction in three-dimensions, selective motion. Unsteady energy and mass balances in three-dimensions. Distributions in more than one variable. Boundary layer theory. Estimation of interfacial transport coefficients. Dispersive flows: Taylor Dispersion. Application to equipment design.

547. Separations Processes II. ***Prerequisite: Chem. Eng. 343.*** (3).
A general approach to the design of separation processes based on mathematical modeling. Fundamental bases for separation and possible arrangements to improve performance. Thermal diffusion, distillation, adsorption; ideal cascades and batch processes.

548. Electrochemical Engineering. ***Prerequisite: Chem. Eng. 344.*** (3).
Analysis of electrochemical systems from a theoretical and practical point of view. Topics include the application of electrochemical thermodynamics and kinetics to batteries, fuel cells, electroplating, electrosynthesis, and corrosion.

552. Fundamentals of Polymer Processing. ***Prerequisite: Chem. Eng. 341 and Math. 216. I. (alternate years).*** (3).
Introduction to rheology of non-Newtonian fluids; analysis of viscometric flows; mathematical modeling of common polymer melt processing operations such as extrusion, spinning, film blowing and injection molding; heat and mass transfer in polymer systems.

566. Process Control in the Chemical Industries. ***Prerequisite: Chem. Eng. 343 and 460.*** (3).
Techniques of regulation applied to equipment and processes in the chemical and petrochemical industries. Linear and nonlinear control theory, largely in the spectral domain. Controller types, transducers, final control elements, interacting systems, and applications.

573. (Mat. Sci. & Eng. 573). Corrosion Engineering. ***Prerequisite: course in Materials Engineering.*** (3).
Fundamentals involved in choosing materials in corroding media, corrosion control methods, and corrosion-failure analysis.

585. Production and Processing of Petrochemicals. ***Prerequisite: Chem. Eng. 343.*** (3).
Production, pipelining, conservation, processing and storage of crude oil and natural gas. Chemical Engineering calculations, economics, and design applied to reservoir engineering, petroleum processing, refining, and other related areas of the petrochemicals industry.

587. Chemical Process Design. II. (2 or 4).
First half-term: Selection and design of chemical, biochemical, or petrochemical processes, equipment and control systems; economic studies; comparison and optimization. Equipment evaluation and estimating procedures; computer methods. Second half-term: Engineering design and economic analysis of a process. Original and individual work, and excellence of reporting are emphasized. Oral examination on final written report.

588. Optimization and Control of Chemical Systems. ***Prerequisite: Chem. Eng. 407 or 508.*** (3).
Techniques for finding extrema of functions and functionals relating to chemical process problems. Solution methods, including digital computation, alternative, and approximate procedures. Geometric, dynamic, and linear programming. Constrained variables and systems. Variational methods, the maximum principle, search methods. Sensitivity and errors.

595. Chemical Engineering Research Survey. (1).
Research activities and opportunities in Chemical Engineering program. Lectures by University of Michigan faculty and guest lecturers. Topics are drawn from current research interests of the faculty.

607. Mathematical Methods in Chemical Engineering. ***Prerequisite: Chem. 507.*** (3).
Matrices and their application to reaction and separation processes. Linear operator theory and application to transport phenomena. Nonlinear systems, stability, bifurcation. Perturbation methods and chaotic systems.

608. Applied Numerical Methods II. ***Prerequisite: Chem. Eng. 508 or EECS 404.*** (2 or 3).
The finite-element method for solving partial differential equations, with applications to incompressible fluid flow and heat transfer, occupies at least one-third of the course. Banded equation-solving techniques. Stiff systems of ordinary differential equations. Boundary-value problems. Hyperbolic equations. Matrix eigenvalues. Computer applications. Credit depends on topics selected.

625. Coupled Rate Processes. ***Prerequisite: Chem. Eng. 528, and 526 or 527 or 529.*** (3).
Theoretical and experimental phenomena associated with the coupling of two or more rate processes. Material selected from contemporary chemical engineering involving reaction kinetics in two-phase flow, thermal effects in chemical reactors, coupled diffusional processes, coupled chemical reactions, flames, and electrolytes.

627. Computational Fluid Mechanics and Rheology. ***Prerequisite: Chem. Eng. 527 or Chem. Eng. 508 or equivalent. II.*** (3).
Conservation equations and boundary conditions. Constitutive equations. Finite element and time-integration. Confined free surface and multilayer flow. Viscoelastic liquids and polymer processing. Processing of composites and semiconductors. Heat and mass transfer. Chemical reaction and phase change. Stability and bifurcation analysis.

628. Industrial Catalysis. ***Prerequisite: Chem. Eng. 528.*** (3).
Theoretical and experimental aspects of heterogeneous catalysis and surface science. Design, preparation, and characterization of catalysts. Kinetics of heterogeneous catalytic reactions, thermal and diffusional effects in catalytic reactors. Case studies of important industrial catalytic processes.

687. Chemical Process Design II. ***Prerequisite: Chem. Eng. 587.*** (3).
The application of machine computation to process and equipment design and simulation. Process-oriented languages, data banks, decompositional methods related to process system arrangement. Heuristic synthesis of equipment sequences. Applications in chemical, petrochemical, and petroleum industrial processes. Recycle, chemical reactors, heat transfer, and separations are emphasized.

695. Research Problems in Chemical Engineering. ***(To be arranged).***
Laboratory and conferences. Provides an opportunity for individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of chemical engineering may be selected. The student writes a final report on his project.

696. Selected Topics in Chemical Engineering. ***(To be arranged).***

697. Problems in Chemical Engineering. ***(To be arranged).***

698. Directed Study in Chemical Engineering. ***(To be arranged).***

707. Special Topics in Mathematical Modeling. ***Prerequisite: graduate standing or permission of instructor. I.*** (3).
Selected topics on modeling chemical engineering processes at both the macroscopic and microscopic levels.

751. (Chem. 751) (Macr. Sci. 751) (Mat. Sci. & Eng. 751) (Physics 751). Special Topics in Macromolecular Science. ***Prerequisite: permission of instructor.*** (2).
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor.

807. Seminar in Mathematical Modeling. ***Prerequisite: candidacy in Chemical Engineering. II.*** (3).
Current literature on mathematical modeling of Chemical Engineering processes will be reviewed and studied.

895. Seminar in Chemical Engineering. ***(To be arranged).***

990. Dissertation/Pre-Candidate. I, II, and III (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student who has not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

Chemistry*

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phone (313) 764-7315

*College of Literature, Science, and the Arts

Professor Curtis, chairman; Professors Ashe, Bartell, Blinder, Coucouvanis, Dunn, Ege, Evans, Francis, Gordus, Kopelman, Koreeda, Kuczkowski, Lawton, Lohr, Marino, Morris, Nordman, Overberger, Rasmussen, Sacks, Sharp, Smith, Westrum, and Wiseman; Associate Professors Griffin, Lubman, and Meyerhoff; Assistant Professors, Pearson, Pecoraro, Penner-Hahn, Knochel, Lee, and Korzeniewski.

Note: Safety regulations forbid the wearing of contact lenses in the laboratory except for medical reasons, in which case special goggles must be worn.

123. General and Inorganic Chemistry: Structure of Matter. ***Prerequisite: three years of high school mathematics or Math. 105. I, II, IIIa.*** (3).
Three lectures, one help session with the Professor, and one recitation. A course intended for students who have had limited earlier exposure to chemistry.

124. General and Inorganic Chemistry: Structure of Matter. ***Prerequisite: three years of high school mathematics and a strong background in high school chemistry validated by a satisfactory grade on the placement test given during the orientation period. I.*** (3).
Three lectures and one recitation. Credit will not be granted for both Chem. 123 and Chem. 124.

125. General and Inorganic Chemistry Laboratory. ***Prerequisite: to be elected concurrently with Chem. 124 or Chem. 126. I, II, IIIa.*** (2).
One four-hour laboratory and one pre-lab lecture. Basic laboratory techniques and their application to simple chemical systems.

126. General and Inorganic Chemistry: Chemical Dynamics. ***Prerequisite: Chem. 123 or 124; to be preceded or accompanied by Chem. 125. I, II, IIIa.*** (3).
A continuation of the lecture topics of Chem. 123 or 124. Three lectures and one recitation.

196. General Chemistry. ***Prerequisite: advanced placement credit in chemistry or permission of instructor; Math. 115 or equivalent, to be taken currently. I.*** (5).
Four lecture-recitation periods and four hours of laboratory work. Equilibria, atomic and molecular structure, introduction to use of thermodynamic functions, kinetics, and topics from inorganic chemistry.

197. General and Quantitative Analytical Chemistry. ***Prerequisite: Chem. 196 or an A grade in Chem. 124 and 125. II.*** (5).
Three lecture periods and eight hours of laboratory work. Includes quantitative inorganic analysis, ionic equilibria, and general solution chemistry.

225. Organic Chemistry. ***Prerequisite: Chem. 126 or 197. I, II, and IIIa.*** (4).
Chem. 225 and 226 constitute a year's course in lecture material in organic chemistry. Course 225 covers aliphatic compounds, carbohydrates, and other selected topics. Students should plan to elect courses 225 and 226 consecutive terms. Three lecture periods and one recitation.

226. Organic Chemistry. ***Prerequisite: Chem. 225. I, II, and IIIa.*** (3).
Aromatic compounds, proteins, and other topics. Three lecture periods.

227. Organic Chemistry. ***Prerequisite: Chem. 225, I, II, and IIIa.*** (2).
Two recitation periods and six hours of laboratory work. Designated to accompany Chem. 226. Basic laboratory procedures involved in the preparation of aliphatic and aromatic compounds.

228. Organic Chemistry. ***Prerequisite: Chem. 226 and 227. I and II.*** (2).
Continuation of the study of laboratory techniques involved in organic chemistry.

348. Quantitative Analytical Chemistry. ***Prerequisite: Chem. 125 and 126. I, II, IIIa.*** (4).
Basic principles of volumetric, gravimetric, electrometric, and colorimetric analysis; sampling theory and separation methods. Three lectures, two laboratory periods.

365. Principles of Physical Chemistry. ***Prerequisite: Chem. 126 or 196, Physics 140-141 or 190 and preceded or accompanied by Math. 215 or 285. II.*** (4).
Kinetic theory of gases, first and second laws of thermodynamics, free energy, spontaneity of chemical reactions, chemical and phase equilibria, kinetics of chemical reactions. A self contained one term course. Lecture and recitation.

403. Inorganic Chemistry. ***Prerequisite: Chem. 348 or Chem. 197 and preceded or accompanied by Chem. 469. I and II.*** (3).
A systematic survey of the chemistry of the elements from the standpoint of atomic structure, periodic and group relationships.

413. Inorganic Chemistry Laboratory. ***Prerequisite: to be preceded or accompanied by Chem. 403. I and II.*** (2).
Laboratory work in the preparation and manipulation of inorganic materials. Techniques such as crystallization, sublimation, high-temperature reactions, and electrochemical preparations are emphasized.

427. Separation, Characterization and Identification of Organic Compounds. ***Prerequisite: Chem. 228. I, II and IIIa.*** (3).
Review of physical and chemical properties of organic compounds that lend themselves to the separation of mixtures and the characterization of ID of compounds of mixtures.

447. Physical Methods of Analysis. ***Prerequisite: Chem. 197 or 348 and 468. I and II.*** (3).
Theory and applicability of principal physical and physicochemical approaches used in chemical analysis, including electrical, optical, and radiochemical methods. Lecture.

448. Physical Methods Laboratory. ***Prerequisite: to be preceded or accompanied by Chem. 300 and Chem. 447. I, II.*** (2).
Laboratory experiments illustrating techniques or analysis discussed in Chem. 447.

468. Physical Chemistry. ***Prerequisite: Physics 240-241 or 190-191, and Math. 216 and three terms of chemistry. I, II, IIIa.*** (4).
Nature of the gaseous and liquid states, solution theory, homogeneous and heterogeneous equilibria, thermochemistry, and thermodynamics.

469. Physical Chemistry. ***Prerequisite: Math. 216 and Physics 240-241 or 190-191 and three terms of Chemistry; Chem. 468 is recommended. I, II and IIIa.*** (4).
Chemical kinetics, statistical thermodynamics, solid state; quantum chemistry, molecular structure and spectroscopy.

481. Physicochemical Measurements. ***Prerequisite: Chem. 197 or 348 and 468. To be preceded or accompanied by Chem. 469. I and II.*** (2).
Laboratory measurements involving properties of pure compounds and solutions, homogeneous and heterogeneous equilibria, kinetics, electrochemistry, and atomic and molecular properties. One discussion period dealing with treatment of errors and related topics.

482. Physicochemical Measurements. ***Prerequisite: Chem. 300 and Chem. 481. I and II.*** (2).
A continuation of Chemistry 481 involving experiments at a more advanced level.

535. Experimental Methods for the Study of Solutions of Macromolecules. ***Prerequisite: Chem. 469. II.*** (2).

536. Laboratory in Macromolecular Chemistry. ***Prerequisite: Chem. 535 or Physics 418 or permission of instructor. I.*** (2).
Experimental methods for the study of macromolecular materials in solution and in the bulk state.

538. Organic Chemistry of Macromolecules. ***Prerequisite: Chem. 226. I.*** (2).
The preparation, reactions, and properties of high molecular weight polymeric material of both natural and synthetic origin.

570. Molecular Physical Chemistry. ***Prerequisite: Chem. 468/469 or equivalent. I.*** (3).
Basic concepts in modern chemical physics; molecular symmetry, group theory, operators, introduction to the electronic structure of atoms and molecules.

575. Chemical Thermodynamics. ***Prerequisite: Chem. 469. II.*** (3).
Application of classical thermodynamics to chemical phase equilibria, solutions, and chemical reactions. Introduction to statistical mechanical calculations and nonequilibruim thermodynamics.

Civil Engineering

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See Page 60 for statement on Course Equivalence.

Faculty

E. Benjamin Wylie, Ph.D., P.E., Professor of Civil Engineering and Chairman of the Department of Civil Engineering

Jonathan W. Bulkley, Ph.D., P.E., Professor of Civil Engineering

Raymond P. Canale, Ph.D., P.E., Professor of Civil Engineering

Robert I. Carr, Ph.D., P.E., Professor of Civil Engineering

Eugene Andrus Glysson, Ph.D., P.E., Professor of Civil Engineering

Subhash C. Goel, Ph.D., P.E., Professor of Civil Engineering

Donald H. Gray, Ph.D., P.E., Professor of Civil Engineering

Robert D. Hanson, Ph.D., P.E., Professor of Civil Engineering

Movses Jeremy Kaldjian, Ph.D., Professor of Civil Engineering

Antoine E. Naaman, Ph.D., Professor of Civil Engineering

Joe E. O'Neal, M.S.E., J.D., P.E., Adjunct Professor of Civil Engineering

Egons Tons, Ph.D., P.E., Professor of Civil Engineering

Walter Jacob Weber, Jr., Ph.D., P.E., Earnest Boyce Professor of Civil Engineering

James Kenneth Wight, Ph.D., P.E., Professor of Civil Engineering

Richard D. Woods, Ph.D., P.E., Professor of Civil Engineering

Glen Virgil Berg, Ph.D., P.E., Professor Emeritus of Civil Engineering

Ernest Frederick Brater, Ph.D., P.E., Professor Emeritus of Hydraulic Engineering, Department of Civil Engineering

Donald E. Cleveland, Ph.D., P.E., Professor Emeritus of Civil Engineering

Donald Nathan Cortright, M.S.E., P.E., Professor Emeritus of Civil Engineering

Robert Blynn Harris, M.S.C.E., P.E., Professor Emeritus of Civil Engineering

Bruce Gilbert Johnston, Ph.D., P.E., Professor Emeritus of Structural Engineering, Department of Civil Engineering

Frank Edwin Richart, Jr., Ph.D., P.E., Walter J. Emmons Professor Emeritus of Civil Engineering

Wadi Saliba Rumman, Ph.D., Professor Emeritus of Civil Engineering

Victor Lyle Streeter, Sc.D., P.E., Professor Emeritus of Hydraulics, Department of Civil Engineering

Victor L. Graf, Jr., B.A., J.D., Adjunct Associate Professor of Civil Engineering

Charles J. Hurbis, B.S.E. (I.E.), J.D., Adjunct Associate Professor of Civil Engineering

Gui Ponce de Leon, Ph.D., P.E., Adjunct Associate Professor of Civil Engineering

Nikolaos D. Katopodes, Ph.D., Associate Professor of Civil Engineering

William F. Maloney, Ph.D., Associate Professor of Civil Engineering

Andrzej S. Nowak, Ph.D., Associate Professor of Civil Engineering

Steven J. Wright, Ph.D., Associate Professor of Civil Engineering

John M. Armstrong, Ph.D., Associate Professor Emeritus of Civil Engineering

Linda M. Abriola, Ph.D., Assistant Professor of Civil Engineering

Will Hansen, Ph.D., Assistant Professor of Civil Engineering

Roman D. Hryciw, Ph.D., Assistant Professor of Civil Engineering

Kim F. Hayes, Ph.D., Assistant Professor of Civil Engineering

Photios G. Ioannou, Ph.D., Assistant Professor of Civil Engineering

Ralf Peek, Ph.D., Assistant Professor of Civil Engineering

Rajendra K. Aggarwala, M.S., Adjunct Lecturer of Civil Engineering

232. Construction Surveying. ***Prerequisite: preceded or accompanied by Math. 116. I.*** (3).
The practice of survey layout associated with construction of civil engineering projects. Computation of vertical and horizontal curve layout data, traverse adjustments and coordinates, bulk material volumes; analysis of mass diagram; design of layout control systems; field exercises using transit, level,

and tapes for layout of control points, a horizontal and a vertical curve, and a building.

280. Environmental Factors in Civil Engineering. (2).
Introductory course for Civil Engineering students to provide a primary technical understanding of the role of various environmental factors in Civil Engineering work. Description of environmental factors in various areas such as transportation, construction and design, water supply, wastewater, solid waste, etc. Description of approaches to deal with environmental factors, critical design factors. Lecture and occasional field trips.

303. (Eng. 303)(Math. 371). Computational Methods for Engineers and Scientists. ***Prerequisite: Eng. 103 and preceded or accompanied by Math. 216. I and II.*** (3).
Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development and comparison of techniques for roots of nonlinear equations, simultaneous linear algebraic equations, curve fitting, numerical integration, and ordinary differential equations.

312. Theory of Structures. ***Prerequisite: Mech. Eng. 211. I.*** (3).
Calculations of reactions, shears, and bending moments in simple, restrained, and continuous beams due to fixed and moving loads; simple trusses with fixed and moving loads; determinate frames; deflections; statically indeterminate structures.

315. Design of Structures. ***Prerequisite: Civ. Eng. 312. II.*** (3).
Fundamentals of design of structural elements in reinforced concrete, steel, and timber. Allowable stress and ultimate strength design procedures. Lectures, problems.

325. (Mech. Eng. 325). Fluid Mechanics. ***Prerequisite: Mech. Eng. 240, preceded or accompanied by Mech. Eng. 235. I and II.*** (3).
Principles of mechanics applied to real and ideal fluids. Topics include fluid properties and statics; continuity, energy and momentum equations by control volume; dimensional analysis and similitude; laminar and turbulent flow; boundary layer, drag, lift; incompressible flow in pipes; free-surface flow; adiabatic flow of ideal gases in conduits; fluid measurement and turbomachinery.

351. Civil Engineering Materials. ***Prerequisite: Mat. Sci. & Eng. 250 and Mech. Eng. 211. II.*** (3).
Studies of single and multicomponent construction materials such as portland cement and bituminous concretes, plastics, wood, steel and others. Evaluation of constituents and design of mixtures or composites, load-time-deformation characteristics, and response to typical service environments. Introduction to concepts of material variability. Lectures and laboratory.

400. Contracts and Engineering Legal Relationships. ***Prerequisite: senior standing. I and II.*** (2).
Principles of contracts including formation, interpretation, performance, and remedies; American legal system; real estate, agency, workers compensation, and professional liability.

405. Civil Engineering Systems. ***Prerequisite: Math. 216. II.*** (3).
Introduction to optimization techniques with applications to civil engineering systems. Statistical topics, stochastic processes, mathematical programming, computer applications, economic concepts, and decision making.

411. (Aero. Eng. 411) (Appl. Mech. 411) (Nav. Arch. 411). Finite Element Applications. ***Prerequisite: Eng. 103, Mech. Eng. 211. I.*** (3).
The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and to interpret results. A short introduction to the underlying theory is also presented.

413. Design of Metal Structures. ***Prerequisite: Civ. Eng. 315. I.*** (3).
Design of metal members and connections, and their use in buildings and bridges. Application of relevant design specifications with emphasis on structural steel. Lectures, problems, and laboratory.

415. Design of Reinforced Concrete Structures. ***Prerequisite: Civ. Eng. 315. II.*** (3).
Design of reinforced concrete members and slabs, and their use in buildings and bridges. Application of relevant design specifications. Lectures, problems, and laboratory.

420. Hydrology. ***Prerequisite: Civ. Eng. 325 (Mech. Eng. 325). I.*** (3).
The hydrologic cycle; precipitation, its causes, distribution, and frequency; snow melting processes; evaporation; transpiration; infiltration; aquifers, well hydraulics; normal and low flows, magnitude and frequency of floods; storm sewer capacities; flood routing; storage requirements for flow augmentation; measurement of river discharge.

421. Hydraulics. ***Prerequisite: Eng. 103 or 120, Civ. Eng. 325 (Mech. Eng. 325). II.*** (3).
Gradually varied flow, controls, and hydraulic jump; orifices, weirs, and venturi meters; turbomachines, pumping systems, pipe flow, and pipe networks; sewer hydraulics and control devices; system optimization; unsteady flow. Lecture, laboratory and computation.

428. Introduction to Groundwater Hydrology. ***Prerequisite: junior standing. I.*** (3).
Importance and occurrence of groundwater; chemical and physical properties of the groundwater environment; basic principles of groundwater flow; measurement of parameters; pump test design and analysis; transport of contaminants; use of computer models for the simulation of flow and transport problems.

430. Special Problems in Construction Engineering. ***Prerequisite: permission of instructor. I, II, IIIa, and IIIb.*** (1-3)
Individual student may choose his or her special problem from a wide range of construction engineering and management areas.

431. Construction Contracting. ***Prerequisite: junior standing. I and II.*** (3).
Emphasis on business aspects of construction. (1) Organization and administration: industry structure; construction contracts, arbitration, bonds, and insurance; accounting and cost control; labor relations. (2) Construction estimating: quantity takeoff and pricing; labor and equipment estimates; estimating excavation, concrete, masonry, and carpentry; proposal preparation. Students prepare detailed estimate of a building.

432. Construction Engineering. ***Prerequisite: junior standing. I and II.*** (3).
Major construction equipment and concrete construction. Selection of scrapers, dozers, cranes, etc., based on applications, methods, and production requirements. Power generation, transmission, and output capacity of equipment engines. Calculation of transport cycle times. Concreting methods include mixing, delivery, and placement. Design of forms for concrete walls and supported slabs.

445. Engineering Properties of Soil. ***Prerequisite: Mech. Eng. 211. I.*** (3).
Soil classification and index properties; soil structure and moisture, seepage; compressibility and consolidation; stress and settlement analysis; shear strength. Lectures, problems, and laboratory.

470. Transportation Engineering. ***Prerequisite: junior standing. II.*** (3).
Planning, location, design, and operation of transportation facilities. Introduction to engineering economics.

480. Environmental Chemodynamics. ***Prerequisite: Chem. 123 or 124, and 125; and Math. 216. I.*** (3).
Transformation processes in environmental systems; transport and reaction phenomena; modeling of homogeneous and heterogeneous chemical and biochemical kinetics and equilibria in lakes, rivers, estuaries, and other natural waters; in water and wastewater treatment processes; and in other systems of concern in environmental engineering and pollution control.

481. Chemical Analysis of Water Quality. ***Prerequisite: preceded or accompanied by Civ. Eng. 480. I.*** (1).
Principles and techniques of methods for analysis of waters, wastewaters, and solid wastes. Conventional and instrumental methods of analysis, including spectrophotometric methods, electrochemical methods, atomic absorption, and vapor-phase chromatography. Designed to accompany Civ. Eng. 480.

482. Environmental Biodynamics. ***Prerequisite: Chem 123, Math. 216. I.*** (3).
Identification, description and activities of the bacteria, algae, protozoa, fungi and viruses as determinants of environmental quality; the role of micro-organisms as contaminants and as agents of purification and transformation; principles and techniques for measuring and predicting microbial activity in water and wastewaters; lecture and lab.

485. Water Supply and Waste-Water Engineering. ***Prerequisite: junior or senior standing. I and IIIa.*** (4).
Sources of public water supply, quality and quantity requirements; design of works for the collection and purification of water for municipal use; requirements for municipal wastewater systems, fundamentals of design of waste-water treatment plants and environmental effects. Lecture and recitation.

501. Legal Aspects of Engineering. ***Prerequisite: Civ. Eng. 400 or a course in contract law. I.*** (3).
Provides insight into various areas of civil litigation. Includes personal and property loss, professional liability, product liability, land use, and the role of the engineer as an expert witness.

511. Fiber Reinforced Cement Based Composites. ***Prerequisite: Civ. Eng. 415 or Civ. Eng. 553. II.*** (3).
Fiber reinforcement of cement based matrices; continuous and discontinuous fibers and meshes. Fiber reinforced concrete and Ferrocement. Behavior and mechanical properties. Mechanics of fiber reinforcement. Constitutive models. High strength, high performance fiber composites. Influence of additives such as superplasticizers, micro-silica and polymers. Lectures, projects and laboratory.

512. Advanced Theory of Structures. ***Prerequisite: Civ. Eng. 312. II.*** (3).
Analysis of structures by flexibility methods; energy theorems and principle of virtual work; deflections by graphical and numerical methods.

513. (Appl. Mech. 513). Fracture Analysis. ***Prerequisite: senior Standing. I.*** (3).
Self-contained introduction to linear elastic fracture mechanics including elements of plane elasticity. Topics: Airy stress function, Green's functions, dislocation solutions, crack tip asymptotics, stress intensity factors, interface cracks, numerical solutions based on singular integral equations.

514. Rigid Frame Structures. ***Prerequisite: Eng. 103 and Civ. Eng. 312. I and IIIa.*** (3).
Analysis of frame structures by stiffness methods, including slope-deflection and moment distribution; matrix procedures and computer solutions.

515. Prestressed Concrete. ***Prerequisite: Civ. Eng. 315. I.*** (3).
Fundamental principles of prestressing; prestressing materials; prestress losses; allowable stress and ultimate strength design methods; analysis and design of beams for flexure, shear, and deflection; composite construction; bridges; slab systems.

516. Bridge Structures. ***Prerequisite: Civ. Eng. 413 and Civ. Eng. 415. I.*** (3).
Advanced concepts and modern trends in design of bridges. Rehabilitation, repair, and retrofit of existing bridges. Use of relevant codes. Study of alternative structural forms and materials for efficiency and economy. Design problems and reports.

517. Structural Safety. ***Prerequisite: Civ. Eng. 315. II.*** (3).
Fundamental concepts related to structural safety, statistical analysis and modeling of resistance and loads, safety measures, optimum safety levels, optimization of building codes.

518. Advanced Design of Reinforced Concrete Structures. ***Prerequisite: Civ. Eng. 415. I.*** (3).
Analysis and design of concrete structural systems including two way floor systems, slender columns, members subjected to torsion, foundation systems, retaining walls, shear walls, deep beams and connections. Applications of computer aided design programs. Use of design code provisions. Design projects.

519. Plastic Analysis and Design of Frames. II. (3).
Plastic analysis of structural frames. Rules of practice for the plastic design of steel structures. Design problems and reports.

520. Deterministic and Stochastic Models in Hydrology. ***Prerequisite: Civ. Eng. 420 and 421. II.*** (3).
Mathematical description of the Hydrologic cycle. Computation of overland flow. Flood routing through reservoirs and rivers. Unit Hydrograph theory. Linear and nonlinear models for small watershed analysis. Application of time series and spectral analysis to hydrologic data. Streamflow stimulation by autoregressive and moving average models.

523. Flow in Open Channels. ***Prerequisite: Civ. Eng. 325 (Mech. Eng. 325). I.*** (3).
Energy and momentum concepts; flow in the laminar and transition ranges; selection of canal cross-sections; minor losses; critical depth; rapidly varied flow; controls; gradually varied flow; channels of varying width; steep chutes; translatory waves; high velocity transitions; bends.

525. Turbulent Mixing in Environmental Applications. ***Prerequisite: Civ. Eng. 325 (Mech. Eng. 325). II.*** (3).
Mechanics of fluid waste discharges to the environment. Solution of the diffusion equation with applications including longitudinal dispersion. Detailed analysis of jet mixing including surface jets, effects of ambient current and density stratification, and buoyancy effects.

526. Design of Hydraulic Systems. ***Prerequisite: Civ. Eng. 420 and preceded or accompanied by Civ. Eng. 421. II.*** (3).
Hydraulic aspects of the design of canals, dams, gates, spillways, sea walls, breakwaters, and other structures. Determination of the most economic design of an hydraulic engineering project. Application of the digital computer to engineering design.

527. Coastal Hydraulics. ***Prerequisite: Civ. Eng. 325. (Mech. Eng. 325). I.*** (3).
Equations of oscillatory wave motion; generation of waves by wind; refraction; energy transmission, breaking waves, diffraction; energy dissipation; run-up and overlapping; wave forces; the design of sea walls and breakwaters; currents and wind tides; shore erosion processes; harbor design.

528. Groundwater Hydraulics. ***Prerequisite: Civ. Eng. 325 (Mech. Eng. 325). I.*** (3).
Basic principles of flow in porous media; practical application of techniques to well, aquifer, and seepage problems; evaluation of hydrogeologic parameters; flow in the unsaturated zone of soils; contaminant transport in groundwater; hydrodynamic dispersion and transport parameters.

529. Hydraulic Transients I. ***Prerequisite: Civ. Eng. 421. I.*** (3).
Incompressible unsteady flow through conduits; numerical, algebraic and graphical analysis of waterhammer; solution of transient problems by the method of characteristics; digital computer applications to pump failures, complex piping systems; valve stroking, and liquid column separation.

531. Construction Cost Engineering. ***Prerequisite: graduate standing and preceded or accompanied by Civ. Eng. 431. I.*** (3).
Cost engineering for construction organizations, projects, and operations. Construction financing; breakeven, profit, and cash flow analyses; capital budgeting. Equipment cost and procurement decisions. Construction financial accounting, cost accounting, cost control systems, databases. Cost indices, parametric estimates, unit price proposals, measuring work and settling claims.

532. Construction Management and Project Engineering. ***Prerequisite: graduate standing and preceded or accompanied by Civ. Eng. 431. I.*** (3).
Planning, organizing, staffing, directing, and controlling construction firms, departments, projects, and operations. Strategic planning; organization design and behavior; construction business functions; marketing; management information systems. Project organizations; man-power planning; jobsite layout; labor, material procurement; time, cost, quality control. Construction operation planning, supervision, analysis work improvement. Case studies, projects from construction.

533. Construction Performance Management. ***Prerequisite: senior or graduate standing. I.*** (3).
Dimensions of performance: effectiveness, efficiency, safety, quality, profitability, productivity, quality of work life, innovation. Factors that influence performance: environment, structure, organizational and behavioral processes such as planning, controlling and motivation. Measurement, analysis, and improvement of performance. Examples and cases from construction settings.

534. Heavy Industrial Construction. ***Prerequisite: senior or graduate standing. IIIa.*** (3).
Design interdependencies, procurement, construction, and start-up of heavy industrial facilities; power plants, chemical plants, oil refineries. Design interfaces, specifications, drawing preparation. Procurement contracts, fabrication, quality control. Construction: site, structural, piping and vessels, electrical, instrumentation. Job planning and organization. Facility start-up. Examples from construction settings.

535. Excavation and Tunneling. ***Prerequisite: Civ. Eng. 445. II.*** (3).
Selection of methods of attack for excavation of tunnels and deep vertical-sided openings. Tunneling procedures based on behavioral characteristics of soil and rock. Study of tunnel boring machines, shielded and drill-and-blast operations, linings. Deep excavation procedures related to support of excavation systems, methods of installation and dewatering.

536. Critical Path Methods. ***Prerequisite: senior or graduate standing. I and II.*** (3).
Basic critical path planning and scheduling with arrow and precedence networks; project control; basic overlapping networks; introduction to resource leveling and least cost scheduling; fundamental PERT systems.

537. Construction of Buildings. ***Prerequisite: Civ. Eng. 315. I.*** (3).
Material selection, construction details, manufacture, fabrication, and erection of building structures using steel, light wood, timber, cast-in-place concrete, precast concrete, and masonry; and of building materials for roof, floor, and wall surfaces. Field trips to fabrication plants and construction sites.

538. Concrete Construction. ***Prerequisite: Civ. Eng. 351 and Civ. Eng. 315. I.*** (3).
Selection of concrete, batch design, additives, and batch plant. Structural design, construction of concrete formwork for buildings, civil works. Transporting, placing, and finishing equipment and methods. Plant and on site precasting and prestressing methods and field erection. Sprayed, vacuum, and preplaced aggregate concrete applications. Industrialized concrete systems. Concrete grouting, repair.

540. (G.S. 540). Seminar in Engineering Geology. ***Prerequisite: Civ. Eng. 445 and a 400-level course in physical geology or geomorphology. II.*** (2).
Study of case histories in engineering geology, dealing with dam sites, slope stability, waste disposal, foundation and bridge problems, power plant siting, groundwater, and other problems.

541. Soil Sampling and Testing. ***Prerequisite: preceded or accompanied by Civ. Eng. 445. I.*** (3).
Field and laboratory practice in sampling and testing of soils for engineering purposes. Field sampling and testing; standard split-spoon sampler, Dutch Cone penetrometer, field vane, Iowa borehole shear device. Lab tests; direct shear, unconfined compression, triaxial compression, consolidation. Laboratory and lecture.

542. Soil and Site Improvement. ***Prerequisite: Civ. Eng. 445. I.*** (3).
Analysis of geotechnical problems affecting site use including weak, compressible soil; water logged conditions; high shrink-swell potential; erodibility. Stabilization techniques including compaction, earth reinforcement, drainage and erosion control, admixture stabilization, grouting, precompression, thermal and electro-kinetic stabilization. Geotechnical aspects of disposal fills, e.g., tailings, fly ash, sanitary landfills, and hazardous waste.

544. Rock Mechanics. ***Prerequisite: Mech. Eng. 210. I.*** (3).
Engineering properties and classification of rocks. Strength and deformability of intact and jointed rock; in-situ stresses; lab and field test methods. Stereonets and structural geology. Rock slopes; stability and reinforcement. Foundations on rock. Rock blasting; explosives; shot design; vibration problems.

545. Foundation Engineering. ***Prerequisite: Civ. Eng. 445. I.*** (3).
Application of principles of soil mechanics to: determination of bearing capacity and settlement of spread footings, mats, single piles and pile groups; site investigation, evaluation of data from field and laboratory tests; estimation of stresses in soil masses; and lateral resistance of piles and pile groups.

546. Stability of Earth Masses. ***Prerequisite: Civ. Eng. 445. II.*** (3).
Stability of hillsides and open cuts, geologic considerations; stability of man made embankments including earth dams and structural fills, compaction and placement of soil in earth embankments, problems of seepage and rapid drawdown, earthquake effects, slope stabilization techniques; lateral earth pressures and retaining walls, braced excavations.

547. Soils Engineering and Pavement Systems. ***Prerequisite: Civ. Eng. 445. II.*** (3).
Soils engineering as applied to the design, construction and rehabilitation of pavement systems. The design, evaluation and rehabilitation of rigid, flexible and composite pavements.

548. Foundations for Marine Structures. ***Prerequisite: Civ. Eng. 445. I.*** (3).
Effects of seepage and dewatering on design of waterfront structures. Soil retaining structures, cellular cofferdams, anchored bulkheads. Compaction and consolidation of soil masses. Water wave forces on offshore and harbor structures. Soil-structure interaction for offshore towers, piers, wharves, sea walls, and jetties.

550. Quality Control of Construction Materials. ***Prerequisite: Civ. Eng. 351. II.*** (3).
Construction material specification and test procedures. Sampling methods, data collection and statistical data distributions. Quality control charts, development of quality assurance specifications and acceptance plans. Examples using data from actual field construction and laboratory experiments collected by destructive and non-destructive methods.

551. Rehabilitation of Constructed Facilities. ***Prerequisite: Civ. Eng. 351. I.*** (3).
Infrastructure needs. Rehabilitation studies of buildings, underground construction, bridges, streets, and highways: Types of distress; numerical condition surveys for foundation, structural, and functional deterioration; design criteria; materials and techniques; predictive performance models; evaluating alternatives; databases; maintenance management.

552. Bituminous and Cement Mixes for Construction. ***Prerequisite: Civ. Eng. 351. II.*** (3).
Types and properties of bituminous, portland, and other cements used in construction. Natural and synthetic aggregate characteristics and uses. Compositions and properties of different mixtures used for highways, airports, parking areas, reservoir linings and other constructed facilities. Laboratory experiments with selected compositions.

553. Advanced Concrete Materials. ***Prerequisite: Civ. Eng. 351. I.*** (3).
Concrete components, microstructure, and properties of portland cement pastes. Early heat of hydration and thermal stress development in concrete. Strength , fatigue, failure mechanisms, creep, shrinkage, and durability of hardened concrete. Special concretes: lightweight, heavyweight, high strength, and ultra high strength.

571. Traffic Engineering. ***Prerequisite: Civ. Eng. 470.*** (3).
Driver, pedestrian, transit rider, vehicle and way characteristics and studies. Traffic system management including planning and design of information and control device applications.

572. Transportation Evaluation Methods. ***Prerequisite: Civ. Eng. 470.*** (3).
Methods of evaluation in transportation systems planning, design and operation. Cost and impact analysis; transportation economics; multi objective decision methods.

573. Geometric Design of Ways and Terminals. ***Prerequisite: Civ. Eng. 470.*** (3).
Land transportation geometric design controls. Alignment, cross section, and intersection design for highway and railway routes. Geometric design of bus and rail terminals, parking facilities, and airports. Lecture, problems, and design laboratory.

574. Public Transportation Systems. ***Prerequisite: Civ. Eng. 470.*** (3).
The planning, location, design, construction, maintenance and operation of railroad facilities, other guideway systems and public bus transportation services.

575. Airport Planning and Design. ***Prerequisite: Civ. Eng. 470.*** (3).
Planning, site selection, and configuration; airport capacities; air traffic control; geometric design of landing area; development of terminal area; lighting; pavement requirements; drainage.

576. Disaggregate Transportation Demand Models. ***Prerequisite: senior or graduate standing.*** (3).
An introduction to the development of disaggregate travel demand methodology including multinomial logic and probit models, aggregation techniques and application to the urban transportation planning process.

577. Traffic Flow I. ***Prerequisite: a course in statistics.*** (3).
Studies of determinants and characteristics of traffic flow and accidents.

578. Transportation Planning. ***Prerequisite: Civ. Eng. 470.*** (3).
Application of systems analysis techniques to the generation, evaluation, and selection of alternative transportation plans. Use of quantitative and qualitative analysis of multimode networks for the selection of operating policies and investment programs. Consideration of planning processes and federal guidelines.

579. Special Problems in Transportation. ***Prerequisite: permission of instructor. I, II, and IIIa.*** (1-3).
Advanced problems selected from the broad area of transportation engineering, including railroads, airports, highways, traffic, and mass transportation.

580. Process Dynamics in Environmental Engineering. ***Prerequisite: Civ. Eng. 480 and concurrent registration in Civ. Eng. 581. II.*** (3).
Reactor systems, dynamics, modeling and design; mass transport, transfer and transformation processes in natural waters and treatment operations; energetics and kinetics of chemical and biochemical processes; chemical and biochemical oxidations; gas transfer; corrosion; electrochemical processes; sorption and exchange reactions; particle growth kinetics and coagulation phenomena.

581. Physicochemical Unit Operations. ***Prerequisite: preceded or accompanied by Civ. Eng. 580. II.*** (1).
Unit operations for treatment of waters and wastewaters. Laboratory studies of reactor configurations and non-ideal behavior; coagulation and sedimentation; filtration; chemical and biochemical oxidations; adsorption and ion exchange; and membrane separations. Designed to accompany Civ. Eng. 580.

582. Biological Processes in Environmental Engineering. ***Prerequisite: Civ. Eng. 482. II.*** (3).
Analysis and modeling of the kinetics of microbial substrate utilization and biomass production as these relate to processes in water quality control. Topical emphasis is placed on aerobic and anaerobic biological unit processes for renovation of waters and wastewaters to illustrate these fundamental principles. Lecture, lab and computation.

584. (E.I.H. 667). Hazardous Waste Processes. I. (3).
The study of thermal, chemical and other systems and processes used in the detoxification of hazardous wastes, other than radioactive wastes.

585. Solid Waste Engineering. II. (3).
The study of methods for managing the solid wastes generated by urban communities, evaluating alternatives and design of disposal facilities. Methods for minimizing adverse effects on the human health and environment are included.

586. Industrial Wastes Characterization. ***Prerequisite: Chem. 123. II.*** (2).
Evaluation of the industrial waste problem. Characterization and identification of industrial wastes. Survey and monitoring techniques. Current topics of special interest.

587. (Nat. Res. 558). Water Resource Policy. ***Prerequisite: senior or graduate standing. I.*** (3).
Consideration of policy processes associated with the development and utilization of water resources. Special attention is given to the history and development of policy related to water quality. Multi-objective planning is presented. Consideration of institutional problems associated with the implementation of water policy in the federal-state-regional-local arenas.

588. Environmental and Water Resource Systems and Economics. I. (3).
Introduction to the concepts of systems analysis and related topics as applied to environmental and water resources problems. Use of decision theory and mathematical programming techniques. Cost benefit analysis, resource economics, and analytical modeling in contemporary environmental and water quality problems.

589. (Nat. Res. 595). Risk and Benefit Analysis in Environmental Engineering. ***Prerequisite: senior or graduate standing. II.*** (3).
Introduction to techniques of risk benefit analysis as applied to water resources and environmental engineering. Techniques of multi-objective water resource planning. The engineering political interfaces; consideration of political bargaining and decision making.

590. Stream, Lake, and Estuary Analysis I. ***Prerequisite: Math. 216. II.*** (3).
Introductory principles of mass transport, kinetics, and material balance. Characteristics and distribution of contaminants in waterways. Effects of biological oxygen demand, reaeration, sludge deposits, nitrification, and aquatic plants. Mathematical models describing oxygen resources in streams, lakes, and estuaries. Demonstration of practical problems.

591. Stream, Lake, and Estuary Analysis II. ***Prerequisite: Civ. Eng. 590. II.*** (3).
Comprehensive examination of water quality survey data from streams, lakes, and estuaries and construction of mathematical models; specification of performance criteria for waste control processes, based on an analysis of the reaction and transport characteristics of contaminants in the aquatic environment; guest lecturers; computer applications.

592. Sludge Treatment and Disposal. ***Prerequisite: preceded or accompanied by Civ. Eng. 485, 580, or 582. II.*** (3).
Processes and operations for concentrating, stabilizing, and disinfecting the solid residuals from water and wastewater treatment plants. Characterization, utilization, and disposal of these sludges. Lecture and lab.

599. (E.I.H. 699). Hazardous Wastes: Regulation, Remediation, and Worker Protection. ***Prerequisite: graduate standing and E.I.H. 503 or E.I.H. 508 or E.I.H. 541 or E.I.H. 650 or E.I.H. 667 or permission of instructor. II.*** (3).
Integration of information on current regulatory climate and governmental guidelines with case studies in hazardous wastes/substances. Case studies provide examples of hazardous waste and remedial actions, with emphasis on site worker exposure and protection, and community exposures to chemical and radiological agents. Lectures, problem solving sessions, and guest speakers.

610. (Nav. Arch. 610). Finite Element Methods. ***Prerequisite: Eng. 103, and Nav. Arch. 510 or Civ. Eng. 512. II.*** (3).
Influence coefficients and stiffness matrices. Formulation and calculation of the finite element matrices using the principle of virtual displacement. Preparing computer programs. Introduction to the isoparametric family of elements. Familiarization with and use of existing finite element programs and pre- and post-processors for data processing and graphic display.

611. Structural Dynamics. I. (3).
Structural vibrations. Transient and steady-state response to dynamic forces. Response beyond the elastic range. Response to nuclear explosions. Earthquake forces. Structural response to earthquake. The response spectrum. Seismic building codes and their relation to structural dynamics.

612. Metal Structural Members. ***Prerequisite: Civ. Eng. 413. I.*** (3).
Elastic and inelastic behavior of beams and columns. Torsion of open and box members. Combined bending and torsion. Buckling of beams and beam-columns. Behavior of steel and aluminum structural members is studied with reference to their code design procedures.

613. Reinforced Concrete Members. ***Prerequisite: Civ. Eng. 415. II.*** (3).
Inelastic behavior of reinforced concrete beams, columns and connections. Combined bending, shear, and torsion in beams. Behavior under load reversals, and development of appropriate hysteresis models. Derivation of relevant design code provisions.

614. Advanced Problems in Statically Indeterminate Structures. ***Prerequisite: Civ. Eng. 512 and 514. I.*** (3).
Review of flexibility and stiffness methods; continuous truss bents; arches; rings; frames with curved members; flexible members, including suspension bridges and towers; frames with semirigid connections.

615. Analysis and Design of Folded Plates, Domes, and Shells. ***Prerequisite: Civ. Eng. 512 and 514. II.*** (3).
Stresses and special design problem in folded plate construction; membrane stresses in domes and double curved shells; flexural action near boundaries; cylindrical concrete shell roofs; cylindrical tanks.

616. Structural Design for Dynamic Forces. ***Prerequisite: Civ. Eng. 611. II.*** (3).
Determination of dynamic loads on structures caused by earthquakes, wind, impact, and vibration. Methods of design to resist these forces utilizing elastic and inelastic material and member characteristics. Lectures and independent projects.

618. Advanced Prestressed Concrete. ***Prerequisite: Civ. Eng. 515. II.*** (3).
Prestressing in statically indeterminate structures; design of prestressed concrete slabs; analysis and design of partially prestressed concrete beams; nonlinear analysis; optimum design; analysis of members prestressed with unbonded tendons; prestressed tensile members. Special research and/or application related topics.

621. Computational Hydraulics. ***Prerequisite: Civ. Eng. 523 and Chem. Eng. 508. II.*** (3).
Development of computational techniques for two- and three-dimensional flow problems. Simulation of shallow-water flow in rivers and estuaries. Floodwaves and tidal bores. Groundwater and seepage models. Computation of contaminant transport in streams and aquifers. Comparative analysis, verification and calibration of regional models. Computer graphics for multidimensional flow problems.

622. Special Problems in Hydraulic Engineering or Hydrology. ***Prerequisite: permission of instructor. I. and II. (To be arranged).***
Assigned work on an individual basis. Problems of an advanced nature may be selected from a wide variety of topics.

624. Free Surface Flow. ***Prerequisite: Civ. Eng. 523.*** (3).
Dynamics of spatially varied flow; unsteady momentum and continuity equations applied to prismatic and nonprismatic channels. Rainfall and overland flow relationships. Different numerical solutions to flood routing in channels and flood plains. Simulation techniques using digital computer.

628. Numerical Modeling of Subsurface Flow. ***Prerequisite: Civ. Eng. 528 and Math. 471.*** (3).
Application of numerical solution methods, including finite differences, finite elements, boundary elements, and method of characteristics to various subsurface flow problems: saturated isothermal flow, solute transport, multiphase flow, geothermal reservoirs, use and modification of existing models in addition to new code development.

629. Hydraulic Transients II. ***Prerequisite: Civ. Eng. 529. II.*** (3).
Steady-oscillatory flow by impedance methods and characteristics methods; self-excited and forced resonance of piping systems; pulsatile flow through distensible tubes. Digital computer applications to reciprocating pumps, valving, resonance in complex piping systems, hydropower systems.

630. Directed Studies in Construction Engineering. ***Prerequisite: graduate standing. I, II, IIIa and IIIb.*** (1-3).
Selected reading in specific construction areas.

631. Construction Decisions Under Uncertainty. ***Prerequisite: Civ. Eng. 405 or a course in probability or statistics such as Stat. 310 or Stat. 311 or S.&M.S. 301. II.*** (3).
Construction project and organization decisions for the uncertain future. Selection of construction method, equipment, contract, markup, and financing alternatives having the highest expected values. Uses decision theory, competitive bid analysis, probabilistic modeling and simulation, and multiple regression analysis in managing construction.

632. International Construction. ***Prerequisite: preceded or accompanied by Civ. Eng. 532.*** (3).
Conditions and practices necessary for multinational construction operations. Financial environment, world trade, and investment. Cross cultural influences. International construction markets. International construction contracts. Mobilization and performance of international construction projects.

633. Construction Management Information Systems. ***Prerequisite: Civ. Eng. 531 and preceded or accompanied by Civ. Eng. 536. II.*** (3).
Design of computerized construction management information systems (MIS). Students perform microcomputer database and spread-sheet programming to develop estimating, planning and scheduling, financial and cost accounting, and project control subsystems having common, integrated data structures. Students implement subsystems as an integrated MIS which they apply to construction problems and case studies.

636. Project Networking Techniques. ***Prerequisite: Civ. Eng. 536.*** (3).
Advanced networking techniques. Unlimited and limited resource leveling. Time-cost trade-offs using precedence networks. Targeting, updating and float trend analyses. Network cost analysis using PMS criteria. Extensions to precedence networks. Survey of computerized CPM systems. CPM implementation in major projects.

645. Theoretical Soil Mechanics. ***Prerequisite: permission of instructor.*** (3).
Stress conditions for failure of soils; earth pressures and retaining walls; arching in soils; theories for elastic and plastic deformations of soil masses; theory of bearing capacity; theories for stresses in semi-infinite and layered elastic solids; theory of elastic subgrade reaction.

648. Dynamics of Soils and Foundations. ***Prerequisite: Civ. Eng. 445. II.*** (3).
Transient and steady state vibrations of foundations; phase plane analysis of foundations with one and two degrees of freedom; dynamic properties of soils; vibration transmission through soils.

649. Civil Engineering Vibrations Laboratory. ***Prerequisite: Civ. Eng. 611 and preceded or accompanied by Civ. Eng. 648. II.*** (2).
Field and laboratory determination of dynamic material properties; measurement of vibration of structures and foundations; introduction to electronics for dynamic measurements; introduction to holographic interferometry.

676. Traffic Control. ***Prerequisite: Civ. Eng. 577.*** (3).
Theory and application of traffic control techniques.

677. Traffic Flow II. ***Prerequisite: Civ. Eng. 676.*** (3).
Detailed studies of microscopic and macroscopic traffic flow theories.

680. Environmental Engineering Design I. ***Prerequisite: graduate standing.*** (2).
The first of a two-course sequence ending with Civ. Eng. 681. Development of information required for the analysis of design problems in contemporary environmental engineering. Topics considered include engineering economics, computer-aided design, and project specification requirements. Formulation and presentation of preliminary facilities and systems designs. Lectures and project work.

681. Environmental Engineering Design. II. ***Prerequisite: Civ. Eng. 680. II.*** (2).
The second of a two-course sequence beginning with Civ. Eng. 680. Performance and presentation of comprehensive open-ended environmental engineering design problems developed in Civ. Eng. 680. Design considerations include system characterization, analysis of alternatives, process and equipment selection and configuration, and cost assessment and analysis.

682. Special Problems in Environmental Engineering. ***Prerequisite: permission of instructor. I, II, IIIa, and IIIb. (To be arranged).***
Special problems designed to develop perspective and depth of comprehension in selected areas of sanitary, environmental or water resources engineering.

687. (E.I.H. 617). Special Problems in Solid Waste Engineering. ***Prerequisite: Civ. Eng. 585 and permission of instructor. I, II, IIIa and IIIb. (To be arranged).***
Application of principles presented in Civ. Eng. 585 to engineering and environmental health problems in the collection and disposal of solid wastes; comprehensive analysis and report assigned on an individual student basis.

810. Structural Engineering Seminar. ***I and II. (To be arranged).***
Preparation and presentation of reports covering assigned topics.

825. Seminar in Hydraulic Engineering. ***Prerequisite: Civ. Eng. 420 and 523. (To be arranged).***
Assigned reading and student reports on problems selected from the field of hydraulic engineering.

830. Construction Engineering and Management Seminar. ***I and II. (To be arranged).***
Assigned reading and student reports on problems selected from the field of construction engineering and management.

870. Transportation and Traffic Engineering Seminar. ***I and II. (To be arranged).***
Assigned reading and student reports on problems selected from the fields of transportation and traffic engineering.

875. Highway Engineering Seminar. ***Prerequisite: graduate standing. I and II. (To be arranged).***
Seminar dealing with highway design, materials and construction. Assigned reading and student reports.

880. Seminar in Environmental Engineering. ***I and II. (To be arranged).***
Presentation and discussion of selected topics relating to environmental engineering. Student participation and guest lecturers.

885. Seminar in Water Resources Management and Science. ***Prerequisite: graduate standing. I and II. (To be arranged).***
Topics are examined which are of particular interest to students in the University of Michigan interdisciplinary graduate program in Water Resources. Student presentations, outside speakers, and faculty participation constitute the seminar.

910. Structural Engineering Research. ***(To be arranged).***
Assigned work in structural engineering as approved by the professor of structural engineering. A wide range of subject matter is available, including laboratory and library studies.

920. Hydrological Research. ***Prerequisite: Civ. Eng. 420. (To be arranged).***
Individual or group research in particular topics in hydrology. A variety of topics may be selected.

921. Hydraulic Engineering Research. ***Prerequisite: permission of instructor. (To be arranged).***
Assigned work in hydraulic research; a wide range of matter and method permissible.

930. Construction Engineering Research. ***(To be arranged).***
Selected work from a wide range of construction engineering areas including planning, equipment, methods, estimating and costs.

946. Soil Mechanics Research. ***(To be arranged).***
Advanced problems in soil mechanics, foundations or underground construction, selected to provide the student with knowledge of recent application and development in engineering design and construction practice. Assigned problems must be carried to a stage of completion sufficient for a written report which will normally be required for credit.

970. Transportation Engineering Research. ***Prerequisite: permission of instructor. (To be arranged).***
Individual research and reports on library, laboratory, or field studies in the areas of transportation and traffic engineering.

975. Highway Engineering Research. ***Prerequisite: permission of instructor. (To be arranged).***
Individually assigned work in the field of highway engineering.

980. Research in Environmental Engineering. ***Prerequisite: permission of instructor. (To be arranged).***
A research study of some problems relating to water resource development and water supply, waste treatment and pollution control, or sanitation and environmental health; a wide range of both subject matter and method is available, including field investigations, laboratory experimentation, library and public record searches, and engineering design work.

990. Dissertation/Pre-Candidate. ***I, II, and III*** (2-8); ***IIIa and IIIb*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as Candidate.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III*** (8); ***IIIa and IIIb*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a Candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Economics*

Department Office:
Room 206, Lorch Hall, (313) 764-2355

*College of Literature, Science, and the Arts.

Professor Porter, Chairman; Professor Brown, Associate Chairman; Professors Anderson, Barlow, Bergstrom, Bornstein, Courant, Cross, Deardorff, Dernberger, Duncan, Feldstein, Gordon, Gramlich, Holbrook, Howrey, Hymans, Johnson, Juster, Kmenta, Laitner, Morgan, Mueller, Salant, Saxonhouse, Shapiro, Stafford, Steiner, Stern, Varian, Weisskopf, White; Emeritus Professors Ackley, Brazer, Fusfeld, Haber, Levinson, Palmer, Stolper; Associate Professors Adams, Blume, Simon, Slemrod, Whatley, Zimmerman; Assistant Professors Almansi, Aschauer, Bagnoli, Barsky, Borenstein, Bound, Freedman, Hartzmark, Jones, Katz, Kimball, Kossoudji, Lam, Levinsohn, Mackie-Mason, Miron, Solon; Emeritus Assistant Professor Freedman; Lecturers Crafton, Gerson, Wolfe; Adjunct Professor Whitman.

A. Introductory Courses

Students who want to take advanced courses in Economics must elect Economics 201 and 202.

201. Principles of Economics I. ***Prerequisite: Open to second-term freshmen. No credit granted to those who have completed Econ. 400. I, II, IIIa and IIIb.*** (4).
The basic ideas of microeconomics: production, consumption, and the markets for outputs and inputs. The virtues of competitive markets are exposed, and the causes and remedies of such market failures as monopoly, indivisibility, spillover costs and inequity are examined.

202. Principles of Economics II. ***Prerequisite: Econ. 201. No credit granted to those who have completed Econ. 400. I, II, IIIa, and IIIb.*** (4).
The basic ideas of macroeconomics: employment, inflation, output and growth. The determinants of the state of the market economy are explored, and the influence of monetary, fiscal and other public policies are examined.

310. Money and the Economy. ***Prerequisite: Econ. 201 and 202. No credit granted to those who have completed or are enrolled in Econ. 411 or 412.*** (3).
A general course on the structure of financial institutions and the role of money in the economy. Emphasis is placed on important contemporary problems in the area of monetary and fiscal policy.

320. Survey of Labor Economics. ***Prerequisite: Econ. 201 and 202. Credit is not granted to those who have taken Econ. 421 and/or 422.*** (3).
A general course that introduces students to the labor market; problems of wages and unemployment; trade unionism and collective bargaining; aspects of public policy toward labor-market issues.

330. Industrial Performance and Public Policy. ***Prerequisite: Econ. 201 and 202. Credit is not granted for Econ. 330 concurrently with or after Econ. 431 or 432.*** (3).
A survey course that develops an analytic framework for evaluating the performance of major U.S. industries and examines the principal government policy instruments affecting industrial performance.

350. Comparative Economic Systems. ***Prerequisite: Econ. 201 and 202. No credit granted to those who have completed or are enrolled in Econ. 451.*** (3).
Theories of capitalism and socialism and of market and planned economies, and their application in selected countries, including the United States and the Soviet Union.

380. Public Finance. ***Prerequisite: Econ. 201 and 202. Credit is not granted for Econ. 380 concurrently with or after Econ. 481 or Econ.482.*** (3).
A survey of government expenditure and revenue issues, designed for students wishing to take a single comprehensive course in the field of public finance.

400. Modern Economic Society. ***Prerequisite: For upperclass and graduate students without prior credit for principles of economics. I, II, IIIa and IIIb.*** (4).
A single-term accelerated treatment of the material of Econ. 201 and 202. (Econ. 400 is sometimes permitted to serve as a prerequisite for advanced courses in Economics. Students who have received credit for Econ. 201 and/or 202 may not receive credit for Econ. 400).

For further details with respect to these courses and for additional courses in the field of economics, consult the Bulletin of the College of Literature, Science, and the Arts.

Electrical Engineering and Computer Science

Department Office:
3303 EECS Building
phone (313) 764-2390
See Page 60 for statement on Course Equivalence.

Faculty

Edward S. Davidson, Ph.D., Professor of Electrical Engineering and Computer Science; Chairman of Electrical Engineering and Computer Science Department

David J. Anderson, Ph.D., Professor of Electrical Engineering and Computer Science

Daniel E. Atkins, Ph.D., Professor of Electrical Engineering and Computer Science and Associate Dean of the College of Engineering

Ben F. Barton, Ph.D., Professor of Electrical Engineering and Computer Science

Spencer L. BeMent, Ph.D., Professor of Electrical Engineering and Computer Science

Frederick J. Beutler, Ph.D., Professor of Electrical Engineering and Computer Science

Pallab K. Bhattacharya, Ph.D., Professor of Electrical Engineering and Computer Science

Theodore G. Birdsall, Ph.D., Professor of Electrical Engineering and Computer Science

William M. Brown, Dr. Eng., P.E., Adjunct Professor of Electrical Engineering and Computer Science

Donald A. Calahan, Ph.D., Professor of Electrical Engineering and Computer Science

Kan Chen, Sc.D., Professor of Electrical Engineering and Computer Science

Chiao-Min Chu, Ph.D., Professor of Electrical Engineering and Computer Science

Kuei Chuang, Ph.D., Professor of Electrical Engineering and Computer Science

Lynn A. Conway, M.S.E.E., Professor of Electrical Engineering and Computer Science and Associate Dean of the College of Engineering

Anthony W. England, Ph.D., Professor of Electrical Engineering and Computer Science

Aaron Finerman, Sc.D., Professor of Electrical Engineering and Computer Science

Gideon Frieder, D.Sc., Professor of Electrical Engineering and Computer Science

Bernard A. Galler, Ph.D., Professor of Electrical Engineering and Computer Science and Associate Director of the Computing Center

Ward D. Getty, Sc.D., P.E., Professor of Electrical Engineering and Computer Science

Elmer G. Gilbert, Ph.D., Professor of Electrical Engineering and Computer Science and Aerospace Engineering

Daniel G. Green, Ph.D., Professor of Electrical Engineering and Computer Science

Yuri Gurevich, Ph.D., Professor of Electrical Engineering and Computer Science

George I. Haddad, Ph.D., Professor of Electrical Engineering and Computer Science

John P. Hayes, Ph.D., Professor of Electrical Engineering and Computer Science

John H. Holland, Ph.D., Professor of Electrical Engineering and Computer Science

Keki B. Irani, Ph.D., Professor of Electrical Engineering and Computer Science and Associate Chairman of the Computer Science and Engineering Division

Ramesh C. Jain, Ph.D., Professor of Electrical Engineering and Computer Science

Stephen Kaplan, Ph.D., Professor of Electrical Engineering and Computer Science

Emmett N. Leith, Ph.D., Professor of Electrical Engineering and Computer Science

Ronald J. Lomax, Ph.D., Professor of Electrical Engineering and Computer Science

Alan B. Macnee, Sc.D., Professor of Electrical Engineering and Computer Science

N. Harris McClamroch, Ph.D., Professor of Electrical Engineering and Computer Science and Aerospace Engineering

Semyon M. Meerkov, Ph.D., Professor of Electrical Engineering and Computer Science

John F. Meyer, Ph.D., Professor of Electrical Engineering and Computer Science

Andrew F. Nagy, Ph.D., Professor of Electrical Engineering and Computer Science and Atmospheric, Oceanic, and Space Sciences and Associate Vice President for Research

Arch W. Naylor, Ph.D., Professor of Electrical Engineering and Computer Science

David L. Neuhoff, Ph.D., Professor of Electrical Engineering and Computer Science and Associate Chairman of the Systems Science and Engineering Division

Andrejs Olte, Ph.D., Professor of Electrical Engineering and Computer Science

Dimitris Pavlidis, Ph.D., Professor of Electrical Engineering and Computer Science

Thomas B. A. Senior, Ph.D., Professor of Electrical Engineering and Computer Science and Associate Chairman of the Electrical Science Engineering Division

Kang G. Shin, Ph.D., Professor of Electrical Engineering and Computer Science

Fawwaz T. Ulaby, Ph.D., Professor of Electrical Engineering and Computer Science

Richard A. Volz, Ph.D., Professor of Electrical Engineering and Computer Science

William J. Williams, Ph.D., Professor of Electrical Engineering and Computer Science

Kensall D. Wise, Ph.D., Professor of Electrical Engineering and Computer Science

George J. Zissis, Ph.D., Adjunct Professor of Electrical Engineering and Computer Science

Richard K. Brown, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Arthur W. Burks, Ph.D., Sc.D., Professor Emeritus of Electrical Engineering and Computer Science

John J. Carey, M.S., P.E., Professor Emeritus of Electrical Engineering and Computer Science

William G. Dow, M.S.E., P.E., Professor Emeritus of Electrical Engineering and Computer Science

Hansford W. Farris, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Ralph E. Hiatt, M.A., Professor Emeritus of Electrical Engineering and Computer Science

Louis F. Kazda, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

John A. M. Lyon, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Charles W. McMullen, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Arthur D. Moore, M.S., Professor Emeritus of Electrical Engineering and Computer Science

Raymond F. Mosher, S.M., P.E., Professor Emeritus of Electrical Engineering and Computer Science

Norman R. Scott, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Charles B. Sharpe, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Melville B. Stout, M.S., Professor Emeritus of Electrical Engineering and Computer Science

Chen-To Tai, Sc.D., Professor Emeritus of Electrical Engineering and Computer Science

Herschel Weil, Ph.D., Professor Emeritus of Electrical Engineering and Computer Science

Chai Yeh, D.Sc., Professor Emeritus of Electrical Engineering and Computer Science

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Trevor N. Mudge, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Clyde L. Owings, M.D. Ph.D., Associate Professor of Electrical Engineering and Computer Science

Stephen C. Rand, Ph.D., Associate Professor of Electrical Engineering and Computer Science

William B. Ribbens, Ph.D., Associate Professor of Electrical Engineering and Computer Science

William C. Rounds, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Jasprit Singh, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Elliot Soloway, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Wayne E. Stark, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Duncan G. Steel, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Quentin F. Stout, Ph.D., Associate Professor of Electrical Engineering and Computer Science

Demosthenis Teneketzis, Ph.D., Associate Professor of Electrical Engineering and Computer Science

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William P. Birmingham, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Richard B. Brown, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Kevin J. Compton, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Edmund H. Durfee, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Glen A.B. Feak, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

James S. Freudenberg, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Jessy W. Grizzle, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Cordelia V. Hall, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Alfred O. Hero III, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Pisti B. Katehi, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

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Stephane Lafortune, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

John E. Laird, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Yung-Chia Lee, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Steven L. Lytinen, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Pinaki Mazumder, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Chinya V. Ravishankar, Assistant Professor of Electrical Engineering and Computer Science

Gabriel Rebeiz, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Andrew L. Robinson, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Karem A. Sakallah, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

John H. Sayler, Ph.D., Visiting Assistant Professor II of Electrical Engineering and Computer Science

Brian G. Schunck, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Stuart Sechrest, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Deepak D. Sherlekar, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Fred L. Terry, Jr. Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Spencer W. Thomas, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

John L. Volakis, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Gregory H. Wakefield, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Doreen A. Weinberger, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Terry E. Weymouth, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Kim A. Winick, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Andrew E. Yagle, Ph.D., Assistant Professor of Electrical Engineering and Computer Science

Eric M. Aupperle, M.S.E., P.E., Lecturer in Electrical Engineering and Computer Science

John H. Bryant, Ph.D., Adjunct Research Scientist in Electrical Engineering and Computer Science

James L. Daws, Jr., Ph.D., Lecturer and Associate Research Scientist in Electrical Engineering and Computer Science

Jack R. East, Ph.D., Lecturer and Associate Research Scientist in Electrical Engineering and Computer Science

David E. Frisque, M.S., M.A., Visiting Lecturer II in Electrical Engineering and Computer Science

Thomas F. Haddock, Assistant Research Scientist of Electrical Engineering and Computer Science

Richard K. Mains, Ph.D., Assistant Research Scientist in Electrical Engineering and Computer Science

Ervin K. Holland-Moritz, M.S., Lecturer in Electrical Engineering and Computer Science

Patrick J. McCleer, Ph.D., P.E., Associate Research Scientist in Electrical Engineering and Computer Science

Kurt Metzger, Ph.D., Assistant Research Scientist in Electrical Engineering and Computer Science

Marlin P. Ristenbatt, Ph.D., Lecturer and Research Scientist in Electrical Engineering and Computer Science

Giorgio Rizzoni, Ph.D., Lecturer in Electrical Engineering and Computer Science

181. Introduction to Computer Systems. ***Prerequisite: none. I and II.*** (4).
Introduces students to computers. Focuses on software, hardware, and social impact of computers. Elementary programming concepts, software packages and applications, word processing, data communications, information management, input-output, data entry, computer hardware components and storage devices, microcomputers, and ethics in computing. Programming assignments using a personal computer. Term paper required. A student cannot receive credit for both EECS 181 and Eng. 103.

213. Network Analysis. ***Prerequisite: preceded or accompanied by Math. 216. I and II.*** (4). ***Not open to electrical engineering students.***
Analysis of linear passive circuits and operational amplifier circuits. Complete solution for linear networks, including transient, periodic and steady-state responses. Phasor and transform analysis techniques. Network theorems and functions, power and energy.

216. Circuit Analysis. ***Prerequisite: preceded or accompanied by Math. 216. I, II and IIIb.*** (4)
Resistive circuit elements; mesh and node analysis; network theorems; network graphs and independence; energy storage elements; one- and two-time-constant circuits; phasors and a.c. steady-state analysis; complex frequency and network functions; frequency response and resonance. Lecture and laboratory.

250. (Nav. Sci. 201). Electronic Sensing Systems. ***Prerequisite: preceded or accompanied by Physics 240. I.*** (3).
Introduction to properties and behavior of electromagnetic energy as it pertains to naval applications of communication, radar, and electro-optics. Additional topics include sound navigation and ranging (SONAR), tracking and guidance systems, and computer controlled systems. Several laboratory demonstrations will illustrate applications of the theories and concepts learned in the classroom.

270. Introduction to Logic Design. ***I and II.*** (4).
Binary and non-binary systems, Boolean algebra digital design techniques, logic gates, logic minimization, standard combinational circuits, sequential circuits, flip-flops, synthesis of synchronous sequential circuits, PLA's, ROM's, RAM's, arithmetic circuits, computer-aided design. Laboratory includes hardware design and CAD experiments.

280. Programming and Introductory Data Structures. ***Prerequisite: Eng. 104 and Math. 115. I and II.*** (4).
Techniques of algorithm development and effective programming, top-down analysis, structured programming, testing, and program correctness. Program language syntax and static and run-time semantics. Scope, procedure instantiation, recursion, abstract data types, and parameter passing methods. Structured data types, pointers, linked data structures, stacks, queues, arrays, records, and trees.

282. Computer Programming. ***Prerequisite: Eng. 103. Not open to Computer Engineering Students. I and II.*** (3).
Elements of the Pascal language. Assembly languages for large-scale and micro-computers. Algorithm development, structured programming, and program debugging. Students will write several programs in Pascal and assembly language.

283. Elementary Programming Concepts. ***I and II.*** (4). ***Not intended for CS or Comp. E. majors.***
Introduction to a high level programming language, top-down analysis, and structured programming. Basic searching and sorting techniques. No previous experience in computer or programming is assumed. Students will write and debug several computer programs.

300. (Math. 300). Mathematical Methods in System Analysis. ***Prerequisite: Math. 216. I, II and IIIa.*** (3). ***A student cannot receive credit for both EECS 300 and Math. 448.***
An introductory course in operational mathematics as embodied in Laplace Transforms, Fourier Series, Fourier Transforms, and Complex Variables, with emphasis on their application to the solution of systems of linear differential equations. The response of linear systems to step, impulse and sinusoidal forcing functions.

303. Algebraic Foundations of Computer Engineering. ***Prerequisite: EECS 280 and Math. 216. I and II.*** (3).
Fundamental concepts of algebra; partially ordered sets, lattices, Boolean algebras, semi-groups, rings, polynomial rings. Graphical representation of algebraic systems; graphs, directed graphs. Application of these concepts to various areas of computer science and engineering.

313. Basic Electronic Circuit Analysis. ***Prerequisite: EECS 213. I and II.*** (4). ***Not open to electrical engineering students.***
Various circuit models of diodes, bipolar junction and field effect transistors, piecewise linear and nonlinear analysis of logic circuits, RAM, ROM, operational amplifier circuits and flip-flops.

314. Circuit Analysis and Electronics. ***Prerequisite: Math. 216 and Physics 240. I, II and IIIa.*** (3). ***Not open to electrical engineering or engineering science students.***
A comprehensive treatment of passive and active (electronic) circuit theory expressly developed to satisfy the requirements of non-electrical engineering students. Formulation of circuit equations; node and loop methods; steady-state and transient response of RL and RC circuits, two-port networks; analysis of basic electronic circuits.

315. Circuit Analysis and Electronics Laboratory. ***Prerequisite: preceded or accompanied by EECS 314. I and II.*** (1).
Laboratory lecture demonstrations and student experiments designed to investigate the principles developed in EECS 314. Measurements of voltage, current, resistance, power, transient response, transistor characteristics, and amplifier performance. Lecture-demonstration and two-hour laboratory. Not open to electrical engineering or engineering science students.

316. Circuits and Systems. ***Prerequisite: EECS 216 and preceded or accompanied by EECS 300. I, II and IIIa.*** (3).
Mesh, node, and state-variable analysis. Complex frequency and s-domain analysis. Feedback. Discrete signals and z-transform methods. Frequency response. Two-port parameters. Convolution. System concepts.

317. Solid-State Devices and Digital Electronics. ***Prerequisite: EECS 216 or 213 and preceded or accompanied by EECS 270. I and II.*** (3).
Circuit models for diodes, bipolar-junction and field-effect transistors; piecewise linear and nonlinear analysis; logic circuits; memory circuits (flip-flops, RAM, ROM); computer analysis of electronic circuits.

318. Analog Electronics. ***Prerequisite: EECS 316, 317. I, II, and IIIa.*** (4)
Operation and small-signal models of diodes, junction and field-effect transistors; basic single-stage and multi-stage amplifiers: gain, biasing, and frequency response; feedback; op-amp circuits: amplifiers, rectifiers, oscillators, filters. Design problems. Lecture and laboratory.

320. Introduction to Semiconductor Device Theory. ***Prerequisite: EECS 216 or 313 or 314, and Physics 242. I, II and IIIa.*** (3).
Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift and diffusion currents, generation and recombination processes. Introduction to: PN junctions, metal-semiconductor junctions, bipolar junction transistors, junction and insulated-gate field-effect transistors.

331. Electromagnetics I. ***Prerequisite: Physics 240, Math. 216. I and II.*** (4).
Gauss's law and the static electric field; boundary value problems in electrostatics. Dielectric and magnetic media. Magnetostatics; Faraday's law and applications. Maxwell's equations; wave equation; plane waves.

332. Electromagnetics II. ***Prerequisite: EECS 331. I and II.*** (3).
Theory and applications of electromagnetic waves; reflection, refraction, and attenuation in various media. Antennas and radiating systems. Introduction to radio and optical transmission including waveguides, striplines, optical fibers, and the earth's atmosphere.

351. Signal Processing and Analysis. ***Prerequisite: EECS 300 and 213 or 316. I, II and IIIa.*** (4).
Fundamentals of the analysis and processing of continuous and discrete signals. Linear systems and filtering. Discrete Fourier Transforms (DFT, FFT) and z transforms. Sampling Theorem. Introduction to analog and digital communications. Computer based simulation and data processing are used to demonstrate the above concepts in a laboratory setting.

359. Measurements and Instrumentation. ***Prerequisite: EECS 213 or 316. I and II.*** (3).
Measurements of circuit parameters, electric and magnetic fields, characteristics of discrete and integrated devices. Basic concepts of modern instrumentation. Two lectures and laboratory.

360. Dynamic Systems and Modeling. ***Prerequisite: EECS 300. I and II.*** (4).
Mathematical models of dynamic systems and input-output relations: state variables, transfer functions, fundamental matrix, convolution. Modeling of physical systems, including nonlinear and distributed parameter systems: electrical, mechanical, chemical, biological, ecological. Basic systems' concepts: linearity, time invariance, causality, differential systems. Simulation on analog, hybrid, and digital computers. Lectures and recitation-demonstration.

370. Introduction to Computer Organization. ***Prerequisite: EECS 270 and 280. I and II.*** (4).
Computer organization will be presented as a hierarchy of virtual machines representing the different abstraction from which computers can be viewed. These include the logic level, microprogramming level, and assembly language level. Lab experiments will explore the design of a microprogrammed computer.

373. Design of Microprocessor Based Systems. ***Prerequisite: EECS 270 and junior standing. I and II.*** (3).
Principles of hardware and software microcomputer interfacing; digital logic design and implementation. Experiments with specially designed laboratory facilities. Introduction to digital development equipment and logic analyzers. Assembly language programming. Lecture and laboratory.

380. Data Structures and Algorithms. ***Prerequisite: EECS 280 and 303 or Math 312. I and II.*** (4).
Abstract data types. Recurrence relations and recursions. Advanced data structures: sparse matrices, generalized lists, strings. Tree-searching algorithms, graph algorithms general searching and sorting. Dynamic storage management. Analysis of algorithms-notation. Complexity. Top-down program development: design, implementation, testing modularity. Several programming assignments.

381. Assembly Language Programming. ***Prerequisite: EECS 280 and 303 or Math 312. I and II.*** (3).
Machine structure and organization, data representation, memory addressing methods, use of registers, bit manipulation, integer and floating point arithmetic, program linking and subroutines, macro-instructions, program debugging, assemblers and loaders. Students write several programs in IBM 370 Assembler language. Three one-hour lectures and a one-hour discussion per week.

383. Programming and Computer Systems. ***Prerequisite: EECS 283 or equivalent. I and II.*** (4).
Advanced topics in PASCAL including the implementation of linked lists, trees, and hashing. Searching and sorting techniques. Assembly language and computer architecture. Selected topics in programming language theory. Students will write several programs in PASCAL and assembly language.

384. Advanced Programming Language or System. ***Prerequisite: EECS 380 or 383. I and II.*** (1).
A four-week mini-course covering an advanced programming language such as LISP, SNOBOL, C, PROLOG, or Modula-2; or a system such as UNIX. Programming problems will be assigned. Specific languages or systems to be offered will be announced in advance.

398. Special Topics. ***Prerequisite: permission of instructor.*** (1-4).
Topics of current interest selected by the faculty. Lecture, seminar or laboratory.

400. (Math. 419). Linear Spaces and Matrix Theory. ***Prerequisite: four semesters of college mathematics beyond Math. 110. I and II.*** (3).
Not open to students with credit for Math. 417 or 513. Finite dimensional linear spaces and matrix representations of linear transformations. Bases, subspaces, determinants, eigenvectors, and canonical forms. Structure of solutions of systems of linear equations. Applications to differential and difference equations. The course provides more depth and content than Math. 417. Math 513 is the proper election for students contemplating research in mathematics.

401. (Aero. Eng. 452). Probabilistic Methods in Engineering. ***Prerequisite: EECS 300 or Math. 448. I, II and IIIa.*** (3).
Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions; averages; independence. Introduction to discrete and continuous random processes: wide sense stationarity, correlation, spectral density. CICE students may not receive graduate credit for both EECS 401 and 501.

410. Circuit Analysis, Properties, and Design. ***Prerequisite: EECS 300 and 316. I.*** (3).
Network analysis methods, formulation for computer solution; properties of network functions; 2-port analysis; computer-aided sensitivity analysis and optimization; numerical methods for linear and nonlinear circuit analysis; static and dynamic solutions.

411. Microwave Circuits I. ***Prerequisite: EECS 332. I.*** (3).
Passive circuits for high frequency electronics. Propagation and reflection on ideal and lossy transmission lines. Smith Chart and applications. Strip lines; microstrip and coplanar lines; cross-talk between coupled lines. Microstrip circuits; analysis and design.

412. Communications Electronics. ***Prerequisite: EECS 318. I.*** (4).
High frequency analysis and design of electronic circuits for communications, including feedback amplifiers, mixers, detectors, tuned amplifiers, and oscillators. Emphasis on practical design considerations and the use of integrated circuits as circuit elements. Two lectures and laboratory.

413. Computer Circuits and Devices. ***Prerequisite: EECS 317. I and II.*** (3).
Electronic implementation of logic; SSI, MSI, and LSI components; BJT, FET, and integrated circuits and applications; computer analysis of nonlinear circuits and transient simulation; memory devices; MOS/bipolar interface considerations.

417. (Bioeng. 417). Electrical Biophysics. ***Prerequisite: EECS 216 or 213 or 314 and preceded or accompanied by EECS 300 or Math. 448. I.*** (3).
Electrical biophysics of muscle, nerve, and synapse; electrical conduction in excitable tissue; models for nerve, muscle and sensory receptors, including the Hodgkin Huxley equations; biopotential mapping, cardiac electrophysiology, and biological noise.

420. Microwave Semiconductor Devices. ***Prerequisite: EECS 320. I.*** (3).
Microwave transit-time devices (IMPATT, BARITT, TUNNETT, etc.). Transferred electron devices. Varactors, tunnel and backward diodes, PIN diodes and mixer diodes, microwave transistors.

421. Properties of Transistors. ***Prerequisite: EECS 320. I.*** (3).
DC, small and large signal AC, switching and power-limiting characteristics, and derivation of equivalent circuit models of: PN junctions, metal-semiconductor and metal-insulator semiconductor diodes, bipolar junction transistors, junction and insulated-gate field-effect transistors, and thyristors.

422. Electronic Properties of Semiconductor Materials. ***Prerequisite: EECS 320. I.*** (3).
Space lattices and crystal structure; lattice vibrations, phonons and specific heat; wave mechanics for periodic structures, band theory and effective mass tensor; transport theory including Boltzmann transport equation, scattering processes, thermo-electric effects, and high-field effects.

423. Solid-State Devices Laboratory. ***Prerequisite: EECS 320. I.*** (3).
Semiconductor material and device fabrication and evaluation: diodes, bipolar and field-effect transistors, passive components. Semiconductor processing techniques: oxidation, diffusion, deposition, etching, photolithography. Lecture and laboratory.

424. Monolithic Device Structures for Integrated Electronics. ***Prerequisite: EECS 320. II.*** (3).
Bipolar and MOS devices for integrated circuits; passive and active component performance; fabrication techniques including epitaxial growth, photolithography, oxidation, diffusion, ion implantation, thin- and thick-film components. Integrated device design and layout. Relationships between integrated device performance and device design, layout, and fabrication technologies used.

425. Integrated Circuits Laboratory. ***Prerequisite: EECS 320 and EECS 427. II.*** (2).
Integrated circuit fabrication; mask design, photographic reduction; photoresist application, exposure, development, and etching, oxidation; diffusion; metal film deposition by evaporation and sputtering; die bonding, wire bonding, and encapsulation; testing of completed integrated circuits.

427. VLSI Design I. ***Prerequisite: EECS 270 and 313 or 317. I and II.*** (4).
Design techniques for rapid implementation of very large-scale integrated (VLSI) circuits, MOS technology and logic. Structured design. Design rules, layout procedures. Design aids: layout, design rule checking, logic, and circuit simulation. Timing. Testability. Architectures for VLSI. Projects to develop and lay out circuits.

429. Semiconductor Optoelectronic Devices. ***Prerequisite: EECS 320. II.*** (3).
Optical processes in semiconductors, luminescence and absorption, effects due to electric field; principles of junction lasers, light-emitting diodes, detectors and solar cells; materials considerations and device properties.

431. Fields and Optics Laboratory. ***Prerequisite: preceded or accompanied by EECS 332. I and II.*** (2).
Experiments and lectures to demonstrate the behavior and practical aspects of electromagnetic fields at microwave and optical frequencies. Microwave experiments involving transmission lines, waveguides, antennas, sources, and detectors. Fiber optics and lasers.

432. (Bioeng. 432). Fundamentals of Ultrasonics with Medical Applications. ***Prerequisite: EECS 331. II.*** (3).
Basic principles; waves, propagation, impedance, reflection, transmission, attenuation, power levels. Generation of ultrasonic waves; transducers, focusing, Fraunhofer and Fresnel zones. Instrumentation; display methods, Doppler techniques, signal processing. Medical applications will be emphasized.

433. Introduction to Optics I. ***Prerequisite: EECS 331. I.*** (3). ***A student cannot receive credit for both Phys. 402 and EECS 433.***
Fundamentals of wave optics: superposition of waves; interference and interferometers; distraction theory. Basic geometrical optics and introductory aberration theory; introduction to Fourier optics and coherence theory. Special topics, such as holography and Fourier transform spectroscopy.

434. Introduction to Optics II. ***Prerequisite: EECS 433. II.*** (3). ***A student cannot receive credit for both Phys. 402 and EECS 434.***
Fundamentals of light propagation; polarization and Jones matrices. Basic interaction of light with materials: electron oscillator model. Optics of solids: crystal anisotropy and birefringence; optical activity and Faraday rotation. Optical devices: multilayer films and polarizing optics. Introductory laser concepts: light quanta; thermal radiation and stimulated emission.

435. Fourier Optics. ***Prerequisite: EECS 300, preceded or accompanied by EECS 433. I.*** (3).
Basic physical optics treated from the viewpoint of Fourier analysis. Fourier-transform relations in optical systems. Theory of image formation and Fourier transformation by lenses. Frequency response of diffraction-limited and aberrated imaging systems. Coherent and incoherent light. Comparison of imagery with coherent and with incoherent light. Resolution limitations. Optical information processing, including spatial matched filtering.

436. Infrared Systems Technology. ***Prerequisite: preceded or accompanied by EECS 433. I.*** (3).
Theory and instrumentation for sensing and measuring visible and infrared radiation. Topics include blackbody radiation, radiometric concepts; radiative transfer through the atmosphere; basic optics of semiconductors; photon detectors (photoconductive, photovoltaic, and photoemissive); thermal detectors; detector noise sources and figures of merit; imaging detectors (pyroelectric arrays and CCD's); LED's and diode laser sources.

437. Coherent Optics Laboratory. ***Prerequisite: preceded or accompanied by EECS 434. II.*** (2).
Experimental aspects and techniques of coherent optics. Lasers, alignment techniques for optical systems, characteristics of photographic recording materials, spatial filtering, coherent imaging, interferometry and coherence measurement of light sources, holography. Lecture and laboratory.

442. Computer Vision. ***Prerequisite: EECS 303 and 380. I.*** (3).
Computational methods for recovery, representation, and application of visual information. Topics from image formation, binary images, digital geometry, similarity and dissimilarity detection, matching, curve and surface fitting, constraint propagation and relaxation labeling, stereo, shading, texture, object representation and recognition, dynamic scene analysis, and knowledge based techniques. Hardware/software techniques.

450. (NR 543). Imaging Radar as a Remote Sensor. ***Prerequisite: NR 541 or senior standing in Elec. or Comp. Eng. II.*** (3).
Descriptive treatment of imaging radar systems, theoretical and operational performance and limitations, reflection from terrestrial and vegetal surfaces, interpretation of imagery; application to topics of student's interest (e.g. geology, oceanography, forestry). Special topics include holographic radar, passive microwave systems, synthetic aperture radar, and imaging sonar.

452. Microwave and Optical Communication Systems. ***Prerequisite: EECS 332. II.*** (3).
Antennas, receiver systems; plane wave propagation effects; different homogeneous media; reflection, refraction, diffraction; fading and diversity; active and passive repeaters; line of sight microwave links; satellite links; fiber optic transmission properties; optical communication components including sources and detectors.

453. Analog Communication Signals and Systems. ***Prerequisite: EECS 351. I.*** (3).
Mathematical analysis of the signals and signal processing used in analog communication systems; spectral analysis, signal transmission; amplitude, phase, frequency, and pulse modulation; modulation and demodulation techniques; frequency and time multiplexing; analysis of signal to noise ratio; application to radio and television.

455. Digital Communication Signals and Systems. ***Prerequisite: EECS 351 and 401. II.*** (3). ***Graduate credit not allowed for both EECS 455 and EECS 554.***
Digital transmission techniques in data communications, with application to computer and space communications; design and detection of digital signals for low error rate; forward and feedback transmission techniques; matched filters, modems, block and convolutional coding, Viterbi decoding.

456. Digital Signal Processing. ***Prerequisite: EECS 351. I.*** (3)
Analysis techniques used in computer processing of signals. Analog to digital conversion. Recursive and nonrecursive digital filtering, correlation and matched filtering. Time series analysis of waveforms, z transforms, fast Fourier transforms, complex demodulation, data compression. Cepstrum techniques and spectral estimation.

457. Instrumentation. ***Prerequisite: EECS 314 and 315. I and II.*** (3). ***May not be elected for credit by EECS students.***
Instrumentation methods for the measurement and recording of time, frequency, temperature, acceleration, pressure, noise, etc. Information storage techniques. Introduction to transducers, motors, and motor control. Advanced instrumentation for spectral analysis and correlation. Logical design and instrumentation. Two lectures and laboratory.

458. (Bioeng. 458). Biomedical Instrumentation and Design. ***Prerequisite: permission of instructor. I and II.*** (4).
Measurement and analysis of biopotentials and biomedical transducer characteristics; electrical safety; applications of FET's, integrated circuits, operational amplifiers for signal processing and computer interfacing; signal analysis and display on the laboratory minicomputer. Lectures and laboratory.

459. Advanced Electronic Instrumentation. ***Prerequisite: EECS 360 or 359 or 453 or 458. I*** (3).
Systematic design of optimum measuring instruments which give maximum confidence in results. Analog and digital signal processing, transducer modeling. A/D and D/A conversion, survey of modern instrumentation components.

460. Fundamentals of Control Systems. ***Prerequisite: Mech. Eng. 240, EECS 316 or 360 and senior standing. I, II, and IIIa.*** (3). ***Not open to students with credit for Aero. Eng. 471.***
Concept and importance of control systems. Control system descriptions; state variable and transfer function representations. System performance and design criteria: stability, sensitivity, time response. Concept of feedback. Time response of linear control systems. Use of Hurwitz, root-locus, Nyquist, and Bode methods for analysis and synthesis of linear control systems.

463. Modern Control Systems Design. ***Prerequisite: EECS 460. II.*** (3).
Introduction to concepts and techniques of modern control in the context of control system design. Topics include: state variable feedback, optimal control, nonlinear control, state estimators, and adaptive control. Both analog and digital control design techniques are presented. Design application is emphasized through use of selected case studies.

467. (I.&O.E. 494)(Mech. Eng. 484). Robot Applications. ***Prerequisite: EECS 280 or 370 or I.&O.E. 373 or Mech. Eng. 340, and Mech. Eng. 240 or EECS 360; and senior standing. Not open to students with previous credit for EECS 567. I and II.*** (3).
Basic concepts in the organization and operation of microcomputer-controlled manipulators. Experiments include kinematics, manipulation, dynamics, trajectory planning and programming language for robots. Applications of computer-controlled robots in

manufacturing and programmable automation. Two one-hour lectures and one three-hour lab.

469. Application of Real Time Computer Systems. ***Prerequisite: EECS 280 or 282; and 300; and senior standing.*** (4).
Principles of application of realtime computer systems to engineering problems. Topics include: computer characteristics needed for real time use, mini/micro computer operating systems, man-computer communication, basic digital logic design, analog signal processing and conversion, and inter-computer communication. Topics investigated via laboratory using a microprocessor system. Three lectures and one three-hour laboratory per week.

470. Computer Architecture. ***Prerequisite: EECS 370. I and II.*** (3).
Basic concepts of computer architecture and organization. Computer evolution. Design methodology. Performance evaluation. Elementary queueing models. CPU architecture. Introductions sets. ALU design. Hardwired and microprogrammed control. Nanaprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

474. Digital Design Laboratory. ***Prerequisite: EECS 373 or 470. I and II.*** (2).
Realistic design problems in digital system engineering. Design, construction, and demonstration of devices which operate alone or in conjunction with digital computers in the laboratory. Lecture and laboratory.

476. Foundations of Computer Science. ***Prerequisite: EECS 280 and either EECS 303 or Math. 312 or equivalent. I and II.*** (3).
An introduction to computation theory: finite automata, regular languages, pushdown automata, context-free language, Turing machines, recursive languages and functions, and computational complexity.

478. Switching and Sequential Systems. ***Prerequisite: EECS 303 and senior or graduate standing. I and II.*** (3).
An introduction to the theory of switching networks and sequential systems. Switching functions and realizations, threshold logic, fault detection, and connectedness and distinguishability, equivalence and minimality, state identification, system decomposition.

480. Data Structures. ***Prerequisite: EECS 380 and 303 or Math 312 or equivalent. I and II.*** (4).
Data structuring principles of use in a wide variety of problem solving areas are covered. Alternatives are considered with respect to utilization of storage and time.

481. Software Engineering. ***Prerequisite: EECS 380 or 480, and senior standing. I and II.*** (4).
Pragmatic aspects of the production of software systems, dealing with structuring principles, design methodologies and informal analysis. Emphasis is given to development of large, complex software systems. A term project is usually required.

482. Introduction to Operating Systems. ***Prerequisite: EECS 380 and 381, or equivalent. I and II.*** (4).
Operating system functions and implementations: multi-tasking; concurrency and synchronization; deadlock; scheduling; resource allocation; real and virtual memory management input/output; file systems. Students write several substantial programs dealing with concurrency and synchronization in a multitask environment.

483. Compiler Construction. ***Prerequisite: EECS 380 or 480.*** (4). ***Honors students may take either 483 or 583, but not both.***
Introduction to compiling techniques including parsing algorithms, semantic processing and optimization. Students implement a compiler for a substantial programming language using a compiler generating system. Intended for undergraduates (graduate students should take EECS 583).

484. (I.&O.E. 484). Database Management Systems. ***Prerequisite: EECS 380 or 480; or I.&O.E. 473. I and II.*** (3).
Concepts and methods in the definition and management of large integrated databases for organizational information systems. Functions and objectives of existing file and data management systems will be considered and methods of analyzing proposals for new data management software will be studied. Additional topics will include database administration, database design, and data security problems.

485. Principles of Programming Languages. ***Prerequisite: EECS 380 or 383, and Math. 312 or equivalent. I and II.*** (4).
Principles of programming languages including Algol-like languages, logic programming and an introduction to program verification and semantics.

486. Ada Based Software Environment. ***Prerequisite: EECS 380. II.*** (3).
Software design concepts such as data and program abstraction, package based decomposition of large systems, real-time task control, and Ada based programming environment. The Ada language will be used. The student is required to complete one medium sized and several small sized programming projects.

487. (I.&O.E. 478). Interactive Computer Graphics. ***Prerequisite: EECS 380 or I.&O.E. 373, and senior standing. I and II.*** (3).
Graphics devices and fundamentals of operation. Two dimensional and three dimensional transformations. Interactive graphical techniques and applications. Three dimensional graphics, perspective transformation, hidden line elimination. Data structures and languages for graphics. Interactive graphical programming.

492. Introduction to Artificial Intelligence. ***Prerequisite: EECS 380 and 303. I and II.*** (4).
Basic artificial intelligence methods using LISP. Topics covered include search, rule-based systems, logic, constraint satisfaction, and knowledge representation.

493. User Interface Design and Analysis. ***Prerequisite: EECS 480 or 481 or equivalent. II.*** (3).
Current theory and design techniques concerning how user interfaces for computer systems should be designed to be easy to learn and use. Focus on cognitive factors, such as the amount of learning required, and the information-processing load imposed on the user, rather than ergonomic factors.

497. Analysis and Design Projects. ***Prerequisite: senior standing in engineering. II.*** (4).
Professional problem-solving methods developed through intensive group and individual studies of two or three significant engineering devices; use of analytic, computer, and experimental techniques where applicable. Two lectures and two project periods.

498. Special Topics. ***Prerequisite: permission of instructor.*** (1-4).
Topics of current interest selected by the faculty. Lecture, seminar or laboratory.

499. Directed Study. ***Prerequisite: senior standing in EECS. I, II and III, IIIa, IIIb.*** (1-6).
Individual study of selected topics in Electrical Engineering and Computer Science. May include experimental investigation or library research. Primarily for undergraduates.

501. (Aero. Eng. 552). Probability and Random Processes. ***Prerequisite: EECS 401 or graduate standing. I and II.*** (4).
Introduction to probability and random processes. Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, Poisson and Wiener processes, stationary processes, autocorrelation, spectral density, effects of filtering, linear least-squares estimation, and convergence of random sequences.

502. (Aero. Eng. 553). Stochastic Processes. ***Prerequisite: EECS 501. II.*** (3).
Correlations and spectra. Quadratic mean calculus, including stochastic integrals and representations, wide-sense stationary processes (filtering, white noise, sampling, time averages, moving averages, autoregression). Renewal and regenerative processes, Markov chains, random walk and ruin, branching processing, Markov jump processes, uniformization, reversibility, and queueing applications.

504. Simulation Methods for Large Scale Systems. ***Prerequisite: EECS 401 or 501. II.*** (3).
Modelling and digital computer simulation of large scale systems. Discrete event simulation, statistical tests, random number generators, experimental design of simulation experiments. Introduction to simulation languages. The course usually involves a project.

505. (I.&O.E. 511) (Math. 562) (Aero. Eng. 577). Continuous Optimization Methods. ***Prerequisite: Math. 417 or Math. 419. I.*** (3).
Survey of continuous optimization problems. Unconstrained optimization problems: unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians and others. Discussion of computer programs for various algorithms.

506. Computing System Evaluation. ***Prerequisite: EECS 280 or 283, and 370 and 501. II.*** (3).
Theory and application of analytic methods for evaluating the performance of reliability of computing systems. Measures of performance, reliability, and performability. Reliability evaluation: classification and representation of faults, stochastic process models, coherent systems. Performance evaluation: Markovian queueing models, networks of queues. Unified performance-reliability evaluation.

507. Introduction to Statistical Pattern Recognition. ***Prerequisite: EECS 401. II.*** (3).
Introduction to statistical pattern recognition as it is applied to engineering problems, biomedical applications, and problems in biology and psychology. Fundamental mathematical tools for statistical decision-making processes. Topics include hypothesis testing, linear classifiers, parameter estimation, feature selection, and clustering.

508. Probability for Computer and Queueing Applications. ***Prerequisite: graduate standing. I.*** (3).
Probability spaces. Elementary probability properties and calculations. Discrete and continuous random variables. Probability distributions. Expectation and conditional expectation. Discrete state stochastic processes: Poisson and renewal processes, Markov chains. Examples will be drawn largely from areas such as computer engineering, queueing and reliability.

509. (I.&O.E. 503). Social Decision Making. ***Prerequisite: Stat. 310 or EECS 401 or EECS 501 or I.&O.E. 315. II.*** (3).
Elementary decision analysis, examples in public sector; basic problems in social decision making; social values and preferences, multiattribute utility functions, subjectivity measurement, Pareto optimality, Arrow's impossibility theorem; group decision analysis, two-person game theory; social decision processes, strategy of conflicts.

510. Linear Circuit Design. ***Prerequisite: EECS 410. II.*** (3).
Synthesis and design of passive and active circuits: physical realizability; constraints of real components; frequency and time domain interrelations; approximation with rational functions; computer-aided techniques.

511. Microwave Circuits II. ***Prerequisite: EECS 411. II.*** (3).
General theory of waveguides; inhomogeneously filled waveguides. Surface waveguides. Circuit theory of waveguiding systems. Passive microwave devices; directional couplers, filters, isolators, circulators.

512. Pulse and Switching Circuits. ***Prerequisite: EECS 413. I.*** (3).
Diode and transistor switches; transient behavior and charge storage model. Clipping, clamping, differentiating, and integrating circuits; voltage and current sweep circuits; Schmitt trigger, pulse formation, timing, flip-flops and multivibrators. Design and limitations of various wave shaping circuits using either discrete components or integrated circuits.

513. Semiconductor and Integrated Circuit Modeling for Computer-Aided Design. ***Prerequisite: EECS 318, and 412 or 512 or 424 or 413. II.*** (3).
Computational aspects of modeling semiconductor devices and integrated circuits. Computer-aided analysis procedures. Adequacy of models; accuracy-efficiency modeling trade-offs; equivalence of models; measurement of model parameters. Models for BJTs, FETs, op-amps, and digital gates.

515. Advanced Electronic Circuit Design. ***Prerequisite: EECS 318, and 412 or 512 or 522. II.*** (3).
In-depth exposure to electronic circuit design concentrating on one or two areas. Emphasis on limitations of real components and integrated circuits realizations, and the possible optimizations and trade-offs. Design problems drawn from various areas such as: low noise systems, high power circuits, fast wideband amplifiers, signal generation, and data conversion. Two lectures and one laboratory period.

517. Physical Processes in Plasmas. ***Prerequisite: EECS 332. II.*** (3).
Collision phenomena, diffusion and mobility; development of the Boltzmann-Vlasov equation; conductivity and dielectric tensors of a plasma; hydromagnetic equations; wave propagation in gaseous plasmas; applications to fusion research and gas lasers.

518. (A.&O. Sci. 595). Magnetosphere and Solar Wind. ***Prerequisite: Graduate Standing. I, even years.*** (3).
General principles of magnetohydrodynamics; theory of the expanding atmosphere; properties of solar winds, interaction of solar wind with the magnetosphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.

519. (Nuc. Eng. 575). Plasma Dynamics and Particle Optics Lab. ***Prerequisite: Preceded or accompanied by a course in plasmas or physical electronics. II.*** (3).
Experimental techniques for plasma dynamics, electron and ion beam technology, and vacuum technology. Experiments on microwave and probe diagnostics of plasmas, plasma instabilities, vacuum systems, plasma generation, electron and ion beam generation and optics, and other topics of current interest. Lectures given for background material.

520. Theoretical Methods for Solid-State Electronics. ***Prerequisite: EECS 422. II, even years.*** (4).
The matrix formulation of quantum mechanics, including time-dependent perturbation theory. Topics from thermodynamics and statistical mechanics, including: temperature, chemical and electrochemical potentials; distribution functions, kinetic theory of gases; photons and blackbody radiation; phonons.

521. High-Speed Transistors. ***Prerequisite: EECS 420 or 421. II.*** (3).
Detailed theory of high-speed digital and high-frequency analog transistors. Carrier injection and control mechanisms. Limits to miniaturization of conventional transistor concepts. Novel submicron transistors including MESFET, heterojunction and quasi-ballistic transistor concepts.

522. Analog Integrated Circuits. ***Prerequisite: EECS 318, 320, and 423 or 424 or 427. II.*** (4).
Analysis, design, and applications of analog integrated circuits. Terminal performance and its dependence on the physics and technology of the monolithic structures involved. Present performance limitations and future trends. Topics include operational amplifiers, comparators, D/A, A/D, phase-locked loops, charge-transfer filters, and solid-state sensors. Design problems.

523. Digital Integrated Circuits. ***Prerequisite: EECS 320, 412 or 413 . I.*** (3).
Device technologies for LSI circuits. Approaches to logic implementation, including gate arrays, master-slices, PLAs. Nonvolatile semiconductor memory structures, including ROM, PROM, EPROM, and EAROM. Static and dynamic random access memory and microcomputers. Relationship of terminal performance to the design, layout, and fabrication techniques used. Circuit layout and computer simulation.

524. Digital Circuits Laboratory. ***Prerequisite: EECS 412 or 512 or 424 or 413. I.*** (2).
Design, characterization, and application of integrated electronics in projects utilizing opto-isolators, phase-locked loops, logic, memory, and a variety of digital and analog signal processing. Applications of microprocessors. Present approaches to solid-state circuits in communications, instrumentation, sensors, and displays. Students select two or three projects. Laboratory work plus directed reading.

525. Solid State Microwave Circuits. ***Prerequisite: EECS 420, and 411 or 414. II.*** (3).
General properties and design of nonlinear solid-state microwave networks, including: negative resistance oscillators and amplifiers, frequency convertors and resistive mixers, transistor amplifiers, power combiners, and harmonic generators.

527. Computer-Aided Design for VLSI System. ***Prerequisite: EECS 478. II.*** (3).
Theory of circuit layout partitioning and placement algorithms. Routing algorithms, parallel design automation on shared memory and distributed memory multiprocessors, simulated annealing and other optimization techniques and their applications in CAD, layout transformation and compaction, fault-repair algorithms for RAM's & PLA's hardware synthesis from behavioral modeling, artificial intelligence based CAD.

528. Principles of Microelectronics Process Technology. ***Prerequisite: EECS 422 and 424. I.*** (3).
Theoretical analysis of the chemistry and physics of process technologies used in microelectronics fabrication. Topics include: semiconductor growth, material characterization, lithography tools, photo-resist models, thin film deposition, chemical etching, plasma etching, electrical contact formation, microstructure processing, and process modeling.

529. Optical and Optoelectronic Devices. ***Prerequisite: EECS 320; 434 or 436. I.*** (3).
Visible and infrared photodetectors, including PIN and avalanche photodiodes, photon-counting devices, and image intensifiers; imaging detectors, including vidicons and Charge Coupled Devices; display devices; semiconductor lasers, acoustic-optic, electro-optic, and waveguide modulators; nonlinear optics, including second harmonic generation and optical bistability.

530. (Appl. Phys. 530). Electromagnetic Theory. ***Prerequisite: EECS 332. I.***(3).
Maxwell's equations; uniqueness of solution. Boundary, radiation, and edge conditions. Sources; potential and multipole expansions. Representations of fields; integral equation formulation of boundary value problems. Reciprocity, equivalence, induction, reaction, and Babinet's theorems. Modal solutions for scattering by conducting cylinders and spheres. Integration of vector wave equation.

531. Antenna Theory. ***Prerequisite: EECS 332. II.*** (3).
Theory of transmitting and receiving antennas. Linear and aperture antennas. Mutual impedance between antennas. Phased arrays. Broadband antennas. Microstrip antennas. Small antennas. Antenna synthesis. Measurements.

532. Microwave Remote Sensing I: Radiometry. ***Prerequisite: EECS 332 and graduate standing. I.*** (3).
Radiative Transfer theory: blackbody radiation; microwave radiometry; atmospheric propagation and emission; radiometer receivers; surface and volume scattering and emission; applications to meteorology, oceanography, and hydrology.

533. Microwave Measurements. ***Prerequisite: EECS 411 and EECS 431 and preceded or accompanied by 525. I.*** (2).
Manual and automatic microwave network analyzer measurements; power, spectrum, and noise measurements; characterization of devices and systems. Special topics will include design and construction of microwave devices, RCS and antenna measurements, microstrip measurements, and microwave circuit measurements.

534. Design and Characterization of Microwave Devices and Monolithic Circuits. ***Prerequisite: EECS 525 or 420 and graduate standing. I.*** (3).
Theory and design of passive and active microwave components and monolithic integrated circuits including: microstrip, lumped inductors and capacitors, GaAs FETs, varactor and mixer diodes, monolithic phase shifters, attenuators, amplifiers and oscillators. Experimental characterization of the above components using network analyzer, spectrum analyzer, power and noise meters. Lecture and laboratory.

535. Optical Information Processing. ***Prerequisite: EECS 300, 434. II, odd years.*** (3).
Theory of image formation with holography; applications of holography; white light interferometry; techniques for optical digital computing; special topics of current research interest.

536. Classical Statistical Optics. ***Prerequisite: EECS 300, 434. II, even years.*** (3).
Applications of random variables to optics; statistical properties of light waves. Coherence theory, spatial and temporal. Information collecting interferometers; stellar, intensity, and speckle. Phase retrieval; imaging through inhomogeneous media; noise processes in imaging and interferometric systems.

537. Integrated and Guided Wave Optics. ***Prerequisite: EECS 332. I.*** (3).
Theory of guided light wave propagation; planar and channel waveguides; optical fibers. Waveguide excitation and coupling; integrated devices; directional couplers, gratings, filters, and modulators. Materials issues; dispersion and attenuation; aspects of waveguide and device fabrication. Introduction to nonlinear optical phenomena in waveguide structures.

538. (Appl. Phys. 550). Lasers and Electro-Optics I. ***Prerequisite: EECS 434. I.*** (3).
Propagation of laser beams: Gaussian wave optics and the ABCD law. Crystal properties and the dielectric tensor; electro-optic effects and devices; acousto-optic diffraction and devices. Introduction to nonlinear optics: coupled mode theory and second harmonic generation; phase matching.

539. (Appl. Phys. 551). Lasers and Electro-Optics II. ***Prerequisite: EECS 538. II.*** (3).
Laser resonators, eigenmodes, and stability analysis; rate equation analysis;

homogeneous and inhomogeneous broadening mechanisms; laser gain and gain saturation; Q-switching and mode locking. Special topics: laser pulse compression; Raman and Brillouin scattering; phase conjugation.

540. (Appl. Phys. 540). Applied Quantum Mechanics I. ***Prerequisite: EECS 300 or Math. 404 and Physics 242. I.*** (3).
Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics; one dimensional quantum problems including the quantum wells, WKB approximation, tunneling and the harmonic oscillator; introduction to angular momentum; the hydrogen atom; molecular orbitals; the rigid rotator and diatomic molecules; spin and identical particles, and time independent perturbation theory.

541. (Appl. Phys. 541). Applied Quantum Mechanics II. ***Prerequisite: EECS 540. II.*** (3).
Advanced theory of angular momentum, time dependent perturbation theory, quantization of fields, the second quantization for bosons and fermions, scattering theory, the density matrix, reservoir theory.

542. Vision Processing. ***Prerequisite: EECS 442. I.*** (3).
Details of image formation theory, including the consideration of dynamic image sequences. The theoretical frameworks for edge detection, feature extraction, and surface description are presented. The relationship between image formation and object features is examined in detail. Programming required.

543. Knowledge-Based Computer Vision. ***Prerequisite: EECS 442 and 492. II.*** (3).
Application of topics in AI to Computer Vision. Central issues are introduced through a critical examination of working image-interpretation systems. Topics: representation of geometric structure, and nongeometric characteristics relation of image features to object structure, reasoning, dealing with uncertainty, and dynamic interpretation. Programming required.

545. Machine Learning. ***Prerequisite: EECS 492. II.*** (3).
Survey of recent research on learning in artificial intelligent systems. Topics include learning based on examples, instructions, analogy, discovery, experimentation, observation, problem solving and explanation. The cognitive aspects of learning will also be studied.

546. Cognitive Theory and Artificial Intelligence. ***Prerequisite: EECS 492. II.*** (3).
Survey of scientific theory and results from cognitive psychology that are relevant to research in Artificial Intelligence. Topics include perceptual information processing, attention, short and long term memory systems, memory organization and the representation of knowledge, mechanisms of learning, natural language processing, problem solving, mental models and expertise.

547. Cognitive Architectures. ***Prerequisite: EECS 492. II.*** (3).
Survey of architectures of symbolic systems in artificial intelligence. Architectures such as blackboards, production systems, logic systems, reflective systems, discovery systems and learning systems. Also integrated cognitive architectures such as ACT*, SOAR, MRS, and EURISKO.

550. Information Theory. ***Prerequisite: EECS 501. II.*** (3).
The concepts of source, channel, rate of transmission of information. Entropy and mutual information. The noiseless coding theorem. Noisy channels; the coding theorem for finite state zero memory channels. Channel capacity. Error bounds. Parity check codes. Source encoding.

553. Analog Communication Theory. ***Prerequisite: EECS 453 and 501. (I).*** (3).
Statistical methods in the analysis of analog transmission systems; bandwidth, signal-to-noise ratio and threshold behavior of amplitude, frequency and pulse modulations; phase-locked loops for coherent detection and FM demodulation; source coding for analog signals, including quantization and PCM.

554. Introduction to Digital Communication and Coding. ***Prerequisite: EECS 351 and 401. I.*** (3). ***Graduate credit not allowed for both EECS 455 and 554.***
Digital transmission of information across discrete and analog channels. Sampling; quantization; noiseless source codes for data compression: Huffman's algorithm and entropy; block and convolutional channel codes for error correction; channel capacity; digital modulation methods: PSK, MSK, FSK, QAM; matched filter receivers. Performance analysis: power, bandwidth, data rate, and error probability.

555. Digital Communication Theory. ***Prerequisite: EECS 501 and 554. I.*** (3).
Theory of digital modulation and coding. Optimum receivers in Gaussian noise. Signal space and decision theory. Signal design. Bandwidth and dimensionality. Fundamental limits in coding and modulation, capacity and cutoff rate. Block, convolutional and trellis coding. Continuous phase modulation. Filtered channels and intersymbol interference. Equalization. Spread-spectrum. Fading channels. Current topics.

556. Image Processing. ***Prerequisite: EECS 501. II.*** (3).
Theory and application of digital image processing. Multidimensional signal processing. Random field models of images. Sampling, quantization, image compression, enhancement, restoration, segmentation, shape description, reconstruction of pictures from their projections, pattern recognition. Applications include biomedical images, time-varying imagery, robotics, and optics.

557. Communication Networks. ***Prerequisite: Graduate standing and preceded by EECS 401 or accompanied by EECS 501. I*** (3).
System architectures. Data link control: error correction, protocol analysis, framing. Message delay: Markov processes, queueing, delays in statistical multiplexing, multiple users with reservations, limited service, priorities. Network delay: Kleinrock independence, reversibility, traffic flows, throughput analysis, Jackson networks. Multiple access networks: ALOHA and splitting protocols, carrier sensing, multi-access reservations.

558. Stochastic Control. ***Prerequisite: EECS 501 and 560. I.*** (3).
Analysis and optimization of controlled stochastic systems. Models: linear and nonlinear stochastic controlled systems, controlled Markov chains. Optimization of systems described by Markov processes; dynamic programming under perfect and imperfect information, finite and infinite horizons. System identification: off-line, recursive. Stochastic adaptive control: Markov chains, self tuning regulators, bandit problems.

559. Advanced Signal Processing. ***Prerequisite: EECS 456 and 501. II.*** (3).
Estimators of second order properties of random processes: nonparametric and model-based techniques of spectral estimation, characterization of output statistics for nonlinear systems, time-frequency representations. Performance evaluation using asymptotic techniques and Monte Carlo simulation. Applications include speech processing, signal extrapolation, multidimensional spectral estimation, and beamforming.

560. (Aero. Eng. 550). Linear Systems Theory. ***Prerequisite: graduate standing. I and II.*** (3).
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability,

observability, realizations, canonical decomposition, stability.

561. (Aero. Eng. 571). Digital Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461. I.*** (3).
Sampling and data reconstruction in computer control systems. Z-transforms and state equations to describe discrete and mixed data systems. Analysis of digital feedback systems using root locus, Nyquist and Jury tests. Design of digital feedback systems using frequency domain techniques and state space techniques. Non-linear digital feedback systems.

562. (Aero. Eng. 551). Non-linear Dynamical Systems. ***Prerequisite: graduate standing. II.*** (3).
Introduction to and analysis of phenomena which occur in non-linear dynamical systems. Topics include: equilibria, limit cycles, second order systems and phase plane analysis, bifurcations and chaos, Liapunov and input-output stability theory, asymptotic analysis including averaging theory and singular perturbations, numerical techniques.

563. (Aero. Eng. 576). Optimal Control. ***Prerequisite: EECS 560/Aero. Eng. 550. II.*** (3).
Definition of optimal control problems. Formulation of discrete time optimal control problems as constrained mathematical programming problems. Formulation of continuous time optimal control problems as variational problems. The Pontryagin necessary conditions. Application to a variety of specific optimal control problems from diverse disciplines. Introduction to computational methods in optimal control.

564. (Aero. Eng. 578). Estimation, Filtering, and Detection. ***Prerequisite: EECS 501 and 560. II.*** (3).
Principles of estimation, linear filtering and detection. Estimation: linear and non-linear minimum mean squared error estimation, and other strategies. Linear filtering: Wiener and Kalman filtering. Detection: simple, composite, binary and multiple hypotheses. Neyman-Pearson and Bayesian approaches.

565. (Aero. Eng. 580). Linear Feedback Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461 and EECS 560/Aero. Eng. 550. II.*** (3).
Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design tradeoffs. Design formulations using both frequency domain and state space descriptions. Pole placement/observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems.

566. (Aero. Eng. 572). Non-linear Control Systems. ***Prerequisite: EECS 460/Aero. Eng. 461/ Mech. Eng. 471 and EECS 562/Aero. Eng. 572. I.*** (3).
Methods of analysis and design of non-linear control systems. Topics include: stabilizing controllers, absolute stability theory, describing function methods, input-output stability of feedback systems. Control techniques for non-linear systems: dither, vibrational control, variable structure systems and sliding mode control, linearization by non-linear feedback.

567. Introduction to Robotics: Theory and Practice. ***Prerequisite: EECS 380. I.*** (3).
Methods of design and operation of computer-based robots. Kinematics and dynamics of a six-jointed arm; force, movement, torque, compliance, control methods, trajectory planning. Integration of computer vision systems to form hand-eye coordinated systems. Man-machine communication via high-level language.

568. Informational Aspects of Biology. ***Prerequisite: graduate standing or permission of instructor. II, alternate years.*** (3).
A survey of the role of information and control processes in biology. Tentative topics: evolution and adaptation: cells and cellular self-reproduction; molecular information processing; discrete and dynamical models in biology; cellular control systems; development and morphogenesis; self-recognition and immunity; information processing in the nervous system and brain; physiological control systems; community and ecosystem.

569. (Bioeng. 569). Introduction to Neurophysiological Systems. ***Prerequisite: EECS 360 or 460. II, odd years.*** (3).
Application of system theory to neurophysiology, a theoretical and experimental study of the application of linear and non-linear systems theory, state-space concepts, and stability criteria to several neurophysiological systems; neuromuscular systems, pupillary control, eye tracking, temperature regulation, and central nervous system function.

570. Parallel Computer Architecture. ***Prerequisite: EECS 470. II.*** (3).
Pipelining and operation overlapping, SIMD and MIMD architecture, numeric and non-numeric applications, VLSI, WSI architectures for parallel computing, performance evaluation. Case studies and term projects.

572. Digital Computer Arithmetic. ***Prerequisite: EECS 470 or 370, and 478. I.*** (3).
Classification and structure of finite number systems and arithmetic including weighted, redundant and signed digit classes of number systems. Theory of modern high-speed computer arithmetic including fast carry logic, multiplier recoding and SRT division. Case studies of general and special purpose arithmetic processors.

573. Database Machine Architecture. ***Prerequisite: EECS 570 and 484. II.*** (3).
Design and evaluation of computer architecture for database processing. Techniques for supporting data models in hardware. Review of associative and parallel processing techniques. Critical study of representative database machines and discussion of query processing, concurrency control, etc. issues. Current trends in architectures for knowledge base management and expert systems.

574. Theoretical Computer Science I. ***Prerequisite: EECS 476. I and II.*** (4).
Formal grammars, recursive functions, logic, complexity theory.

575. Theoretical Computer Science II. ***Prerequisite: EECS 574. II.*** (4).
Advanced computational complexity, intractability, classical probability and information theory, algorithmic information theory, and special topics such as computational algebra, concurrency, semantics, and verification.

577. Reliable Computing Systems. ***Prerequisite: EECS 478 and 280. II.*** (3).
An introduction to models and methods used in the analysis and design of reliable hardware systems, software systems and computing systems. Aspects of reliability considered include fault tolerance, fault detection and diagnosis, reconfiguration, design verification and testing, and reliability evaluation.

579. Digital System Testing. ***Prerequisite: EECS 478. I.*** (3).
Overview of fault-tolerant computing. Fault sources and models. Testing process. Combinational circuit testing. D-Algorithm and PODEM. Sequential circuit testing. Checking experiments. RAM and microprocessor testing. Fault simulation. Design for testability. Testability measures. Self-testing circuits and systems.

581. Software Engineering Tools. ***Prerequisite: EECS 481 or equivalent progamming experience. II.*** (3).
Fundamental areas of software engineering including life cycle paradigms, metrics, and tools. Information hiding architecture, modular languages, design methodologies, incremental programming, and very high level languages.

582. Advanced Operating Systems. ***Prerequisite: EECS 482. II.*** (4).
Course discusses advanced topics and research issues in operating systems. Topics will be drawn from a variety of operating systems areas such as distributed systems and languages, networking, security, and protection, real-time systems, modeling and analysis, etc.

583. Compiler Construction. ***Prerequisite: EECS 480 or 380. I and II.*** (4). ***Honor students (LSA) may take either 483 or 583, but not both.***
Introduction to compiling techniques including parsing algorithms, semantic processing, and optimization. Students implement a compiler for a substantial programming language using a compiler generating system.

584. Advanced Database Concepts. ***Prerequisite: EECS 484. II.*** (3)
Database design methodologies, distributed database systems, and recent developments in knowledge-based and object-based systems. Distributed transaction management, concurrency control, location transparency, and query optimization. Semantic data modeling, normalization, fragmentation and data allocation. Students design and implement a distributed database application. A term paper is required.

585. Relational Database Theory. ***Prerequisite: EECS 303 or equivalent. I.*** (3).
The theory of relational databases; operators, dependencies, normal forms, representation systems, relational algebra and calculus, query systems, database semantics, and example query languages.

586. Design and Analysis of Algorithms. ***Prerequisite: EECS 480. II.*** (3).
Design of algorithms for nonnumeric problems involving sorting, searching, scheduling, graph theory, and geometry. Design techniques such as approximation, branch-and-bound, divide-and-conquer, dynamic programming, greed, and randomization applied to polynomial and NP-hard problems. Analysis of time and space utilization.

588. (I.&O.E. 578). Geometric Modeling. ***Prerequisite: EECS 487 or 488. II.*** (3).
Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces, and bodies. Algorithms for set operations. Euler operations and deformations. Design and experimentation with geometric modeling facilities.

589. Raster Graphics-Principles and Applications. ***Prerequisite: EECS 487 or 488. I.*** (3).
A detailed account of modern raster-based computer graphics. Topics include solid area scan conversion, color theory and application, hidden surface elimination, shading, highlights, animation, painting, and standardization graphics software.

590. EECS Introductory Seminar. ***Prerequisite: senior standing. I.*** (1).
Introduction to the technical areas of graduate study and research in the EECS department. Discussion of the policies and practices of graduate study.

591. Natural Language Semantics. ***Prerequisite: EECS 492. I.*** (3).
A survey of various theories of meaning, or semantics, which have been developed in artificial intelligence and linguistics, ranging from logical semantics to frame-based theories. Work involves programming projects implementing aspects of these theories.

592. Advanced Artificial Intelligence. ***Prerequisite: EECS 492 or permission of instructor. II.*** (4).
Advanced topics in artificial intelligence. Issues in knowledge representation, knowledge based systems, problem solving, planning and other topics will be discussed. Students will work on several projects.

593. The Human as an Information Processing System. ***Prerequisite: graduate standing and permission of instructor. I.*** (3).
Basic human information handling processes such as perception, learning cognitive map information, and problem solving are analyzed in an evolutionary context. Emphasis is largely theoretical. Includes the application to the human-computer interface of the principles that emerge.

594. Introduction to Adaptive Systems. ***Prerequisite: EECS 476 or permission of instructor. I.*** (3).
A study of programs and automata that "learn" by adapting to their environment; programs that utilize genetic plans for learning are a major topic. Samuel's checker-playing program, prototypes of several well-known artificial intelligence systems, parallel automata and the Fisher-Kimura development in mathematical genetics are among the topics discussed.

595. (Ling. 541). Theory of Natural Language Structure. ***Prerequisite: EECS 492. II.*** (3).
A survey of structural or syntactic theories of natural language, including phrase-structure and unification-based grammars, methods of parsing, and connections with semantics and pragmatics. Coursework will include the use of existing natural language computer systems.

597. Technology Planning and Assessment. ***Prerequisite: senior or graduate standing. I.*** (3).
Interdisciplinary lecture and project course in strategic planning and management of technology in both private and public sectors, and policy-oriented assessment of societal effects of technology. Typical projects; planning and assessment of microcomputers, communications, transportation systems, and alternative energy sources.

598. Special Topics in Electrical Engineering and Computer Science. ***Prerequisite: permission of instructor or counselor. I, II, III, IIIa and IIIb.*** (1-4).
Topics of current interest in electrical engineering and computer science. Lectures, seminar, or laboratory. Can be taken more than once for credit.

599. Directed Study. ***Prerequisite: prior arrangement with instructor. I, II, III, IIIa, and IIIb.*** (1-4).
Individual study of selected advanced topics in electrical engineering and computer science. May include experimental work or reading. Primarily for graduate students. To be graded on satisfactory/unsatisfactory basis ONLY.

600. (Aero. Eng. 651). Function Space Methods in System Theory. ***Prerequisite: EECS 400.*** (3).
Introduction to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert spaces, resolution spaces. Emphasis on using these concepts in systems problems.

602. (Aero. Eng. 652). Theory of Stochastic Processes. ***Prerequisite: EECS 502.*** (3).
Measure theoretic treatment of stochastic processes. Analysis and representation of various stochastic processes using function analytic concepts. Wiener processes, martingales, diffusion processes. Stochastic integrals, introduction to stochastic differential equations and stochastic calculus.

603. (Aero. Eng. 653). Topics in Stochastic Systems and Control. ***Prerequisite: permission of instructor.*** (3).
Advanced topics on stochastic systems such as stochastic calculus, non-linear filtering, stochastic adaptive control, decentralized control, and queueing networks.

617. (Aero. Eng. 673) (Nuc. Eng. 673). Topics in Theoretical Plasma Physics. ***Prerequisite: Nuc. Eng. 571 or EECS 517 or Aero. Eng. 726. II.*** (3).
An advanced course in theoretical plasma physics covering topics of current research

interest. Specific content varies from year to year. Representative topics include; studies of weakly ionized plasmas with applications to gas lasers; space plasmas; laser function plasmas; and non-linear plasma dynamics and plasma turbulence. May be taken for credit more than once.

620. Quantum Electronics. ***Prerequisite: EECS 520. II, odd years.*** (3).
Principles and applications of quantum electronics. Field quantization; interaction of fields and charges; photon emission by free electrons; interaction of bound electrons and photons; masers and lasers; noise in quantum devices; Rayleigh scattering; Raman scattering; non-linear optics; coherent transient effects.

621. Electronic Properties of Solid State Materials. ***Prerequisite: EECS 520. II, odd years.*** (3).
Detailed treatment of the properties of semiconductor materials: weak and tight binding approximation; energy bands in solids; Fermi surfaces; Boltzmann transport equation; scattering processes; magnetoresistance; free carrier optical processes; theory of dielectrics; paramagnetic; diamagnetic and ferromagnetic materials; de Haas-Van Alphen effect; Landau levels; superconductivity.

627. VLSI Design II. ***Prerequisite: EECS 527. II.*** (4).
Advanced very large scale integrated (VLSI) circuit design: VLSI CAD tools and techniques. IC failure modes: testing. Design for testability. Self-checking circuits. Automated layout. Design verification; placement and compaction; routing. Gate arrays; silicon compilers. Advanced projects in chip design and CAD tool development. Testing of chips fabricated in EECS 527. (3 hours lecture plus design laboratory).

630. (Appl. Phys. 531 Advanced Electromagnetics. ***Prerequisite: EECS 530 and graduate standing. II.*** (3).
Laws of electrodynamics. Interaction of waves and various media. Green's functions. Diffraction of waves by smooth, spherical earth, Fock theory. Waves in anisotropic media: ferrites, ionosphere. Wave propagation in random media. Special theory of relativity.

631. Electromagnetic Scattering. ***Prerequisite: EECS 530 and graduate standing. II, odd years.*** (3).
Integral representation of fields: E and H integral equations. Reaction theorem. Impedance boundary conditions. Numerical techniques. Fourier methods: angular spectrum method, Wiener-Hopf technique. High frequency scattering by a cylinder and a sphere; Watson transformation. Rayleigh scattering. Asymptotic techniques: geometrical theory of diffraction (GTD), applications of GTD. Hybrid Methods.

632. Microwave Remote Sensing II. Radar. ***Prerequisite: EECS 532 and graduate standing. II, even years.*** (3).
Radar equation; noise statistics; resolution techniques; calibration; synthetic aperture radar; scatterometers; scattering models; surface and volume scattering; land and oceanographic applications.

633. Advanced Antenna Theory. ***Prerequisite: EECS 530 and graduate standing. I, odd years.*** (3).
Self impedance and mutual impedance of antenna elements, dipoles over plane impedance boundaries. Surface wave antennas; dielectric rod antenna. Leaky-wave antennas. Microstrip antennas; microstrip patch, microstrip disk. Microstrip slot antennas. Microstrip antenna arrays.

634. Nonlinear Optics. ***Prerequisite: EECS 530, 539. II*** (3).
Formalism of wave propagation in nonlinear media; susceptibility tensor; second harmonic generation and three-wave mixing; phase matching; third order nonlinearities and four-wave mixing processes; stimulated Raman and Brillouin scattering. Special topics: nonlinear optics in fibers, including solitons and self-phase modulation.

638.(Physics 610). Quantum Theory of Optical Physics. ***Prerequisite: EECS 541; preceded or accompanied by EECS 630. II.*** (3).
The atom-field interaction; density matrix; quantum theory of radiation including spontaneous emission; optical Bloch equations and theory of resonance fluorescence; coherent pulse propagation; dressed atoms and squeezed states; special topics in nonlinear optics.

650. Channel Coding Theory. ***Prerequisite: EECS 501 and 400.II, Even years.*** (3).
The theory of channel coding for reliable communication and computer memories. Error correcting codes; linear, cyclic and convolutional codes; encoding and decoding algorithms; performance evaluation for codes on a variety of channels.

651. Source Coding Theory. ***Prerequisite: EECS 501. II, Odd years.*** (3).
Introduction to a variety of source coding techniques such as quantization, block quantization; and differential, predictive, transform and tree coding. Introduction to rate-distortion theory. Applications include speech and image coding.

652. Signal Detection. ***Prerequisite: EECS 501 and 564.*** (3).
Binary decisions and reduction of uncertainty through observations. Likelihood ratios and detection criteria. Study of signal plus Gaussian noise. Optimum detectors. Interrelation of detection, parameter estimation and noise environment analysis. Applications to communications.

658. Fast Algorithms for Signal Processing. ***Prerequisite: EECS 456, EECS 501. I, Odd years.*** (3).
Introduction to abstract algebra with applications to problems in signal processing. Fast algorithms for short convolutions and the discrete Fourier transform; number theoretic transforms; multi-dimensional transforms and convolutions; filter architectures.

659. Adaptive Signal Processing. ***Prerequisite: EECS 559. I, Even years.*** (3).
Theory and applications of adaptive filtering in systems and signal processing. Iterative methods of optimization and their convergence properties: transversal filters; LMS (gradient) algorithms. Adaptive Kalman filtering and least-squares algorithms. Specialized structures for implementation; e.g., least-squares lattice filters, systolic arrays. Applications to detection, noise cancelling, speech processing, and beam forming.

670. Advanced Topics in Computer Architecture. ***Prerequisite: EECS 570, graduate standing & permission of instructor. II.*** (3)
Advanced concepts and specialized areas in computer system design are discussed and analyzed in depth. Topics chosen by instructor. Examples are database machines, highly reliable systems, computers for artificial intelligence, architectural support for operating system functional, high-level language architectures, object oriented architecture, other special purpose architecture (vision, dataflow).

681. Advanced Software Engineering. ***Prerequisite: EECS 481 and either 581, 582, 583, or 584. I.*** (3).
Problems of current research interest in software engineering such as software environments, program transformations, application generators, and very high level languages. A term project will be required.

682. Advanced System Programming. ***Prerequisite: EECS 482 or 582. I or II.*** (3).
This course introduces the student to the more difficult problems and techniques of system programming. Such areas as dynamic storage allocation and relocation, interaction between central and peripheral hardware units, etc., will be discussed.
The main emphasis of the course is a group project and the handling of the problems that are involved in all aspects of system design and final implementation.

694. Theory of Adaptive Systems. ***Prerequisite: EECS 594 or permission of instructor. I or II*** (3).
Development of the theoretical underpinnings of the topics discussed in EECS 594. Topics include the common mathematical framework underlying mathematical genetics, mathematical economics, adaptive control, game theory and learning. The course presents a series of theorems concerning feasible adaptive plans and makes a detailed study of general applicability of genetic operators to searches and optimization.

695. (Psych. 640). Neural Models and Psychological Processes. ***Prerequisite: permission of instructor. II.*** (3).
Consideration of adaptively and biologically oriented theories of human behavior. Emphasis on both the potential breadth of application and intuitive reasonableness of various models. There is a bias toward large theories and small simulations.

698. Master's Thesis. ***Prerequisite: election of an EECS Master's Thesis Option. (May be elected for a maximum of 6 credit hours). I, II, IIIa, IIIb, III.*** (1-6).
To be elected by EE and EES students pursuing the Master's Thesis option. May be taken more than once up to a total of 6 credit hours. To be graded on a satisfactory/unsatisfactory basis only.

699. Research Work in Electrical Engineering and Computer Science. ***Prerequisite: graduate standing and permission of instructor. I, II, III, IIIa, IIIb.*** (1-6).
Students working under the supervision of a faculty member plan and execute a research project. A formal report must be submitted. May be taken for credit more than once up to a total of 6 credit hours. To be graded satisfactory/unsatisfactory only.

700. Special Topics in System Theory. ***Prerequisite: permission of instructor. (To be arranged).***

720. Special Topics in Solid-State Devices, Integrated Circuits, and Physical Electronics. ***Prerequisite: permission of instructor.*** (1-4).
Special topics of current interest in solid-state devices, integrated circuits, microwave devices, quantum devices, noise, plasmas. This course may be taken for credit more than once.

730. Special Topics in Electromagnetics. ***Prerequisite: permission of instructor.*** (1-4). ***(To be arranged).***

750. Special Topics in Communication and Information Theory. ***Prerequisite: permission of instructor. (To be arranged).***

760. Special Topics in Control Theory. ***Prerequisite: permission of instructor. (To be arranged).***

770. Special Topics in Computer Systems. ***Prerequisite: permission of instructor. (To be arranged).***

874. Seminar in Theory of Computing. ***Prerequisite: EECS 574. I and II.*** (2).
Advanced graduate seminar devoted to new developments in theory of computing. Topics may include theory of programming languages, complexity, algorithms, AI, and applications of logic and mathematics to computer science.

892. Seminar in Artificial Intelligence. ***Prerequisite: EECS 592 or equivalent. I and II.*** (2).
Advanced graduate seminar devoted to discussing current research papers in artificial intelligence. The specific topics vary each time the course is offered.

990. Dissertation/Pre-Candidate. I, II and III. (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by a doctoral student not yet admitted to Candidate status.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II and III.*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by a doctoral student who has been admitted to Candidate status.

Engineering

See Page 60 for statement on Course Equivalence.

All undergraduate degree programs in the College of Engineering will accept up to four credit hours of elective courses from this group as free and/or technical electives.

103. Digital Computing. I. (3).
Digital-computer organization, algorithms, flow diagrams, and interactive digital computing. Use of the Michigan Terminal System. Design, implementation, and analysis of computer programs for numerical and non-numerical computations including computer graphics.

104. PC Pascal. I and II. (3).
Introduction to the personal computer, its operating system, visual editing, and PASCAL as a programming language. Local-area networks and communication with the Michigan Terminal System. Compute programs for numerical and non-numerical computations Not open to students with credit for Eng. 103 or 105.

105. The Personal Computer and the Michigan Terminal System. ***Prerequisite: knowledge of a programming language. I and II.*** (3).
Introduction to the personal computer, its operating system, and visual editing. Local-area networks and communication with the Michigan Terminal System. Not open to students with credit for Eng. 103 or 104.

150. (Mat. Sci. & Eng. 150). Introduction to Engineering Materials. ***Prerequisite: Chem. 123 or 124. II.*** (4).
A course in engineering materials covering the structure, properties and processing of metals, polymers and ceramics. Open only to freshmen; satisfies any program requirement of Mat. Sci. & Eng. 250.

151. (Chem. Eng. 151). Plastics. ***Prerequisite: high school chemistry.*** (3).
Plastics such as nylon, lucite, and polystyrene will be synthesized, analyzed, molded and tested mechanically by the students. The instructor will demonstrate advanced methods of characterization and processing. Lecture followed by a three-hour laboratory. Local plant visits.

195. Selected Topics in Engineering. ***(To be arranged).***

303. (Civ. Eng. 303)(Math. 371). Computational Methods for Engineers and Scientists. ***Prerequisite: Eng. 103 and preceded or accompanied by Math 216. I and II.*** (3).
Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development evaluation and comparison of various techniques for roots of non-linear equations, simultaneous linear algebraic equations, curve fitting, numerical integration and ordinary differential equations.

390. Special Topics in Engineering. ***Prerequisite: permission of instructor. (To be arranged).***
Individual or group study of 300-level, undergraduate topics of current interest.

400. Engineering Cooperative Education. ***Prerequisite: permission of Program Director. I, II, and II. No Credit.***
Off-campus work within the cooperative education program. Engineering work experience in government or industry.

490. Special Topics in Engineering. ***(To be arranged).***
Individual or group study of topics of current interest selected by the faculty.

Geological Sciences*

Department Office:
1006 C.C. Little
phone (313) 764-1435

*College of Literature, Science and the Arts

Professor H. N. Pollack, Chairman; Professors Beck, Essene, Farrand, Gingerich, Kelly, Kesler, Meyers, O'Neil, Outcalt, Owen, Peacor, Pollack, Rea, Smith, Van der Voo, Walker, Wilkinson; Associate Professors Arculus, Fisher, Halliday, Kitchell, Lohmann, Ruff; Assistant Professors Lay, Van der Pluijm; Visiting Assistant Professors Davidson, McLeod.

116. Introductory Geology in the Field. ***Not open to those who have had an introductory course in geology on campus. IIIb.*** (8).
An introduction to geology in the field. This course is the equivalent of G.S. 117 or 121 but is taught at Camp Davis, the University's Rocky Mountain Field Station near Jackson, Wyoming. The principles and procedures involved in the study of earth materials and processes are stressed. Minerals, rocks, and fossils are studied in their natural settings. Lectures are given both in camp and in the field, but a majority of time is spent outdoors in the nearby Teton, Hoback, Gros Ventre, and Snake River Ranges. Trips are also taken to areas of special significance, including the Wind River Range, Craters of the Moon, and Yellowstone Park. Lectures, laboratory, extensive field studies. Application forms for admission are available from the departmental administrative assistant in 1008 C.C. Little Building in January of the year that the course is to be elected.

117. Introduction to Geology. ***Not open to those who have had an introductory course in geology. I.*** (5).
A basic single-term course in introductory geology concentrating on the evolution of the Earth in physical and chemical terms. Reference to the interaction of the external biosphere-atmosphere-hydrosphere with the Earth's interior is an essential component of the course. The laboratory provides a practical study of minerals, rocks, fossils, and geologic maps. One hour each week is scheduled for review and discussion topics covered in class. Lectures, laboratory, discussion.

119. Introductory Geology Lectures. ***Not open to those who have had an introductory course in geology. I.*** (4).
This course consists of lectures shared with geology 117 but does not include the laboratory section. A separate discussion section is also scheduled to ensure continuity with class material and student teacher contact. Students interested in a one-term laboratory introductory science course should elect geology 117. Lectures and discussion.

120. Geology of National Parks and Monuments. ***Credit is not granted for G.S. 120 to those with credit for an introductory course in geology. II.*** (4).
This course approaches earth history by examining the geology of places rather than geological processes. There are three lectures each week and one two-hour demonstration. Lecture material covers the geologic history of selected National Parks and Monuments chosen so that those in which the oldest rocks are exposed are discussed first. The demonstrations provide first-hand experience with rocks, minerals, and fossils and an opportunity to discuss these in small groups.

123. Life and the Global Environment. ***II.*** (2).
A hard look at the Gaia hypothesis. Do organisms cooperate to control the compositions of ocean atmosphere? Can life prevent harmful changes in the global environment? Does the geologic record provide answers to these questions? What future change in the global environment can we expect?

125. Evolution and Extinction. ***II.*** (3)
This course will describe the linkage of the phenomena of evolution with the historical extinction of species.

135. History of the Earth. ***II.*** (3). (NS).
This lecture course is intended for students with a strong high school background in math and science. It will serve as a broad introduction to the earth sciences for students considering a Geological Sciences concentration, as well as for students interested in studying the earth sciences as part of a general science background. Topics covered include methods of determining relative and absolute ages, the early history of the earth, its accretion and chemical differentiation, the development of continental and oceanic lithosphere, the evolution of plate tectonics, the history of the crust, sediments, oceans, atmosphere, and life. The unique aspects of earth history will be highlighted by viewing the development of the earth from the perspective of the evolution of the moon and the other terrestrial planets. Evaluation will be based on three examinations.

280. Mineral Resources, Politics and the Environment. ***I.*** (2).
This course concerns the origin, distribution, and remaining supplies of mineral resources such as gold, iron, oil, and salt. These and other important mineral resources are discussed in terms of the economic, engineering, political, and environmental restrictions that govern their recovery, processing, and use. Among topics considered are mineral discovery, rated strip mining, smelting methods, oil and gas transport, nuclear waste disposal, taxation, royalties, and corporate profits in the mineral industry. No previous knowledge of geology is required for this course.

351. Structural Geology. ***G.S. 305 or permission of instructor. II.*** (4).
Sedimentary, metamorphic, and igneous rock structures and the mechanics of rock deformation. Three-dimensional structure problems and geologic map interpretation given in the laboratory. Lectures and laboratory.

415. Introductory Economic Geology (Metals). ***G.S. 310, 351, or permission of instructor. I.*** (4).
This is a survey economic geology course whose main emphasis is on gaining an understanding of how we study and describe ore deposits as well as studying specific examples of each major type. Fossil fuels and most nonmetallic ore deposits are left to other courses in the department. Such a study of the processes, controls on, and extent of different kinds of ore deposits will allow the student to better understand the problems in locating concentrations of natural resources as well as the technical, practical, environmental and monetary considerations that decide whether or not an elemental concentration is an ore. The course is directed to the senior/first-year graduate student who has completed the core courses in geology and as such is an elective outside the required departmental sequence. The method of teaching will combine lecture and discussion with a one hour per week lab session which will be devoted to problem solving the first half of the term and small lab exercises the second half. There will be a midterm and final as well as a term paper on a subject of the students' choosing. No text books are required but the GEOLOGY OF ORE DEPOSITS by Guilbert and Park is recommended.

420. Introductory Earth Physics. Math. 116. ***I.*** (3).
This course is intended to be a comprehensive introduction to the physics of the solid earth. Topics to be included are: seismology and structure of the earth's interior; geodynamics; gravity and the figure of the earth; isostasy; geomagnetism and paleomagnetism and its implications for plate tectonics; geothermics and the thermal history of the earth.

422. Principles of Geochemistry. ***G.S. 231, 305, 310, and Chem. 126. II.*** (3).
Instruction is directed toward how geochemical methods, such as stable isotope and trace element analysis, radioactive age dating, determination of phase relations

of minerals and melts at low to high temperature and pressure, and computation of or experimentation on equilibria in the hydrosphere, hydrothermal solutions, and metamorphic and igneous systems, can unravel and provide insight into the origin and chemical evolution of the earth and its parts (core, mantle, crust, crustal rocks).

442. Geomorphology. I. (4).
A study of the processes that affect the Earth's surface and that determine its form. Geomorphology is concerned with both modern and ancient landscapes. The course is designed for geology concentrators and advanced students in the natural sciences and archeology. Lectures, discussions, and field trips.

444. Soils and Their Development. *An introductory geological sciences course or permission of the instructor. I.* (3).
Field identification and laboratory analysis of soils; study of their genesis as controlled by geologic, biotic, and climatic determinants and of their evolution through time; and consideration of soils as environmental factors. Lectures, laboratory, and required field trips.

447. Archeological Geology. *G.S. 442 or 448 or equivalent and one course in archeology (Anthro. 282, or 581, or Class. Arch. 323. II.* (3).
In-depth treatment of geological concepts and techniques important in and applicable to the study of archeological sites. Lectures, laboratory, and optional field trips.

448. Pleistocene Geology. *An introductory physical geology course or permission of instructor. I.* (4).
Study of geologic phenomena characteristic of the Pleistocene epoch, including glaciation, pluviation, and marine phenomena. Three required field trips, including at least one overnight. Lectures, recitation, and field trips.

480. (A.O.&S.S. 480). The Planets: Composition, Structure and Evolution. *Math 216, Physics 240, Chem. 126. I.* (3).
Origin and distribution of material in the solar system, gross composition and radial distribution of material in the planets and satellites; gravity fields and their relationship to shape and internal density distribution; origin and significance of surface topography; thermal, ionospheric and extended structure of planetary atmospheres; magnetism; energetics and dynamics of planetary interiors and atmospheres, thermal histories and evolution of solid interiors, devolatilization, origin, and evolution of atmospheres.

483. Geophysics: Seismology. *Math. 215 at least concurrently and Phys. 240; or permission of instructor. II.* (4).
Elastic properties of rocks, elastic waves, seismological instruments and data, use of body wave travel times, surface wave dispersion, and periods of free vibrations to infer the structure and composition of the earth's interior; earthquake intensity and magnitude scales; spatial, temporal and magnitude distribution of earth dynamics and global tectonics, moonquakes, underground nuclear explosions and "man-made" earthquakes, earthquake prediction and control. Lectures and laboratory.

484. Geophysics: Physical Fields of the Earth. *Math. 216 at least concurrently and Physics 240, or permission of instructor. II* (4).
Newtonian attraction; the potential function, spherical harmonics; attraction of special distributions, gravity exploration techniques; isostasy, the figure of the earth; earth tides, the magnetic field of the earth, spatial and temporal variations, theories of origin; rock magnetism, paleomagnetism, contributions to earth dynamics and global tectonics; magnetic field of special distributions, magnetic exploration techniques; temperatures and heat transport in the earth, geothermal measurements, implications for tectonic processes. Lectures and optical laboratory.

485. Computer Utilization in the Earth Sciences. *Calculus and experience in computer programming. II.* (3).
Application of computers to earth science problems. Utilization of existing programs, data inventories, and specialized equipment. Topics include mapping, data management, and analysis and simulation.

486. Permafrost, Snow, and Ice. *Math. 116 or equivalent. II.* (3).
Introduction to the environmental conditions in high altitudes and latitudes for students of natural sciences and engineering. Topics include general climatology and geography of alpine and arctic regions, economic development, environmental protection problems.

540. (Civ. Eng. 540). Seminar in Engineering Geology. *Civ. Eng. 445 and a 400-level course in physical geology or geomorphology. II.* (2).
Study of case histories in engineering geology, dealing with dam sites, slope stability, waste disposal, foundation and bridge problems, power plant siting, groundwater and other problems.

589. (A.O.&S.S. 589). Global Geochemical Cycles and Fluxes. *Prerequisite: permission of instructor. II.* (2).
The processes that control the composition of the lithosphere, hydrosphere, and atmosphere. The budgets of major constituents and of isotopes. Quantitative modeling of possible changes with time in the compositions of oceans, sedimentary rocks, and atmosphere. Global productivity and the impact of life. Climatic consequences of geochemical change.

Humanities

(See also Technical Communication)

Office:
130C West Engineering Building
phone (313) 764-1420
See Page 60 for statement on course equivalence.

Faculty

David Yerkes Hughes, Ph.D., Professor of Humanities

Ralph A. Loomis, Ph.D., Professor of English, Humanities Coordinator

Edward M. Shafter, Jr., Ph.D., Professor Emeritus of Humanities

Henryk Skolimowski, D. Phil., Professor of Humanities

Robert Allen Martin, Ph.D., Professor Emeritus of English

Stephen Sadler Stanton, Ph.D., Professor Emeritus of English

Gorman Lynn Beauchamp, Ph.D., Associate Professor of Humanities

Hubert Irwin Cohen, Ph.D., Associate Professor of Humanities

William Byrom Dickens, Ph.D., Associate Professor Emeritus of English

Warne Conwell Holcombe, Ph.D., Associate Professor Emeritus of English

Richard John Ross, Ph.D., Associate Professor Emeritus of Humanities

Chester Raymond Leach, Ph.D., Assistant Professor of Humanities

Thomas C. Edwards, A.M., Assistant Professor Emeritus of Humanities

Humanities seminars and elective courses in the College can be used to meet humanities and free elective requirements. Normally, a student will take a three-hour Technical Communication course in the senior year with the Engineering College.

A student is expected to maintain a satisfactory standard of English in all courses. Failing to do so, a student may be reported to the Assistant Dean who, with the student's program advisor and a Humanities or Technical Communication faculty representative, may prescribe additional study.

Humanities Courses

The Humanities faculty offers a variety of courses. These courses are open to all students in the University, but are specifically designed to help engineering students fulfill their program requirements. (Not every course is taught every term.)

Sophomore standing is a prerequisite for the following 200 and 300 level humanities courses.

239. Quest for Utopia. (3).
Reading and discussion of some of the major efforts to chart the good society from Plato's Republic to Orwell's 1984. The chief purpose of this survey of utopias and anti-utopias is to help the student evaluate the present order.

310. Science Fiction. (3).
This course will survey major works and themes of science fiction in their historical context. Selected works of such writers as Mary Shelley, Verne, Wells, Heinlein, Clarke, and Asimov will be studied.

337. Problems in Film Criticism. *Prerequisite: Humanities 236.* (3).
After identifying a film's visual-aural-affective elements (Humanities/Film & Video Studies 236), we are ready to interpret and judge it. We must decide what critical approach (e.g., literal, mythic, psychoanalytical, auteurist, Marxist) will most fruitfully reveal the film's meaning, and judge how effectively (in terms of unity, intensity, etc.) the elements are structured to convey the meaning. The intent of this course is to provide students with the tools to make these judgments.

410. Cinematic Experience: Theories, Criticism, Directors, Film Movements. *Prerequisite: Humanities 236 or University Course 236 or Speech 220.* (3).
Each semester the course will focus on one or two of the following: film criticism (e.g., Kael, Sarris, Pechter), film theory (Bazin, Kracauser), film genre (e.g., western, documentary); a significant historical movement (e.g., neo-realism), or the works of a single director (e.g., Capra, Bergman).

418. (Univ. Crse. 488). Alternative Futures. (3).
A study of human problems in a highly developed technological society: a critical examination of the philosophic premises underlying contemporary society, selected proposals for alternative societies, and the philosophic arguments justifying such alternatives.

Directed Study Courses

Prerequisite: permission of Humanities faculty. (elective credit only).
Conference and tutorial sessions which provide the opportunity for students with special interests to work on a tutorial basis with a member of the Humanities faculty.

These courses are not intended as substitutes for regularly scheduled courses. Students who wish to elect Directed Study must confer with an instructor about the proposed study. If the instructor agrees to accept the student for this study, the two agree on a contract. (Directed Study contract forms and additional information are available from the Humanities office.)

275. 375. 475. (1-4)

Selected Topics

Study of selected topics. When offered, the course or courses will be announced in the *Time Schedule.*

151. (1-4)

301. ***Prerequisite: sophomore standing. (To be arranged).***

401. ***Prerequisite: junior standing. (To be arranged).***

Seminars in Humanities

In these courses, a selection of significant works, in some instances thematically organized, will be examined intensively through discussions and written assignments.

420. Chaucer. *Prerequisite: junior standing.* (3).
A study of The Canterbury Tales and other works, in translation, to emphasize the relevance of Chaucer's art and insight.

421. Shakespeare. *Prerequisite: junior standing.* (3).
A study of selected plays, including some of the great tragedies, to illustrate the depth and variety of Shakespeare's insight, thought, and art.

430. Major British Writers. *Prerequisite: junior standing.* (3).
A study of the major works of several significant British authors such as Swift, Fielding, Blake, Dickens, Hardy, Conrad, Joyce, Lawrence, and Shaw.

431. Major European Writers. *Prerequisite: junior standing.* (3).
A study of the major works of several significant European authors such as Cervantes, Balzac, Baudelaire, Chekhov, Tolstoy, Kafka, and Camus.

432. Major American Writers. *Prerequisite: junior standing.* (3).
A study of the major works of several significant American authors such as Hawthorne, Whitman, Twain, O'Neill, Frost, Faulkner, and Hemingway.

440. Fiction. *Prerequisite: junior standing.* (3).
To acquaint the student with basic elements of the novel, novella, and short story—the plot, setting, character, style, and theme. In any specific section, the focus may be a particular type and/or period of fiction, but the distinctive features of fiction as a unique literary genre will be emphasized.

441. Poetry. *Prerequisite: junior standing* (3).
To acquaint the student with basic elements of poetry—the rhythm, imagery, pattern, tone, and meaning. In any specific section, the focus may be a particular type and/or period of poetry, but the distinctive features of poetry as a unique literary genre will be emphasized.

442. Drama. *Prerequisite: junior standing.* (3).
To acquaint the student with basic elements of dramas—the plot, character, ideas and staging, stage history, and production techniques. In any specific section, the focus may be a particular type and/or period of drama, but the distinctive features of drama as a unique literary genre will be emphasized.

443. American Drama. *Prerequisite: junior standing.* (3).
A study of representative plays and productions of the 20th century American theater. A secondary purpose of the course is to increase the student's critical awareness of drama as a form and as an expression of American life and culture. Typical authors studied are Eugene O'Neill, Tennessee Williams, Arthur Miller, and Edward Albee.

450. Literature and Philosophy. *Prerequisite: junior standing.* (3).
Readings in literature and modern thought in order to introduce the students to some important philosophical questions in literature.

452. Literature and Technology. *Prerequisite: junior standing.* (3).
To explore the literary responses to technology, particularly since the advent of the Industrial Revolution. Themes such as the effects of machine production on society, the alienation of the worker, urbanization, and the emergence of the expert will be explored as they are manifested in significant works of literature.

460. Themes in the Humanities. *Prerequisite: junior standing.* (3).
An examination of a significant theme, or themes, treated in one or more of the following disciplines: history, philosophy, art, music, film, and literature. Such themes might include Primitivism, the Faustian hero, or the collapse of Realism in the 20th century.

461. Images of America. ***Prerequisite: junior standing.*** (3).
To explore the variety of ways in which "the American experience" has been projected in literature, history, biography, sociology, and popular culture and film. While a particular section might be devoted to a single theme, the readings exemplifying this theme will be multidisciplinary.

462. Technology and Man: A Philosophy of Technology from a Social Point of View. ***Prerequisite: junior standing.*** (3).
Technology is analyzed within the framework of western civilization as a social force, as a cognitive phenomenon, as ideology. The goal is to evaluate the significance of technology in the development of western civilization.

463. Engineering Ethics. ***Prerequisite: junior, senior, or graduate standing. I and II.*** (3).
Open-forum discussion of ethical, social, and professional dilemmas in engineering today. History of technology within the social context: human nature and the nature of technology; theories of ethics; social responsibility; professional responsibility; codes of ethics; engineers and the law; ethics in the workplace. Discussion and lecture.

496. Creative Writing—Fiction, Poetry, Drama. ***Prerequisite: senior standing.*** (3).
Application and analysis of the principles and techniques involved in writing short stories, one-act plays, and poetry, with the opportunity to specialize in any one of the forms. The course proceeds from theory to practice, from class discussions to individual conferences on manuscripts in progress.

Industrial and Operations Engineering

Department Office:
240 Industrial and Operations Engineering Building
phone (313) 764-3297
See Page 60 for statement on Course Equivalence.

Faculty

Stephen M. Pollock, Ph.D., Professor of Industrial and Operations Engineering and Chairman of the Department of Industrial and Operations Engineering

Seth Bonder, Ph.D., Adjunct Professor of Industrial and Operations Engineering

Don B. Chaffin, Ph.D., P.E., Professor of Industrial and Operations Engineering

Walton M. Hancock, D. Eng., P.E., Professor of Industrial and Operations Engineering and Hospital Administration and Associate Dean of the College of Engineering

Gary D. Herrin, Ph.D., Professor of Industrial and Operations Engineering

Katta G. Murty, Ph.D., Professor of Industrial and Operations Engineering

Ramesh Saigal, Ph.D., Professor of Industrial and Operations Engineering

Robert L. Smith, Ph.D., Professor of Industrial and Operations Engineering

Daniel Teichroew, Ph.D., Professor of Industrial and Operations Engineering

James A. Gage, M.S. (M.E.), Professor Emeritus of Industrial and Operations Engineering

Herbert P. Galliher, Ph.D., Professor Emeritus of Industrial and Operations Engineering

Wilbert Steffy, B.S.E. (Ind.-Mech.), B.S.E. (M.E.), Professor Emeritus of Industrial and Operations Engineering

Richard C. Wilson, Ph.D., Professor Emeritus of Industrial and Operations Engineering

Thomas Armstrong, Ph.D., Associate Professor of Industrial and Operations Engineering

James C. Bean, Ph.D., Associate Professor of Industrial and Operations Engineering

John R. Birge, Ph.D., Associate Professor of Industrial and Operations Engineering

Gary D. Langolf, Ph.D., Associate Professor of Industrial and Operations Engineering

Jeffrey J. Liker, Ph.D., Associate Professor of Industrial and Operations Engineering

Jack R. Lohmann, Ph.D., Associate Professor of Industrial and Operations Engineering and Associate Dean of the College of Engineering

James M. Miller, Ph.D., P.E., Associate Professor of Industrial and Operations Engineering

Tony C. Woo, Ph.D., Associate Professor of Industrial and Operations Engineering

Candace A. Yano, Ph.D., Associate Professor of Industrial and Operations Engineering

Yavuz Bozer, Ph.D., Assistant Professor of Industrial and Operations Engineering

Jay Elkerton, Ph.D., Assistant Professor of Industrial and Operations Engineering

Paul A. Green, Ph.D., Adjunct Assistant Professor of Industrial and Operations Engineering

W. Monroe Keyserling, Ph.D., Assistant Professor of Industrial and Operations Engineering

Ching Yee Teresa Lam, Ph.D., Assistant Professor of Industrial and Operations Engineering

M. M. Srinivasan, Ph.D., Assistant Professor of Industrial and Operations Engineering

James A. Foulke, B.S.E. (E.E.), Lecturer in Industrial and Operations Engineering

300. Management of Technical Change. ***I and II.*** (3).
Implementation of technical change. The process and factors affecting technical change in operating systems. Resistance to change and methods of reducing resistance to change. The characteristics of blue and white collar forces. The effects of group formation; cohesiveness, management style, worker and management attitudes on the change process.

310. Introduction to Optimization Methods. ***Prerequisite: Math. 215. I and II.*** (3).
An introduction to deterministic models in operations research with special emphasis on linear programming; the simplex, transportation, and assignment algorithms and their engineering applications. Brief introduction to integer, dynamic, and other non-linear programming models.

315. Stochastic Industrial Processes. ***Prerequisite: preceded or accompanied by Math. 116. I and II.*** (3).
Elementary concepts in discrete and continuous time Markov chains, queueing and birth/death processes, the Poisson process and underlying elements of probability. Applications to replacement strategy, machine repair strategy, inventory, and other engineering problems.

333. Human Performance. I and II. (3).
Introduction to the functional processes of the human system that pertain to an understanding of the limitations of humans in man-machine systems. Psychology, physiology, ergonomics, and safety in the context of measuring and predicting human performance. Principles are applied through design problems.

334. Human Performance Laboratory. ***Prerequisite: preceded or accompanied by I.&O.E. 333. I and II.*** (1)
Principles of measurement and prediction of human performance in man-machine systems. Laboratory experiments investigating human capabilities of vision, hearing, information processing, memory, motor processes, strength, and endurance.

365. (Stat. 311). Engineering Statistics. ***Prerequisite: I.&O.E. 315 or Stat. 310, Math. 215, and Eng. 103. I and II.*** (4).
Analysis of engineering data associated with stochastic industrial processes. Topics include: fundamentals of distribution analyses; process model identification, estimation, testing of hypotheses, validation procedures, and evaluation of models by regression and correlation. Students are required to use the MTS computer system for problem solving.

373. Data Processing. ***Prerequisite: Eng. 103. I and II.*** (4).
Introduction to the systems organization and programming aspects of modern digital computers. Concepts of algorithms and data structure will be discussed with practical business applications.

416. Queueing Systems. ***Prerequisite: I.&O.E. 315.*** (3).
Introduction to queueing processes and their applications. The M/M/s and M/G/1 queues. Queue length, waiting time, busy period. Case studies in production, transportation, communication, and public service systems.

421. Work Organizations. ***Prerequisite: I.&O.E. 300 and senior standing. I.*** (3).
Applications of organizational theory to the design and management of work organizations is emphasized through case studies, group exercises, and written assignments. Topics include: attitudes and work performance, theories of motivation, groups in organizations, leadership styles, planning and control, technological innovation, and organizational change strategies.

424. Special Projects in Production and Service Systems. ***Prerequisite: senior standing and permission of instructor. I and II.*** (3).
Student teams will work with an organization on a design project with potential benefit to the organization and to the students.

432. Industrial Engineering Instrumentation Methods. ***Prerequisite: I.&O.E. 365. IIIa.*** (3).
The characteristics and use of analog and digital instrumentation applicable to industrial engineering problems. Statistical methods for developing system specifications. Applications in physiological, human performance, and production process measurements are considered.

433. (E.I.H. 556). Ergonomics. I. (3).
The concept of the human-machine system is used as a basis of study of worker safety, health, and performance. Topics including work measurement, anthropometry, biomechanics, work physiology, cumulative trauma, information presentation and processing problems, and control design are presented through lectures, laboratory demonstrations, and projects. Ergonomic problems related to design of jobs and consumer products discussed. Not open to students who have credit for I.&O.E. 333.

436. Human Factors in Computer Systems. ***Prerequisite: I.&O.E. 333 or permission of instructor. II.*** (3).
The design and evaluation of computer systems for ease of use. Topics to be covered include keyboards and how people type, vision and video display design, human body size and computer furniture, regulations concerning working conditions, software issues, methods for studying user performance, documentation, and information systems of the future.

439. Safety Management. ***Prerequisite: I.&O.E. 300 or graduate standing. I.*** (3).
Standards, government regulations, accident investigation, databases, and user/operator characteristics in relation to risk/safety management. How human errors relate to design/use of machines and products, and to accident causation. Accident reconstruction examples using cases from occupational, transportation, consumer, and recreational environments.

441. Production and Inventory Control. ***Prerequisite: I.&O.E. 310 and 365.*** (3).
Models and techniques for managing inventory systems and for planning production. Topics include basic deterministic and probabilistic inventory models and extensions; production loading, planning, and smoothing; and sequencing problems.

447. Facility Planning. ***Prerequisite: I.&O.E. 310, 315, and 373.*** (3).
Theory and methodology for determining optimal capacity and location of production and service facilities. Elementary engineering and economic considerations in the application of material handling equipment.

451. Engineering Economy. I. (3).
The logic of economic decision making common to engineering, industrial management, and personal finance is developed. Concepts of compound interest, capital growth, and equivalence are developed. Commonly used measures of worth are defined and compared. Decisions involving taxes, multiple alternatives, financing, replacement, and uncertainty are considered.

460. Decision Analysis. ***Prerequisite: I.&O.E. 310 and I.&O.E. 315, and senior standing. I.*** (3).
Theory and methods for the analysis of decisions under uncertainty. The use of expert judgment and value of information. The encoding of attitudes toward risk. Applications selected from capital investment, bidding, purchasing, inspection, inventory control, and other areas.

463. Work Measurement and Prediction. ***Prerequisite: I.&O.E. 333, I.&O.E. 334 and I.&O.E. 365. I.*** (3).
The analysis and prediction of human performance in industrial and service man-machine systems. The use of predetermined time systems, learning curves, operator selection procedures, work sampling, and motion economy principles in the design of the work place.

465. Design and Analysis of Industrial Experiments. ***Prerequisite: I.&O.E. 365. I.*** (3).
Methods of design and analysis of industrial experiments. Topics include: general regression and variance analysis, mixed models, efficient statistical search procedures, model assessment, and remedial measures.

466. (Stat. 466). Statistical Quality Control. ***Prerequisite: I.&O.E. 365. II.*** (3).
Design and analysis of procedures for forecasting and control of production processes. Topics include: attribute and variables sampling plans; sequential sampling plans; rectifying control procedures; charting, smoothing, forecasting, and prediction of discrete time series.

471. (Mech. Eng. 483). Computer Control of Manufacturing Systems. ***Prerequisite: Mech. Eng. 381; or I.&O.E. 373 and Mech. Eng. 252. II.*** (3).
Basic elements of numerical control of metal processing systems; programming languages for point to point and contouring machines; interaction between geometry and machinability decision. Laboratory experiments in optimizing part-programming and equipment utilization. Computerized numerical control, adaptive control, industrial robots, flexible manufacturing systems. Two one-hour lectures and two two-hour laboratories.

472. Operations Research. ***Prerequisite: preceded or accompanied by Stat. 310.*** (3).
Introduction to operations research; the methodology of mathematical modeling and its relation to problems in industrial, commercial, and public systems. The use of queueing theory, linear programming, inventory theory, simulation, decision analysis. Not open to industrial and operations engineering undergraduate students.

473. Information Processing Systems. ***Prerequisite: I.&O.E. 373.*** (3).
Organization of major types of information processing systems. Programming languages (COBOL, PL/1). Database management systems. Alternative system organizations. Techniques for evaluation of performance of systems.

474. Simulation. ***Prerequisite: I.&O.E. 315, 365 and 373.*** (3).
Digital simulation of complex discrete-event systems with applications in industrial and service organizations. Course topics include modeling and programming simulations in FORTRAN; use of a high-level simulation language as SIMSCRIPT, GPSS, SLAM, or SIMAN; input distribution specification; random number generators; generating random variables; statistical analysis of simulation output data.

478. (EECS 487). Interactive Computer Graphics. ***Prerequisite: I&OE 373 or EECS 380, and senior standing. I and II.*** (3).
Graphics devices and fundamentals of operation. Two- and three-dimensional transformations. Interactive graphical techniques and applications. Three-dimensional graphics, perspective transformation, hidden line elimination. Data structures and languages for graphics. Interactive graphical programming.

479. (IPPS 479). Operations Research for Public Policy. ***Prerequisite: Math. 413 and Pub. Pol. 529. I.*** (3).
The philosophy and use of quantitative methods of analyzing public sector problems. Decision analysis as a framework for choice under uncertainty. Simulation, mathematical programming, and probabilistic methods presented with case studies and examples from the literature. Not open to students with credit for I.&O.E. 472 or I.&O.E. 460.

481. Special Projects in Hospital Systems. ***Prerequisite: I.&O.E. 300. I and II.*** (3).
Projects in hospital systems. Projects will be offered from areas of industrial and operations engineering, including work measurement and control, systems and procedures, management, organization, and information systems. Lectures will deal with the hospital setting, and project methodologies. Faculty, administrative, and engineering personnel will be available during the term for project aid.

484. (EECS 484). Database Management Systems. ***Prerequisite: EECS 380 or 480; or I.&O.E. 473. I and II.*** (3).
Concepts and methods in the definition and management of large integrated databases for organizational information systems. Functions and objectives of existing file and data management systems will be considered and methods of analyzing proposals for new data management software will be studied. Additional topics will include database administration, database design, and data security problems.

490. Directed Study, Research, and Special Problems I. ***Prerequisite: permission of department.*** (3 maximum).
Individual or group study, design, or laboratory research in a field of interest to the student or group. Topics may be chosen from any area of industrial and operations engineering including management, work measurement, systems, and procedures. Pass/Fail only.

491. Special Topics in Industrial and Operations Engineering. ***(To be arranged).***
Selected topics of current interest in industrial and operations engineering.

494. (EECS 467). Robot Applications. ***Prerequisite: EECS 280 or 370 or I.&O.E. 373 or Mech. Eng. 340 and Mech. Eng. 240 or EECS 360 and senior standing. Not open to students with previous credit for EECS 567. II.*** (3).
Basic concepts in the organization and operation of microcomputer-controlled manipulators. Experiments include kinematics, manipulation, dynamics, trajectory planning and programming language for robots. Applications of computer-controlled robots in manufacturing and programmable automation.

499. Senior Design Projects. ***Prerequisite: Senior standing and permission of instructor. I and II.*** (3).
Selected design projects in industrial and operations engineering to be conducted for clients.

503. (EECS 509). Social Decision Making. ***Prerequisite: Stat. 310 or I.&O.E. 315 or EECS 401 or EECS 501.*** (3).
Elementary decision analysis, examples in public sector; basic problems in social decision making; social values and preferences; multiattribute utility functions, subjectivity measurement; Pareto optimality. Arrow's impossibility theorem; group decision analysis, two-person game theory; social decision processes, strategy of conflicts.

510. (Math. 561) (S.&M.S. 518). Linear Programming I. ***Prerequisite: Math. 417.*** (3).
Formulation of problems from the private and public sectors using the mathematical model of linear programming. Development of the simplex algorithm; duality theory and economic interpretations. Postoptimality (sensitivity) analysis; applications and interpretations. Introduction to transportation and assignment problems; special purpose algorithms and advance computational techniques. Students have opportunities to formulate and solve models developed from more complex case studies and to use various computer programs.

511. (EECS 505) (Math. 562) (Aero. Eng. 577). Continuous Optimization Methods. ***Prerequisite: Math. 417 or Math. 419. I and II.*** (3).
Survey of continuous optimization problems. Unconstrained optimization problems; unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.

512. Dynamic Programming. ***Prerequisite: EECS 503 or I.&O.E. 515.*** (3).
The techniques of recursive optimization and their use in solving multistage decision problems, applications to various types of problems. Algorithms for solving Markovian programming problems and their applications.

515. Stochastic Industrial Processes. ***Prerequisite: I.&O.E. 315 or Stat. 310.*** (3).
Introduction to basic stochastic processes encountered in operations research and industrial applications. Independent processes. Discrete-state Markov models. Renewal processes. Elementary queueing systems. Numerical solution techniques.

522. Theories of Administration. ***Prerequisite: I.&O.E. 421. II.*** (3).
Provide insight into leading theories concerning the administration of research and industrial organizations. Treat the concepts needed for describing, assessing, and diagnosing organizations; processes of organizational communication, motivation, and conflict management; adaptation of organization systems to the requirements of work and information technologies.

533. Human Factors in Engineering Systems I. ***Prerequisite: I.&O.E. 365 and 333/433 (EIH 556). I.*** (3).
Principles of engineering psychology applied to engineering and industrial production systems. Visual task measurement and design, psychophysical measurements, signal detection theory and applications to industrial process control. Human information processing, mental workload evaluation, human memory and motor control processes.

534. Occupational Biomechanics. ***Prerequisite: I.&O.E. 333 and 334, or I.&O.E. 433/E.I.H. 556. II.*** (3).
Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain (1) muscle strength performance, (2) cumulative and acute musculoskeletal injury, (3) physical fatigue, and (4) human motion control.

539. Occupational Safety Engineering. ***Prerequisite: I.&O.E. 365 or Biostat. 500. II.*** (3).
Design/modification of machinery/products to eliminate or control hazards arising out of mechanical, electrical, thermal, chemical, and motion energy sources. Application of retrospective and prospective hazard analysis, systems safety, expert systems and accident reconstruction methodologies. Case examples: industrial machinery and trucks, construction and agriculture equipment, automated manufacturing systems/processes.

541. Inventory Analysis and Control. ***Prerequisite: I.&O.E. 441 or permission of instructor. II.*** (3).
Review of basic inventory models. Models and solution techniques in various problems related to multi-stage production and distribution systems. Topics include: assembly systems, material requirements planning, hierarchical production planning, flexible manufacturing systems, distribution systems. Readings will include classic works and recent papers on techniques and applications.

543. Theory of Scheduling. ***Prerequisite: I.&O.E. 315 or 515, and I.&O.E. 310. I.*** (3).
The problem of scheduling several tasks over time, including the topics of measures of performance, single-machine sequencing, flow shop scheduling, the job shop problem, and priority dispatching. Integer programming, dynamic programming, and heuristic approaches to various problems are presented.

547. Plant Flow Analysis. ***Prerequisite: I.&O.E. 515 and I.&O.E. 510. II.*** (3).
The development and application of mathematical models for the analysis of problems arising in the location and allocation of capacity to facilities and transportation systems with non-linear cost functions.

551. Capital Budgeting. ***Prerequisite: I.&O.E. 365 and 451. I.*** (3).
The role and logic of capital budgeting decisions in engineering management is developed. Decisions involving capital rationing, incomplete information, replacement, and a probabilistic treatment of uncertainty are studied in depth. The relative effectiveness of commonly used capital budgeting decision procedures on the growth of the firm is examined.

560. (Stat. 550) (Stat. & Mgt. Sci. 603). Bayesian Decision Analysis. ***Prerequisite: Stat. 425.*** (3).
Axiomatic foundations for personal probability and utility; interpretation and assessment of personal probability and utility; formulation of Bayesian decision problems; risk functions, admissibility; likelihood principle and properties of likelihood functions; natural conjugate prior distributions; improper and finitely additive prior distributions; examples of posterior distributions, including the general regression model and contingency tables; Bayesian credible intervals and hypothesis tests; applications to a variety of decision-making situations.

563. Labor and Legal Issues in Industrial Engineering. ***Prerequisite: I.&O.E. 463 or I.&O.E. 433.*** (3).
A case study approach to engineering related issues in union-management relations, professional and product liability, and worker rights legislation.

564. (Mech. Eng. 564). Computer Aided Design Methods. ***Prerequisite: Mech. Eng. 464 or Appl. Mech. 460 or I.&O.E. 373.*** (3).
Generalized mathematical modeling of engineering systems, methods of solution and simulation languages. Analysis methods in design; load, deformation, stress and finite element considerations; non-linear programming. Computational geometry; definition and generation of curves and surfaces. Computer graphics; transformations; clipping and windowing; graphics systems; data structures; command languages; display processors.

565. Forecasting and Time Series Analysis. ***Prerequisite: I.&O.E. 465. II.*** (3).
Forecasting and prediction of time series including regression, moving averages, exponential smoothing, direct smoothing, adaptive control procedures, Bayesian methods, and Box/Jenkins models with applications to production, inventory, and quality control.

567. Advanced Work Measurement and Design. ***Prerequisite: I.&O.E. 433 or I.&O.E. 463. II*** (3).
Non-traditional approaches to job evaluation are applied to a variety of manufacturing and service jobs. Topics include: computer-aided job analyses and design, ergonomic work measurement, evaluation of "white collar" productivity, and high level predetermined time systems. Case studies are used extensively to develop observational, analytical, and design skills.

573. Analysis, Design, and Management of Large-Scale Administrative Information Processing Systems. ***Prerequisite: I.&O.E. 473. I.*** (3).
Introduction to informal and formal techniques or analysis, design, and management of large scale information processing systems in administrative environments; presentation of techniques to control and aid in the process by which computer systems are developed with major emphasis on the collection and analysis of user requirements.

574. Simulation Analysis. ***Prerequisite: I.&O.E. 474. II.*** (3).
Underlying probabilistic aspects of simulation and statistical methodology of designing simulation experiments and output interpretation. Random number generators, variate and process generation, output analysis, regenerative method, variance reduction techniques, multiple comparisons, ranking and selection problems as applied to simulation.

575. Information Processing System Engineering. ***Prerequisite: I.&O.E. 473. II.*** (3).
Software design methodologies for development of large-scale information processing systems. Application of database management systems, distributed processing, microprocessors and communication networks. Design and use of computer-aided software development systems. Software engineering and project management. Ergonomics aspects of information systems. Emphasis is placed on practical experience in software design projects.

578. (EECS 588). Geometric Modeling. ***Prerequisite: EECS 487 or 488. II.*** (3).
Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces, and bodies. Algorithms for set operations, Euler operations and deformations. Design and experimentation with geometric modeling facilities.

579. Performance Modeling and Evaluation of Large Systems. ***Prerequisite: I.&O.E. 416 or EECS 501. II.*** (3).
Introduction to queueing models, isolated queues, open and closed networks of queues, concept of local balance, algorithms for analysis of closed networks, model calibration and workload characterization simulation of models, applications in computer networks: routing and flow control, cyclic service models for token ring networks; models of flexible manufacturing systems.

581. Hospital Systems Engineering. ***Prerequisite: I.&O.E. 365 or Hosp. Admin. 654. I.*** (3).
Systems methodologies to aid in the more efficient and effective operation of the major administrative systems in hospitals. Inpatient admissions scheduling, operating room scheduling, patient classification, nurse staffing, departmental productivity, patient flow processes, facility planning; including bed and ancillary facilities, and length of stay determinants.

590. Directed Study, Research, and Special Problems II. ***Prerequisite: permission of instructor. (3 maximum).***
Continuation of I.&O.E. 490.

591. Special Topics. ***Prerequisite: permission of instructor. (To be arranged).***
Selected topics of current interest in industrial and operations engineering.

610. (Math. 660). Linear Programming II. ***Prerequisite: I.&O.E. 510.*** (3).
Primal-dual algorithm. Resolution of degeneracy, upper bounding. Variants of simplex method. Geometry of the simplex method, application of adjacent vertex methods in non-linear programs, fractional linear programming. Decomposition principle, generalized linear programs. Linear programming under uncertainty. Ranking algorithms, fixed charge problem. Integer programming. Combinatorial problems.

611. (Math. 663). ***Non-linear Programming. Prerequisite: I.&O.E. 510.*** (3).
Modeling, theorems of alternatives, convex sets, convex and generalized convex functions, convex inequality systems, necessary and sufficient optimality conditions, duality theory, algorithms for quadratic programming, linear complementary problems, and fixed point computing. Methods of direct search, Newton and Quasi-Newton, gradient projection, feasible direction, reduced gradient; solution methods for non-linear equations.

612. Network Flows. ***Prerequisite: I.&O.E. 510.*** (3).
Flow problems on networks. Maximum flow minimum cut theorem. Labelling algorithms. Circulation and feasibility theorems. Sensitivity analysis. Incidence matrices. Shortest routes. Minimum cost flows, out-of-kilter algorithm. Critical path networks, project cost curves. Multicommodity flow problem, biflows. Matching problems in graph theory.

614. Integer Programming. ***Prerequisite: I.&O.E. 510.*** (3).
Modeling with integer variables, total unimodularity, cutting plane approaches, branch-and-bound methods, Lagrangean relaxation, Bender's decomposition, the knapsack, and other special problems.

616. Queueing Theory. ***Prerequisite: I.&O.E. 515. II.*** (3).
Methods and analytical techniques of queueing theory. Markovian queues: finite queue size, finite population, bulk arrivals and departures, Jackson networks. The M/G/I and GI/M/s queues. Pre-emptive and non-preemptive priority systems.

633. Man-Machine Systems. ***Prerequisite: I.&O.E. 533 or equivalent. II.*** (3).
Introduction to advanced concepts in the identification, design, analysis, development, and implementation of human operated systems; existing and emerging systems identified from industrial and service organizations. Students handle case examples. Relevant theories of communication, decision, and control augmented by readings and laboratory demonstrations where appropriate.

635. (Bioeng. 635). Laboratory in Biomechanics and Physiology of Work. ***Prerequisite: I.&O.E. (Bioeng.) 534. II.*** (2).
This laboratory is offered in conjunction with the Biomechanics and Physiology of Work course to allow students to experimentally determine (1) musculoskeletal reactions to volitional acts, (2) how EMG is used in muscle actions and fatigue evaluation, and (3) how the cardiopulmonary systems respond to various work stressors.

639. Research Topics in Safety Engineering. ***Prerequisite: I.&O.E. 439 or I.&O.E. 539 or permission of instructor. II.*** (3).
Selected topics studied in depth necessary to critique existing and to propose future research. Topics from accident model; safety performance measurement; accident prevention philosophies; hazard analysis and systems safety techniques; expert systems; warnings and instructions; machine, tool, and consumer product safety; slips/falls/climbing; vehicle operator visibility; robotics/automated systems.

640. Concepts in Mathematical Modeling of Large Scale Systems. ***Prerequisite: I.&O.E. 310 and 365 and 515. II.*** (3).
Application or engineering, operations research, and economic concepts to the operational analysis and planning for large-scale systems. Practice in mathematical modeling and critical evaluation of various aspects of existing and proposed models of systems in the public and private sector.

641. Seminar in Production Systems. ***Prerequisite: I.&O.E. 541 or permission of instructor. I.*** (3).
Analysis and discussion of classic and state-of-the-art research papers on production and service systems. Research issues and research methodology will be emphasized.

645. Reliability, Replacement, and Maintenance. ***Prerequisite: I.&O.E. 515. II.*** (3).
Analytic stochastic models for the failure of components and systems. Analysis of policies for optimal reliability, including strategies for surveillance, inspection, maintenance, repair, and replacement.

690. Graduate Study in Selected Problems I. ***Prerequisite: permission of graduate committee. (To be arranged).***

691. Special Topics. ***Prerequisite: permission of instructor. (To be arranged).***
Selected topics of current interest in industrial and operations engineering.

712. Infinite Horizon Optimization. ***Prerequisite: I.&O.E. 510 or 512. II.*** (3).
A seminar on optimization problems with an infinite time horizon. Topics include topological properties, optimality definitions, decision/forecast horizons, regenerative models, and stopping rules. Applications discussed include capacity expansion, equipment replacement, and production/inventory.

790. Graduate Study in Selected Problems II. ***Prerequisite: permission of graduate committee. (To be arranged).***

800. First Year Doctoral Seminar. ***Prerequisite: permission of instructor. I.*** (1).
Presentation by I.&O.E. faculty members of current and future research activities within the department. Discussion of procedural, philosophical, and professional aspects of doctoral studies in industrial and operations engineering.

801. Directed Research. ***Prerequisite: I.&O.E. 800.*** (1-3).
Directed research on a topic of mutual interest to the student and the instructor. This course complements I.&O.E. 800, First Year Doctoral Seminar.

810. (Math. 861). Seminar in Mathematical Programming. ***Prerequisite: permission of instructor.*** (1 or 2).

815. Seminar in Stochastic Service Systems. ***Prerequisite: permission of instructor.*** (1-3).
A working seminar for researchers in stochastic service systems.

836. Seminar in Human Performance. ***Prerequisite: graduate standing.*** (1-2).
Case studies of research techniques used in the human performance and safety fields. Speakers actively engaged in research will discuss their methods and results.

837. Seminar in Occupational Health and Safety Engineering. ***Prerequisite: graduate standing.*** (1-2).
This seminar provides an opportunity for graduate students interested in occupational health and safety engineering problems to become acquainted with various related contemporary research and professional activities, as presented by both staff and guest speakers.

843. Seminar in Operations Research. (1 or 2).
Study of recent developments and ongoing research in OR methodology, operational science and OR practice.

873. Seminar in Administrative Information Processing Systems. ***Prerequisite: I.&O.E. 575.*** (1-3).
Recent developments, case studies, and individual or group development projects in administrative information processing systems.

878. Seminar in Computer Graphics. ***Prerequisite: I.&O.E. 578.*** (1-3).
Selected lectures and readings on recent developments in computer graphics.

881. Research Seminar in Hospital and Medical Systems. ***Prerequisite: I.&O.E. 581 or graduate standing. (To be arranged).***
The use of quantitative techniques in hospital and medical care research. Discussion and review of current research and related methodological techniques in this area of interest. Outside speakers will present selected research topics. Readings, survey, and development of research projects. May be elected more than once.

906. Master's Thesis Project. ***Prerequisite: permission of department. (6 maximum total—may be spread over several terms).***

916. Professional Thesis Project. ***Prerequisite: permission of department. (To be arranged).***

990. Dissertation/Pre-Candidate. ***Prerequisite: permission of department. I, II, and III. (2-8); IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status of Candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III.*** (8).; ***IIIa and IIIb*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Materials Science and Engineering

Department Office:
3062 Dow Building
phone (313) 763-4970
See Page 60 for statement on Course Equivalence.

Faculty

Ronald Gibala, Ph.D., Professor of Materials Science and Engineering and Chairman of the Department of Materials Science and Engineering

Wilbur Charles Bigelow, Ph.D., Professor of Materials Science and Engineering

Frank E. Filisko, Ph.D., P.E., Professor of Materials Science and Engineering

Amit K. Ghosh, Ph.D., Professor of Materials Science and Engineering

William F. Hosford, Jr., Sc.D., Professor of Materials Science and Engineering

Edward Ernest Hucke, Sc.D., Professor of Materials Science and Engineering

Robert Donald Pehlke, Sc.D., P.E., Professor of Materials Science and Engineering and Chemical Engineering

Richard E. Robertson, Ph.D., Professor of Materials Science and Engineering

Tseng-Ying Tien, Ph.D., Professor of Materials Science and Engineering

Albert F. Yee, Professor of Materials Science and Engineering

Edwin Harold Young, M.S.E., P.E., Professor of Chemical Engineering and Materials Science and Engineering

Richard A. Flinn, Sc.D., Professor Emeritus of Materials Science and Engineering

William Cairns Leslie, Ph.D., Professor Emeritus of Materials Science and Engineering

Lawrence H. Van Vlack, Ph.D., P.E., Professor Emeritus of Materials Science and Engineering

I-Wei Chen, Ph.D., Associate Professor of Materials Science and Engineering

J. Wayne Jones, Ph.D., Associate Professor of Materials Science and Engineering

David J. Srolovitz, Ph.D., Associate Professor of Materials Science and Engineering and Applied Physics

David C. Van Aken, Ph.D., P.E., Assistant Professor of Materials Science and Engineering

Gary S. Was, Ph.D., Associate Professor of Nuclear Engineering and Materials Science and Engineering

Walter Bertram Pierce, Assistant Professor Emeritus of Foundry Practice

150. (Eng. 150). Introduction to Engineering Materials. ***Prerequisite: Chem 123 or 124. II.*** (4).
A course in engineering materials with sequential emphasis on metals, plastics, and ceramics. Structure, properties, and processing aspects are considered. Open only to freshmen; satisfies any program requirement for Mat. Sci. & Eng. 250.

230. (Chem. Eng. 230). Thermodynamics I. ***Prerequisite: Eng. 103, Chem 126, Math. 116. I.*** (4).
An introduction to applications of the first law of thermodynamics. Steady and unsteady state material and energy balances, the equilibrium concept. Properties of fluids. Engineering systems.

250. Principles of Engineering Materials. ***Prerequisite: Chem. 123 or 124; preceded or accompanied by Physics 240.*** (3).
An introductory course in the science of engineering materials. The engineering properties (mechanical, thermal, and electrical) of metals, polymers, and ceramics are correlated with: (1) their internal structures (atomic, molecular, crystalline, micro-, and macro-) and (2) service conditions (mechanical, thermal, chemical, electrical, magnetic, and radiative). Two lectures and two recitations.

351. Structure and Properties of Materials. ***Prerequisite: Mat. Sci. & Eng. 250 I.*** (4).
The basic materials operations such as solidification, sintering, deformation, and heat treating are studied, with emphasis on laboratory methods used for analyzing the accompanying structure and property changes.

371. Engineering Materials Systems. ***Prerequisite: Mat. Sci.. & Eng. 351. II.*** (4).
Structure, properties and processing of commercial materials. The selection of materials for engineering applications. Lecture, recitation, and laboratory.

410. (Bioeng. 410). Biomedical Materials. ***Prerequisite: Mat. Sci. & Eng. 250 or permission.*** (2).
Interactions of materials implanted in the body. Histological and hematological considerations including general foreign body reactions, inflammation and reparation, carcinogenicity, thrombosis, hemolysis, protein and cellular issues, immunogenic and toxic properties. Basic discussion of implants vs. transplants and relevant biological components. Tours of relevant university facilities.

423. Deformation Behavior of Materials. ***Prerequisite: Mat. Sci. & Eng. 250 and Mech. Eng. 211.*** (3).
Elastic, anelastic, plastic, and fracture behavior of crystalline and amorphous materials. Dislocations, slip twinning, strengthening mechanisms, and fracture. Composite materials and plastic forming.

430. Thermodynamics of Condensed Phases. ***Prerequisite: Chem. 365.*** (4).
Application of basic thermodynamic principles to problems involving solid and liquid solutions, phase transformations, heterogeneous equilibria, interfacial phenomena, defects in solids, non-stoichiometric phases and related topics involving solid and liquid phases.

450. Physical Ceramics I. ***Prerequisite: Mat. Sci. & Eng. 351.*** (4).
The nature, properties, processing, and application of ceramic materials.

451. (Chem. Eng. 451). Introduction to Polymers. ***Prerequisite: junior standing in engineering or science.*** (4).
Preparation, properties, and utilization of polymeric materials. Lectures, recitation, and laboratory.

452. (Chem. Eng. 452) (Macr. Sci. 452). Applied Polymer Processing. (3).
Theory and practice of polymer melt processing. Non-Newtonian flow; extrusion, injection and molding operations; fiber, film and rubber processing; kinetics of solidification; mechanical orientation; product characterization; structure-property relations.

456. Ceramics Processing and Characterization. ***Prerequisite: Mat. Sci. & Eng. 351 or 450 or 472. I.*** (2).
Principles and practices of fabricating ceramics and measuring their properties.

457. (Chem. Eng. 457). Fundamentals of Polymeric Materials. ***Prerequisite: Mat. Sci. & Eng. 250. I.*** (3).
Basic preparation, characterization, identification of bulk polymers and polymer molecules including the amorphous, glassy, and crystalline states; basics of forming and processing techniques, engineering and design properties including tensile behavior, creep and stress relaxation, fracture, fatigue.

472. X-ray Studies of Engineering Materials. ***Prerequisite: Mat. Sci. & Eng. 250.*** (3).
Generation and properties of X-rays. Radiographic methods. Crystal geometry, stereographic projections. The diffraction of X-rays by crystals. Basic diffraction methods and their use in determining crystal size, shape, perfection and orientation. Identification of crystalline phases, measurement of lattice parameters and internal stress. Survey of crystal structure determination and chemical analysis by fluorescence and absorption spectroscopy. Lectures, recitation, and laboratory.

475. Fundamentals of Metal Casting. ***Prerequisite: Mat. Sci. & Eng. 351 or Mech. Eng. 251.*** (3).
Application of chemistry and physics to the liquid state and solidification of castings. Quantitative application of thermodynamics, heat transfer, and fluid mechanics to the design problems associated with the casting process. Experimental work on solidification rates, fluidity of liquid metal, physics of mold design, slag-metal-gas equilibria and an individually selected short research problem.

480. Materials Science and Engineering Design. ***Prerequisite: senior standing. I.*** (3).
Design concepts, engineering economics, problems of scaling, materials substitution, competitive processes, case histories, and professional considerations. Written and oral presentations of solutions to design problems.

485. Design Problems in Materials Science and Engineering. ***Prerequisite: Mat. Sci. & Eng. 480. I and II. (To be arranged: 4 credit hours maximum).***
Design problem supervised by a faculty member. Individual or group work in a particular field of materials or metallurgy of particular interest to the student. The design problem is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required.

489. Materials Process Design. ***Prerequisite: preceded or accompanied by Chem. Eng. 341.*** (4).
Unit process treatment of extractive metallurgical operations. Applications of principles involved in the extraction of metals from ores and scrap, the production of alloys, and their commercial shapes or forms.

490. Research Problems in Materials Science and Engineering. ***I, II, IIIa, IIIb, and III. (To be arranged).***
Individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required. Not open to graduate students. Laboratory and conferences.

493. Special Topics in Materials Processing and Application. ***Prerequisite: Mat. Sci. & Eng. 351. (To be arranged).***
Selected topics of current interest for students entering industry.

511. (Chem. Eng. 511). Rheology of Polymeric Materials. ***Prerequisite: a course in fluid mechanics or permission from instructor.*** (3).
An introduction to the relationships between the chemical structure of polymer chains and the rheological behavior. The course will make frequent reference to synthesis, processing, characterization, and use of polymers for high technology applications.

512. (Chem. Eng. 512). Physical Polymers. ***Prerequisite: senior or graduate standing in engineering or physical science.*** (3).
Structure and properties of polymers as related to their composition, annealing, and mechanical treatments. Topics include creep, stress relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation, and morphology.

514. Composite Materials. ***Prerequisite: MSE 351.*** (3).
Behavior, processing, and design of composite materials, especially fiber composites. Emphasis is on the chemical and physical processes currently employed and expected to guide the future development of the technology.

515. Mechanical Behavior of Solid Polymeric Materials. ***Prerequisite: Mat. Sci. & Eng. 457, Mech. Eng. 210 and 211, or permission of instructor. II.*** (3).
The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, crazing, fatigue, and fracture mechanics. The materials include toughened plastics, polymer alloys and blends, and composite materials. Structural design with plastics is also considered.

520. Physical Metallurgy II and Physical Ceramics II. ***Prerequisite: Mat. Sci. & Eng. 351.*** (3).
Diffusion, ternary phase diagrams and quantitative metallography.

523. (Mech. Eng. 552). Metal-Forming Plasticity. (3).
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of work hardening and friction, temperature, strain rate, and anisotropy.

525. Dislocations and Plastic Flow of Materials. ***Prerequisite: Mat. Sci. & Eng. 423 or graduate standing in engineering or physical science. II.*** (3).
Fundamentals of dislocation theory. Applications to the understanding of physical and mechanical behavior of materials. Dislocation bases for materials design.

532. Thermodynamics of Systems with Solids. ***Prerequisite: Mat. Sci. & Eng. 430.*** (3).
Application of the laws of thermodynamics to metals and other inorganic material systems.

550. Fundamentals of Materials Science and Engineering. ***Prerequisite: senior or graduate standing. II.*** (3).
An advanced level introductory lecture/discussion course on fundamental principles underlying the structure-properties-processing-service relationships for metals, ceramics and polymers. Not open to students with an undergraduate degree in materials-related curricula.

551. Structure and Processing of Electrical Materials. ***Prerequisite: Mat. Sci. & Eng. 450 or EECS 314.*** (2).
The role of chemistry, structure, and processing on electrical materials.

552. Reactions in Ceramic Processes. ***Prerequisite: Mat. Sci. & Eng. 450, or graduate standing in engineering or physical science.*** (3).
Dissociation, sintering, vitrification, devitrification, and thermochemical reactions in ceramic processing.

553. Structures of Ceramic Compounds. ***Prerequisite: Mat. Sci. & Eng. 450, or graduate standing in engineering or physical science.*** (3).
Structure and crystal chemistry of ceramic compounds.

554. Properties of Ceramic Compounds. ***Prerequisite: Mat. Sci. & Eng. 450 or graduate standing in engineering or physical science.*** (3).
Consideration of mechanical, thermal, dielectric, ferroelectric, magnetic, and semiconducting properties of ceramic compounds.

562. Electron Microscopy I. ***Prerequisite: Mat. Sci. & Eng. 472. I.*** (4).
An introduction to electron optics, vacuum techniques and the operation of electron optical instruments. The theory and applications of transmission and scanning electron microscopy and electron microprobe analysis in the study of nonbiological materials.

571. Physical Metallurgy of Steels. ***Prerequisite: Mat. Sci. & Eng. 371.*** (3).
Properties of iron and other bcc metals. Relations between microstructure and mechanical or physical properties of steel products, with emphasis on products of greatest economic importance, including sheet carbon, high-strength low-alloy, alloy, and stainless steels.

573. (Chem. Eng. 573). Corrosion Engineering. ***Prerequisite: course in Materials Engineering.*** (3).
Fundamentals involved in choosing materials in corroding media, corrosion control methods, and corrosion-failure analysis.

574. High Temperature Materials. ***Prerequisite: Mat. Sci. & Eng. 371.*** (3).
Principles of behavior of materials at high temperatures. Microstructure-property relationships including phase stability and corrosion resistance to high temperature materials. Fracture and fatigue at elevated temperatures. Damage accumulation behavior and engineering applications of service life techniques.

577. Failure Analysis of Materials. ***Prerequisite: Mat. Sci. & Eng. 371. II.*** (3).
Analysis of failed structures due to tensile overload, creep, fatigue, stress corrosion, wear and abrasion, with extensive use of scanning electron microscope. Identification and role of processing defects in failure.

580. Materials Science and Engineering Design. ***Not open to students who have taken Mat. Sci. & Eng. 480. I.*** (4).
Design of materials processing systems. Selection and utilization of materials in engineering applications, economic aspects of design, estimating procedures.

581. Cast Metals in Engineering Design. ***Prerequisite: Mat. Sci. & Eng. 371. II.*** (3).
The correlation of metallic structure and properties in the important casting alloys. Variation in casting problems such as gas porosity, solidification shrinkage, residual stresses with alloy system. New alloy development and individual investigation of service failures in automotive, aircraft, railroad, machine tool, and other fields.

583. Applied Chemical Metallurgy. ***Prerequisite: Mat. Sci. & Eng. 450 or Mat. Sci. Eng. 489.*** (3).
Equilibria and kinetics of reactions involving metal, slag, refractory, inclusion, and gas phases. Application to melting, refining, and related industrial processes.

585. Materials or Metallurgical Design Problem. ***Prerequisite: Mat. Sci. & Eng. 480 or to be taken concurrently with Mat. Sci. & Eng. 580. I.*** (2).
Engineering design and economic evaluation of a specific process and/or materials application. Original and individual work and excellence of reporting emphasized. Written and oral presentation of design required.

590. Materials Science and Engineering Research Survey. (2).
Research activities and opportunities in the Materials Science and Engineering programs. Lecture by faculty and guest lecturers. Topics are drawn from current research interest of the faculty. Brief weekly reports.

620. Phase Transformations in Solids. ***Prerequisite: graduate standing.*** (3).
Mechanisms of phase transformation by nucleation and growth, precipitation, massive, cellular, pearlitic, bainitic, martensitic, spinodal, and ordering reactions.

662. Electron Microscopy II. ***Prerequisite: Mat. Sci. & Eng. 562.*** (3).
Advanced methods in electron microscopy such as: high resolution bright field and dark field imaging, micro and convergent beam diffraction, analysis of thin film specimens, and electron energy loss spectroscopy. Two lectures and one three-hour laboratory-discussion session per week.

690. Research Problems in Materials Science and Engineering. ***I, II, and III. (To be arranged).***
Laboratory and conferences. Individual or group work in a particular field or on a problem of special interest to the students. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of materials and metallurgy may be selected. The student writes a final report on this project.

693. Special Topics in Materials Science and Engineering. ***(To be arranged)***

751. (Chem. Eng. 751) (Chem. 751) (Macr. Sci. 751) (Physics 751). Special Topics in Macromolecular Science. ***Prerequisite: permission of instructor.*** (2).
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor.

890. Seminar in Materials Science and Engineering. ***(To be arranged).***
Selected seminar topics in physical metallurgy, mechanical metallurgy, chemical metallurgy, physical ceramics, process ceramics, physical polymers, polymerization reactions, or electronic materials.

990. Dissertation/Pre-Candidate. ***I, II and III.*** (2-8); ***IIa and IIb*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as Candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral Candidate. I. II, and III.*** (8); ***IIIa and IIIb*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a Candidate. The defense of the dissertation that is, the final oral examination, must be held under a full term candidacy enrollment.

Mathematics*

Department Offices:
3217 Angell Hall
phone (313) 764-0337
and 347 West Engineering
phone (313) 764-6485

*College of Literature, Science, and the Arts. Other courses in mathematics are listed in the Bulletins of that College and of the Horace H. Rackham School of Graduate Studies.

Professor D.J. Lewis, Chairman; Professors Blass, Brown, Burns, Dickson, Dolgachev, Duren, Federbush, Gehring (T.H. Hildebrandt Distinguished University Professor), Griess, Higman, Hinman, Hochster (R.L. Wilder Professor), Kister, Krause, Lewis, Masser, McLaughlin, Milne, Montgomery, Pearcy, Ramanujan, Rauch, Raymond, Scott, Shields, Smoller, Storer, Taylor, Titus, Ullman, Wasserman, Winter, Woodroofe; Associate Professors Barrett, Clozel, Goldberg, Hanlon, Harer, Hoppe, D. Jones, Lee, Rosen, Schwartz, Shih, Simon, Weinstein; Assistant Professors Borgers, Coombes, Dunbar, Golitzin, Harabetian, Krasny, Lim, Lott, Mclarnan, Moss, Pego, Ryba, Sundaram; Hildebrandt Research Assistant Professors; Bloch, Grant, Keating, Maginnis, Murnaghan, Ringseth, Teitelbaum; Lecturers Plochinski, Shure; Professors Emeriti Bartels, Brumfiel, Cesari (R. L. Wilder Professor), Dolph, Ellis, Fischer, Harary, Hay, Heins, P.S. Jones, Kaplan, Kincaid, Lyndon, Nesbitt, Piranian, Reade, Rothe, and Wendel.

105. Algebra and Analytic Trigonometry. ***Prerequisite: one to one and one-half units of geometry, and one to one and one-half units of algebra. I and II.*** (4).
Number systems; factoring; fractions; exponents and radicals; systems of equations; linear, quadratic, trigonometric, exponential, and logarithmic functions, their graphs and properties; triangle solutions; curve sketching. *(No credit for engineering students).*

106. Algebra and Analytic Trigonometry. ***Prerequisite: one to one and one-half units of algebra and one to one and one-half units of geometry. I and II.*** (4).
Course content is identical with Math. 105. There are no lectures—students are assigned to a tutor in the Math Lab for individualized instruction.

107. Trigonometry. ***Prerequisite: one and one-half to two units of algebra, and one to one and one-half units of geometry. I and II.*** (2).
Numbers and coordinate systems; trigonometric functions and their graphs; inverse functions; applications. *(No credit for engineering students).*

108. Trigonometry. ***Prerequisite: one and one-half to two units of algebra, and one to one and one-half units of geometry. I and II.*** (2).
Course content is identical with Math. 107. There are no lectures—students are assigned to a tutor in the Math Lab for individualized instruction.

109. Pre-calculus. ***Prerequisite: two years of high school algebra. I and II.*** (2); ***no credit for students who already have 4 credits for pre-calculus mathematic courses).***
Linear, quadratic, and absolute value equations and inequalities. Algebra of functions; trig identities. Functions and graphs: trig and inverse trig, exponential and logarithmic, polynomial and rational. Analytic geometry of lines and conic sections.

110. Pre-calculus. ***(Self-paced). See Math 109.***

115. Analytic Geometry and Calculus I. ***Prerequisite: one and one-half to two units of high school algebra, one to one and one-half units of geometry, one-half unit of trigonometry. (Math. 107 may be taken concurrently). I, II, IIIa, and IIIb.*** (4).
Functions and graphs; derivatives, differentiation of algebraic functions, applications; definite and indefinite integrals, applications to polynomial functions.

116. Analytic Geometry and Calculus II. ***Prerequisite: Math. 115. I, II, IIIa, and IIIb.*** (4); ***students with credit for Math. 117 only receive 3 credits for Math. 116).***
Review of transcendental functions; techniques of integration; conic sections; infinite sequences and series; power series.

185, 186. Analytic Geometry and Calculus I and II. ***Prerequisite: permission of the Honors counselor. 185, I; 186, I and II.*** (4 each).
For students well-qualified in mathematics. Material covered in the sequence Math. 185, 186, 285 is approximately that included in Math. 115, 116, and 215.

195, 196. Honors Mathematics. ***Prerequisite: permission of the Honors counselor. 195, I; 196, II.*** (4 each).
For students with an outstanding high school record in mathematics who wish to develop their creative talents. The principal subject is analysis on the real line, with emphasis on questions of continuity, integrability, and differentiability, and on convergence of sequences and series. Other typical material; the Cauchy-Schwartz inequality and its applications to n-dimensional geometry and to function theory; Fourier series, quadric surfaces; selected number-theoretic problems. The sequence Math. 195, 196, 295, 296, 495, 496 includes the material of Math. 115, 116, 215, 216, 404, 451, 551, 513. The aim is not acceleration, but deep penetration and generous enrichment.

215. Analytic Geometry and Calculus III. ***Prerequisite: Math. 116. I, II, IIIa and IIIb.*** (4).
Vector algebra and calculus; solid analytic geometry; partial differentiation; multiple integrals; applications; vectors in R^n and matrices; solutions of systems of linear equations by Gaussian elimination determinants.

216. Introduction to Differential Equations. ***Prerequisite: Math. 215. I, II, IIIa, and IIIb.*** (4); ***students with credit for Math. 117 only receive 3 credits for Math 216).***
First order differential equations; linear differential equations with constant coefficients; vector spaces, differential operators, and linear transformations; systems of linear differential equations; power series solutions, applications.

217. Linear Algebra. ***Prerequisite: Math. 215. I and II.*** (4).
Algebra of matrices. Real vector spaces. Linear transformations. Determinants. Invariants and canonical forms. Elementary theory of similarity. Math 217 will be an alternative to Math. 216 as a prerequisite for mathematics concentration.

285. Analytic Geometry and Calculus III. ***Prerequisite: Math. 186. I and II.*** (4).
Continuation of the sequence Math. 185, 186.

286. Differential Equations. ***Prerequisite: Math. 285. I and II.*** (3).
For well-qualified students. Material covered is approximately that included in Math. 216 with some deeper penetrations and some additional topics.

289. Problem Seminar. ***Prerequisite: permission of instructor or Honors counselor. I.*** (1).
The course focuses on the development of mathematical problem solving skills. Problems will be taken from classical analysis, elementary number theory, and geometry. For students with outstanding problem-solving ability. May be taken for credit more than once.

295. Honors Analysis I. ***Prerequisite: Math. 196. I.*** (4).
Analysis I: Multivariable differential calculus. Designed primarily for mathematics Honors students who have had 195 and 196. The material covered in 295, 296 and 496 is approximately that of Math. 216, 404, 451 and 551 but there is a deeper penetration into many topics.

296. Honors Analysis II. ***Prerequisite: Math. 295. II.*** (4).
Analysis II: Multivariable integral calculus. (See Math 295 Description).

300. (EECS 300). Mathematical Methods in Systems Analysis. ***Prerequisite: Math. 216. I and II.*** (3).
An introductory course in operational mathematics as embodied in Laplace transforms, Fourier series, Fourier transforms, and complex variables with emphasis on their application to the solution of systems of linear differential equations. The response of linear systems to step, impulse, sinusoidal forcing functions. Credit is not granted for both Math. 300 and Math. 448.

312. Applied Modern Algebra. ***Prerequisite: Math. 116, or permission of mathematics counselor. I.*** (3).
Sets and functions, relations and graphs, rings and Boolean algebras, semigroups and groups, lattices. Applications chosen from such areas as switching theory, automata theory, coding theory and may include finite

state machines, minimal state machines, algebraic descriptions of logic circuits, semigroup machines, binary codes, fast adders, Polya enumeration theory, series and parallel decomposition of machines.

316. Differential Equations. ***Prerequisites: Math. 215 and 217 or equivalent. I and II.*** (3).
Math. 316 is a rigorous course on differential equations for math, science, and engineering majors with a good background in both calculus and linear algebra. As well as material normally included in a junior level differential equations course, Math. 316 will include qualitative theory, and existence and uniqueness theorems. The use of microcomputers and standard commercial programs available for such a course will be encouraged. Credit can be received for only one of Math. 216 or 316, and credit can be received for only one of Math. 316 or 404.

350. (Aero Eng. 350). Aerospace Engineering Analysis. ***Prerequisite: Math. 216.*** (3).
Formulation and solution of some of the elementary initial—and boundary—value problems relevant to aerospace engineering. Application of Fourier series, separation of variables, and vector analysis to problems of forced oscillations, wave motion, diffusion, elasticity, and perfect-fluid theory.

371. (Civ. Eng. 303) (Eng. 303). Computational Methods for Engineers and Scientists. ***Prerequisite: Eng. 103 and preceded or accompanied by Math. 216. I and II.*** (3).
Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development and comparison of techniques for roots of non-linear equations, simultaneous linear algebraic equations, curve fitting, numerical integration, and ordinary differential equations.

404. Differential Equations. ***Prerequisite: Math. 216 or 286. I, II, IIa, and IIIb.*** (3).
Systems approach to linear differential equations and physical applications. Simultaneous linear equations, solutions by matrices. Power series solutions. Numerical methods. Phase plane analysis of non-linear differential equations.

405. Differential Equations and Numerical Analysis. ***Prerequisite: Math. 216 and one course in computer programming.*** (3).
Numerical methods for solving the initial value problem for ordinary differential equations and related numerical analysis; e.g., solving non-linear equations, numerical integration, polynomial approximations. Systems of linear ordinary differential equations, and modeling with such systems.

412. First Course in Modern Algebra. ***Prerequisite: Math. 215 or 285 or permission of instructor. I, II, IIIa and IIIb.*** (3).
Fields and domains. Polynomials. Divisibility. Solution of polynomial equations. Symmetric functions. Determinants. Vector spaces.

416. Theory of Algorithms. ***Prerequisite: Math. 312 or 412 or EECS 303, and EECS 383. I and II.*** (3).
Enumeration-type algorithms: sieve formulas, binomial coefficients, Stirling numbers. Generation-type algorithms: generating permutations, subsets, partitions, Random generators. Graph algorithms: paths, depth-first search, spanning trees, cliques. Complexity: run and storage restrictions, n.-p. completeness.

417. Matrix Algebra I. ***Prerequisite: three terms of college mathematics. I, II, IIIa and IIIb.*** (3).
Algebra of matrices. Real vector spaces. Linear transformations. Determinants. Invariants and canonical forms. Elementary theory of similarity. Students intending to continue to research level should elect Math. 513. No credit for Math. 417 will be given to those with credit for Math. 513.

419. (EECS 400). Linear Spaces and Matrix Theory. ***Prerequisite: four semesters of college mathematics beyond Math. 110. I and II.*** (3).
Not open to students with credit for Math. 417 or 513. Finite dimensional linear spaces and matrix representations of linear transformations. Bases, subspaces, determinants, eigenvectors, and canonical forms. Structure of solutions of systems of linear equations. Applications to differential and difference equations. The course provides more depth and content than Math. 417. Math. 513 is the proper election for students contemplating research in mathematics.

420. Matrix Algebra II. ***Prerequisite: Math. 417 or 419. II.*** (3).
Hermitian, positive definite and unitary matrices. Applications in mechanics. Linear programming, simplex algorithm. Selected topics from theory of finite elements, coding theory, Rayleigh quotients, and others.

425. (Statistics 425). Introduction to Probability. ***Prerequisite: Math. 215. I, II and IIb.*** (3).
Basic concepts of probability; discrete sample spaces; conditional probabilities and independence of events; random variables; expectation and variance; binomial and Poisson distribution; DeMoivre-Laplace limit theorem; introduction to continuous probability.

433. Introduction to Differential Geometry. ***Prerequisite: Math. 215. II.*** (3).
Curves and surfaces in three-space, using calculus. Curvature and torsion of curves. Curvature, covariant differentiation, parallelism, isometry, geodesics, and area on surfaces. Gauss-Bonnet Theorem. Minimal surfaces.

445. Celestial Mechanics. ***Prerequisite: Math. 216 or 286.*** (3).
Mathematical theory of the motion of astronomical bodies. Problems of two, three and n bodies.

448. Operational Methods for Systems Analysis. ***Prerequisite: Math. 450 or 451. I.*** (3).
Introduction to complex variables. Fourier series and integrals. Laplace transforms, application to systems of linear differential equations; theory of weighting function, frequency response function, transfer function, stability criteria, including those of Hurwitz-Routh and Nyquist. Math. 448 and Math. 300 cannot both be taken for credit.

450. Advanced Mathematics for Engineers I. ***Prerequisite: Math. 216 or 286. I, II, IIIa, and IIIb.*** (4).
Topics in advanced calculus including vector analysis, improper integrals, line integrals, partial derivatives, directional derivatives, infinite series.

451. Advanced Calculus I. ***Prerequisite: Math. 215 and one course beyond 215 or alternatively Math. 285. Intended for mathematics majors, other students desiring advanced calculus should elect Math. 450. I, II, IIIa.*** (3).
Calculus of functions of one variable, including their expansion into power series, and foundation of calculus of functions of two or more variables.

452. Advanced Calculus II. ***Prerequisite: Math. 451 and 513 or 417 (513 or 417 may also be taken concurrently). Doctoral students of mathematics elect 551.*** (3).
Multi-variable calculus, topics in differential equations, and further topics.

454. Fourier Series and Applications. ***Prerequisite: Math. 216 or 286. I, II, and IIIa.*** (3).*
Orthogonal functions Fourier series, Bessel functions. Legendre polynomials and their applications to boundary value problems in mathematical physics.

455. Boundary Value Problems and Complex Variables. ***Prerequisite: Math. 450. Not open to students with credit for Math. 454 or 555. II.*** (4).
Intended primarily for undergraduate students; graduate students should normally take Math. 554 and need special per-

mission of the counselor to register for Math. 455. Topics in advanced calculus include functions of a complex variable, separation of variables techniques to solve boundary value problems, special functions, and orthogonal series. Complex variables are used to evaluate residue integrals arising from Fourier integrals, calculate asymptotic behavior of Bessel functions, etc.

*Math. 454 carries 1 hour credit for students with credit for Math. 455 or 554.

462. Mathematical Models. ***Prerequisite: Math. 216 and 417. II.*** (3).
Construction and analysis of mathematical models involving probability, combinatories, decision theory, optimization, games, and dynamics. Applications to some of the physical, social, life, and decision sciences.

471. Introduction to Numerical Methods. ***Prerequisite: Math. 216 or 286 and some knowledge of computer programming. I. and II.*** (3).
Examples of basic mathematical methods used in computing. Polynomial interpolation. Numerical integration. Numerical solution of ordinary differential equations. Linear systems of equations. Monte Carlo techniques. Roundoff error. Students will use a digital computer to solve problems.

481. Introduction to Mathematical Logic. ***Prerequisite: Math. 412 or 451 or permission of instructor. I.*** (3).
Formal languages and their interpretations. Propositional logic, predicate logic, and applications to problems of consistency, completeness, and decidability of mathematical theories.

490. Introduction to Topology. ***Prerequisite: Math. 216 or 286. I.*** (3).
Compactness and connectivity in Euclidean and other metric spaces. Selected topics from homology, classification of two-dimensional surfaces, complexes and covering spaces.

495. Honors Introduction to Modern Algebra. ***Prerequisite: Math. 296. I.*** (3).
An introduction to modern algebra with emphasis on polynomial and linear algebra. Designed primarily for Mathematics Honors students.

496. Honors Analysis III. ***Prerequisite: Math. 296. I.*** (3).
Analysis III: Differential Equations. (See Math. 295 Description.)

499. Independent Reading. ***Prerequisite: graduate standing in a field other than mathematics.*** (1-4).
This course is designed for graduate students in fields other than mathematics who require mathematical skills not otherwise available through existing courses.

512. Algebraic Structures. ***Prerequisite: Math. 385 or one 400 level course or permission of instructor. Math. 512 requires more mathematical maturity than 412. Credit is not given for both Math. 412 and 512. I and II.*** (3).
Description and in-depth study of the basic algebraic structures groups, rings, fields, including: set theory , relations, quotient groups, permutation groups, Sylow's Theorem, quotient rings, field of fractions, extension fields, roots of polynomials, straightedge and compass solutions, and other topics.

513. Introduction to Linear Algebra. ***Prerequisite: Math. 412. I and II.*** (3).
Vector spaces; linear transformations and matrices, equivalence of matrices and forms, canonical forms; application to linear differential equations. One credit for 513 will be given to those with credit for Math. 417.

514. Topics in Linear Algebra. ***Prerequisite: Math. 513. I.*** (3).
Advanced theory of vector spaces. Geometry of bilinear forms. Modules over principal ideal domains. Similarity theory. Multilinear algebra.

516. Topics in the Theory of Algorithms. ***Prerequisite: Math. 416 and 417, EECS 480, or equivalent.*** (3).
Strassen's matrix multiplication, fast Fourier transforms, RASM and RASP models, pattern recognition problems, class P, NP, NP-complete, and NP-hard algorithms; integer and polynomial arithmetic, deterministic and non-deterministic Turing machines; special topics such as randomizing algorithms, applications to mathematical proofs; solution of the four-color problem.

525. (Stat. 525). Probability. ***Prerequisite: Math. 450 or 451; or permission of the instructor. I and II.*** (3).
Axiomatic probability; combinatorics; random variables and their distributions; expectation; the mean, variance, and moment generating function; induced distributions; sums of independent random variables; the law of large numbers; the central limit theorem. Optional topics drawn from: random walks, Markov chains, and/or martingales. Carries one unit of credit for students with credit for Math./Stat. 425.

526. (EECS 503) (Stat. 526). Discrete State Stochastic Processes. ***Prerequisite: EECS 501 or Math. 525 or Stat. 510.*** (3).
Review of discrete distributions; generating functions; compound distributions; renewal theorem; systems as Markov chains. Properties of Markov chains: Chapman-Kolmogorov equations; return and first passage times; classification of states and periodicity; absorption probabilities; forward equation; stationary distributions; backward equation; ergodicity; limit properties. Branching and queueing processes; examples from engineering, biological and social sciences; continuous time Markov chains; embedded chains; the M/G/1 queue; Markovian decision processes; inventory problems.

543. Ordinary Differential Equations and Special Functions of Mathematical Physics. ***Prerequisite: Math. 555.*** (3).
Linear equations of the second order; solution by power series; Riccati equations; extensive treatment of the hypergeometric equation; solutions of the equations of Bessel, Hermite, Legendre, and Laguerre; asymptotic analysis.

554. Advanced Mathematics for Engineers II. ***Prerequisite: Math. 450. I.*** (4). ***Not open to students with credit for Math. 454 or 555.***
Topics in advanced calculus including functions of a complex variable, Fourier series and orthogonal functions, applications to boundary value problems.

555. Introduction to Functions of a Complex Variable with Applications. ***Prerequisite: Math. 450 or 451. I and II.*** (3).*
Intended primarily for students of engineering and of other cognate subjects. Doctoral students of mathematics elect Mathematics 603. Complex numbers, continuity; derivative; conformal representation, integration; Cauchy theorems, power series; singularities; application to engineering and mathematical physics.

556. Methods of Applied Mathematics I. ***Prerequisite: Math. 555 or 554. I.*** (3).
A study of some of the differential equations of mathematical physics and methods for their solution. Separation of variables for the heat, wave, Laplace's and Schrödinger's equations; special functions, their integral representations and asymptotic properties; eigenvalues as solutions of variational problems.

557. Methods of Applied Mathematics II. ***Prerequisite: Math. 556. II.*** (3).
Continuation of Math. 556. Elementary distributions; Green's functions and integral solutions for nonhomogeneous problems; Fourier and Hankel transforms; Fredholm alternative and elementary methods of solution of integral equations; additional topics as time permits.

558. Theory of Initial Value Problems. ***Prerequisite: Math. 216 and advanced calculus and some linear algebra, or permission of instructor.*** (3).
Picard theorem, method of successive approximations, theory of characteristics for first and second order partial differential

equations, the Cauchy-Kowalewski theorem, elementary classification of second order partial differential equations, elementary representation theorems.

561. (S&M.S. 518) (I.&O.E. 510). Linear Programming I. ***Prerequisite: Math. 417 or I.&O.E. 310. I and II.*** (3).
Formulation of problems from the private and public sectors using the mathematical model of linear programming. Development of the simplex algorithm; duality theory and economic interpretations. Postoptimality (sensitivity) analysis; applications and interpretations. Introduction to transportation and assignment problems; special purpose algorithms and advanced computational techniques. Students have opportunities to formulate and solve models developed from more complex case studies and to use various computer programs.

*Math. 555 carries 1 hour credit for students with credit for Math. 455 or 554.

562. (EECS 505) (I.&O.E. 511) (Aero. Eng. 577). Continuous Optimization Methods. ***Prerequisite: Math. 417 or Math. 419.*** (3).
Survey of continuous optimization problems. Unconstrained optimization problems; unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques for unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.

565. Theory of Graphs. ***Prerequisite: Math. 215.*** (3).
Historical introduction, basic concepts of graphs and directed graphs, cutpoints, bridges and blocks, trees, connectivity, graphical partition, Eulerian graphs, factorization, coverings, topological graph theory, coloring problems. Applications.

566. Combinatorial Theory. ***Prerequisite: Math. 216 or 286 or permission of instructor.*** (3).
Permutations, combinations, generating functions, and recurrence relations. The existence and enumeration of finite, discrete configurations. Systems of representatives, Ramsey's Theorem, and extremal problems. Construction of combinatorial designs.

571. Numerical Methods for Scientific Computing I. ***Prerequisite: Math. 417 or 513, and 450 or 451. I.*** (3).
Numerical linear algebra; solution of linear equations by direct and iterative methods: analysis of algorithms for matrix eigenvalue problems and non-linear systems of equations. Approximation of functions by polynomials, splines, and finite elements.

572. Numerical Methods for Scientific Computing II. ***Prerequisite: Math. 404 or 450 or 451. Usually preceded by Math. 571, but may be taken separately. II.*** (3).
Numerical solution of differential equations. Finite difference and finite elements methods for elliptic boundary value problems and parabolic problems. Difference methods for hyperbolic problems.

601. Real Analysis I. ***Prerequisite: Math. 451 and 513. I.*** (3).
Lebesgue measure and integration on the line; convergence theorems, functions of bounded variation, absolute continuity, differentiation theory in one and several variables; general measure spaces; product spaces, Fubini's theorem; Radon-Nikodym theorem.

602. Real Analysis II. ***Prerequisite: Math. 590 and 601. II.*** (3).
Introduction to functional analysis; metric spaces, completion, Banach spaces, Hilberg spaces, Lp spaces; linear functionals, dual spaces; Riesz representation theorems; principle of uniform boundedness, closed graph theorem. Hahn-Banach theorem, Baire category theorem; applications to classical analysis.

603. Complex Analysis I. ***Prerequisite: Math. 451. II.*** (3).
Elementary functions of a complex variable; linear fractional transformations; complex derivatives; conformality; Cauchy's theorem, Cauchy's integral formula and consequences; Taylor and Laurent series; analytic continuation. Students with credit for Math. 555 will receive 2 hours credit for Math. 603.

604. Complex Analysis II. ***Prerequisite: Math. 603. I.*** (3).
Selected topics such as normal families, Riemann mapping theorem, conformal mapping of multiply connected domains; elliptic functions; entire and meromorphic functions, Picard's theorem, value distribution theory; Phragmen-Lindelof theorems; harmonic functions, Dirichlet problem; schlict functions.

607. Theory of Distributions. ***Prerequisite: Math. 601.*** (3).
Theory of distributions. Sobolev spaces. Fundamental solution of partial differential equations. Boundary value problems. Solutions of problems of optimization with partial differential equations as side conditions. Theorems of regularity. Characterization of singularities.

625. (Statistics 625). Probability and Random Processes I. ***Prerequisite: Math. 601. II.*** (3).
Axiomatics; measures and integration in abstract spaces. Fourier analysis, characteristic functions. Conditional expectation. Kolmogorov extension theorem. Stochastic processes; Wiener-Levy, infinitely divisible, stable. Limit theorems, law of the iterated logarithm.

626. (Statistics 626). Probability and Random Processes II. ***Prerequisite: Math. 625. I.*** (3).
Selected topics from among: diffusion theory and partial differential equations; spectral analysis; stationary processes and ergodic theory; information theory; martingales and gambling systems; theory of partial sums.

651. Foundations of Applied Mathematics I. ***Prerequisite: Math. 451, 555, and one other 500 level course in analysis or differential equations or consent of the instructor. I.*** (3).
The regular Sturm-Liouville theory for ordinary and partial differential equations including the rudiments of spectral theory and operator theory.

652. Foundations of Applied Mathematics II. ***Prerequisite: Math. 651 or consent of instructor. II.*** (3).
A continuation of Math. 651. Spectral theory of self-adjoint operations and an introduction to the singular Sturm-Liouville theory.

656. Advanced Partial Differential Equations. ***Prerequisite: Math. 558, 601, and 603 or permission of instructor.*** (3).
Modern developments in the theory of partial differential equations.

658. Ordinary Differential Equations. ***Prerequisite: Math. 602.*** (3).
Existence theorems, linear systems, Sturm-Liouville theory. Qualitative study of flows and vector fields in the plane and on 2-manifolds. Periodic solutions, Hamiltonian systems, stability.

660. (I.&O.E. 610). Linear Programming II. ***Prerequisite: Math. 561. II.*** (3).
For description, see I.&O.E. 610.

663. (I.&O.E. 611). Non-linear Programming I. ***Prerequisite: Math. 561, 594, or 490. I.*** (3).
For description, see I.&O.E. 611.

668. Topics in Graph Theory. ***Prerequisite: Math. 565 or 566, or permission of instructor.*** (3).
Selected subjects chosen usually from the areas of graphs and matrices, graphs, and their groups, topological graph theory, and extremal problems.

669. Topics in Combinatorial Theory. ***Prerequisite: Math. 565 or 566, or permission of instructor.*** (3).
Selected topics from the foundations of combinatorics, including the analysis of general

partially ordered sets, combinatorial designs in loops and structures in abstract systems, enumeration under group action, combinatorial aspects of finite simple groups.

671. Analysis of Numerical Methods I. ***Prerequisite: Linear algebra and advanced calculus. I.*** (3).
A rigorous introduction to the mathematics of numerical analysis. The first term will consist of numerical linear algebra, solution of linear equations via iterative methods, solution of non-linear equations, and least-squares approximation. The course is intended primarily for mathematics graduate students, although it is also appropriate for mathematically mature undergraduates and science and engineering students with strong theoretical interests.

672. Analysis of Numerical Methods II. ***Prerequisite: Linear algebra and advanced calculus; usually preceded by Math. 671 but may be taken separately. II.*** (3).
A rigorous introduction to the mathematics of numerical analysis. Polynomial interpolation, numerical differentiation and integration, and solution of ordinary and partial differential equations by difference methods. The course is intended primarily for mathematics graduate students, although it is also appropriate for mathematically mature undergraduates and science and engineering graduate students with strong theoretical interests.

Mechanical Engineering

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See Page 60 for statement on Course Equivalence.

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Orlan William Boston, M.S.E., M.E., P.E., Professor Emeritus of Mechanical Engineering and of Production Engineering

Robert Macormac Caddell, Ph.D., P.E., Professor Emeritus of Mechanical Engineering

James Wallace Daily, Ph.D., Professor Emeritus of Fluid Mechanics and Hydraulic Engineering

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Gretar Tryggväson, Ph.D., Assistant Professor of Mechanical Engineering and Applied Mechanics

Donald Geister, M.S., Lecturer, Mechanical Engineering and Applied Mechanics

Vernon A. Phelps, M.Sc., Lecturer, Mechanical Engineering and Applied Mechanics

101. Introduction to Computer Aided-Design. *I, II and IIIa.* (2)
High end engineering computer workstations and CAD software with 3D wireframe, surfacing and solids. Use of such computers and software to generate the necessary geometry and data for the engineering analysis/design/manufacturing process. Graphical communication via freehand sketching.

110. Statics. *Prerequisite: Math. 115. I, II, IIIa, and IIIb.* (2).
Basic principles of mechanics; concepts of statics, vectors, and vector additions and products; moments and couples; resultants and equilibrium of general force systems; free body method of analysis; applications to simple problems in all fields of engineering, elementary structures, cables, friction, centroids. Two lecture-recitation classes per week.

210. Introduction to Solid Mechanics. *Prerequisite: Math. 116, and Mech. Eng. 110. I, II, IIIa, and IIIb.* (3).
Introduction to mechanics of deformable bodies; concepts of stress and strain, classification of material behavior, stress-strain relations, and generalized Hooke's law. Applications involve members under axial load, torsion of circular rods, bending, and shear stresses in beams, combined stresses, deflection of beams. Three lectures per week and six two-hour laboratories per term.

211. Introduction to Solid Mechanics. *Prerequisite: Physics 140 and Math. 116. I, II, IIIa, and IIIb.* (4). ***Not open to mechanical engineering students.***
Principles of statics including equilibrium and static equivalence. Determination of moment and force resultants in slender members. Introduction to mechanics of deformable bodies; concepts of stress and strain, classifications of material behavior, stress-strain relations and generalized Hooke's law. Application to engineering problems involving members under axial load, torsion of circular rod and tubes, bending and shear stresses in beams, combined stresses, deflection of beams. Four lecture-recitation classes per week and six self-contained, two-hour laboratory sessions per semester.

231. Classical and Statistical Thermodynamics. *Prerequisite: Chem. 123 or 124, and 125, and Math. 215. I and II.* (4). ***Not open to mechanical engineering students.***
Basic thermodynamics, first law, second law, properties of a pure substance, ideal gases and gaseous mixtures, applications to heat-power machinery. Introduction to statistical thermodynamics and evaluation of thermodynamic properties. Not open to mechanical engineering students. Four recitations.

235. Engineering Thermodynamics. *Prerequisite: Chem. 123 or 124, and 125, and Math. 116. I, II, and IIIa.* (3). ***Not open to Mechanical Engineering students.***
Basic course in engineering thermodynamics. First law, second law, system and control volume analyses; properties and behavior of pure substances, ideal gases and mixtures. Three recitations.

236. Thermodynamics I. *Prerequisite: Chem. 123 or 124 and 125, and Math. 116. I, II, and IIIa.* (4).
Basic course in engineering thermodynamics. First law, second law, system and control volume analyses; properties and behavior of pure substances, ideal gases and

mixtures; thermodynamic availability; power and refrigeration cycles. Four recitations.

240. Introduction to Dynamics. ***Prerequisite: Physics 140 and preceded or accompanied by Math. 216. I, II, IIIa and IIIb.*** (3). Vector description of force, position, velocity and acceleration in fixed and moving reference frames. Kinetics of particles, assemblies of particles and of rigid bodies, energy and momentum concepts. Euler's equations. Moment of inertia properties. The simple oscillator and its applications. Three lecture-recitation classes per week.

251. Mechanical Behavior of Solids. ***Prerequisite: Mat. Sci. & Eng. 250 and preceded or accompanied by Mech. Eng. 210 or 211. I, II, and IIIa.*** (3). Fundamentals of strengthening mechanisms in solids. Control of mechanical properties through control of microstructure. Use of ferrous and nonferrous alloy systems, polymers, and glasses to emphasize the application of basic principles. Fracture modes and fracture toughness concepts. Two two-hour recitation-laboratory periods.

252. Elements of Manufacturing Systems. ***Prerequisite: Physics 240 and 241. I and II.*** (3). ***Not open to mechanical engineering students.*** Introduction to subsystems concerned with workpiece, equipment, kinematics, energy, information, and organization; discussion of dependent relationships between subsystems and cost and quality of products; relevant laboratory projects including use of conventional and numerically controlled machine tools. Two one-hour lecture-recitations and one three-hour laboratory discussion period per week.

311. Strength of Materials. ***Prerequisites: ME 210 and MA 216. I, II, and IIIa.*** (3). Energy methods; buckling of columns, including approximate methods; bending of beams of unsymmetrical cross-section; shear center and torsion of thin-walled sections; membrane stresses in axisymmetric shells; elastic-plastic bending and torsion; axisymmetric bending of circular plates.

324. Fluid Mechanics. ***Prerequisite: Mech. Eng. 236 and Mech. Eng. 240. I, II, IIIa, and IIIb.*** (4). Control volume analysis; continuity, momentum, angular momentum, and energy equations. Dimensional analysis and similitude. Introduction to differential analysis; kinematics; fluid statics; inviscid flow; potential flow; simple viscous incompressible flow; lift and drag. Steady one-dimensional compressible flow. Applications to fluid machinery and systems. Three lectures and one three-hour laboratory.

325. (Civ. Eng. 325). Fluid Mechanics. ***Prerequisite: Mech. Eng. 240, preceded or accompanied by Mech. Eng. 235. I, II, IIIa, and IIIb.*** (3). ***Not open to mechanical engineering students.*** Principles of mechanics applied to real and ideal fluids. Topics include fluid properties and statics; continuity, energy and momentum equations by control volume; dimensional analysis and similitude; laminar and turbulent flow; boundary layer, drag, lift; incompressible flow in pipes; free-surface flow; adiabatic flow of ideal gases in conduits; fluid measurement and turbomachinery.

335. Thermodynamics Ia. ***Prerequisite: Mech. Eng. 235. Not open to students with credit for Mech. Eng. 236. I and II.*** (1). Thermodynamic availability; power and refrigeration cycles. One recitation.

336. Thermodynamics II. ***Prerequisite: Eng. 103; Mech. Eng. 236 or Mech. Eng. 235 and Mech. Eng. 335. I and II.*** (3). Introduction to statistical thermodynamics and evaluation of thermodynamic properties; general thermodynamic relations, equations of state, and compressibility factors; chemical reactions; combustion; gaseous dissociation; phase equilibrium. Two recitations and one three-hour laboratory.

340. Introduction to System Dynamics. ***Prerequisite: Mech. Eng. 240 or 241. I, II, and IIIa.*** (4). Unified approach to modeling and analysis of active and passive mechanical, fluid, thermal, and electrical devices. Derivation of governing differential equations. Introduction to state variables, superposition free and forced response, stability and system characterization. Solution to state equations by direct analysis and digital computer methods. Three lectures and one 3-hour lab.

362. Mechanical Design I. ***Prerequisite: Mech. Eng. 210 or 211 and Mech. Eng. 251. I and II.*** (3). Application of the fundamentals of engineering mechanics, materials, and manufacturing to the analysis and design of mechanical elements and systems.

371. Heat Transfer. ***Prerequisite: Mech. Eng. 236 and 324. I, II, and IIIa.*** (4). Mechanisms of heat transfer. Steady and transient condition in solids; approximate and exact solution procedures. Convection processes; laminar and turbulent (dimensional analysis with experiment). Heat exchanger design and performance. Thermal radiation. Introduction to diffusion and mass transfer between phases. Three one-hour lectures and one three-hour laboratory.

381. Manufacturing Processes. ***Prerequisite: Mech. Eng. 251. I, II and IIIa.*** (3). Modeling and quantitative analysis of the processes used to manufacture mechanical systems; process costs and limits, influence of processes on the final mechanical properties of the product. Two recitations and one two-hour laboratory.

400. Mechanical Engineering Analysis. ***Prerequisite: Mech. Eng. 210 or 211. Mech. Eng. 240 and Math. 216. I.*** (4) Exact and approximate techniques for analysis of problems in Mechanical Engineering including structures, vibrations, control systems, fluids, and design. Emphasis is on applications.

404. (Appl. Mech. 404). Coherent Optical Measurement Techniques. ***Prerequisite: senior or graduate standing. II.*** (4) Modern optical techniques using lasers in measurements of mechanical phenomena. Introduction to the nature of laser light and Fourier optics; use of holography and laser speckle as measurement techniques; laserdoppler velocimetry.

416. Special Topics in Mechanical Engineering. ***Prerequisite: Permission of instructor. I, II, IIIa, and IIIb. (To be arranged.)*** Selected topics pertinent to mechanical engineering.

424. Fundamentals of Noise Control. ***Prerequisite: Mech. Eng. 324. I.*** (3) Characteristics of sound waves. Sound levels and frequency spectra. Sound and vibration transducers. Instrumentation and measurement techniques. Data analysis. Sound transmission and propagation outdoors. Acoustic controls. Physical and psychological effects of noise. Criteria for noise regulations and control. Practical noise control in offices, homes, shops, aircraft, cars, and trucks.

426. Hydraulic Machinery. ***Prerequisite: Mech. Eng. 324 or 325. II.*** (3) Flow along streamlines and in blade passages. Influence of blade shape and number. Design of impellers and passages. Hydraulic systems. Losses and efficiency in hydraulic machinery. Applications to centrifugal and axial machinery, e.g., fans, pumps, and torque converters.

432. Combustion. ***Prerequisite: Mech. Eng. 336, preceded or accompanied by Mech. Eng. 371. I.*** (3) Introduction to combustion processes, reaction kinetics, ignition, and flame propagation. Combustion of sprays. Detonation, temperature, and radiation. Spectrographic analysis. Optical methods for combustion studies. Otto, diesel, gas turbine, and rocket combustion.

436. Direct Energy Conversion. ***Prerequisite: Mech. Eng. 336. I.*** (3)
Thermodynamic and operational analysis of direct energy conversion devices. Topics include fuel cells, thermoelectric generators and coolers, thermionic, photovoltaic, and magnetohydrodynamic converters; demonstration of selected devices.

437. Applied Energy Conversion. ***Prerequisite: Mech. Eng. 336. I.*** (3)
Quantitative treatment of energy resources, conversion processes, and energy economics. Consideration of fuel supplies, thermodynamics, environmental impact, capital and operating costs. Emphasis is placed on conversion of natural energy sources to electric, treating both the technical and economic aspects of fossil, nuclear, solar, and geothermal power production.

440. Intermediate Vibrations. ***Prerequisite: Mech. Eng. 240. I, II, and IIIa.*** (3).
Transient and forced single-degree-of-freedom linear vibrations: support motion, rotating unbalance, vibration isolation. Linear multiple-degree-of-freedom systems, analysis by matrix and approximate methods. Lagrange formulation. Continuous systems, modal summation.

442. Analysis & Synthesis of Motion. ***Prerequisite: Mech. Eng. 240. II.*** (3).
Particle and rigid body kinematics in 3D rotating reference frames. Algebraic and graphical analysis and synthesis of planar mechanisms. Coordinate translations and rotations, homogeneous displacement matrices. Solution of direct kinematics problem. Euler and Rodrigues parameters. Solution of indirect kinematics problem. Computer projects. Applications to robotics.

460. Mechanical Design II. ***Prerequisite: Mech. Eng. 340 and Mech. Eng. 362; preceded or accompanied by Mech. Eng. 381. I, II, and IIIa.*** (3).
A mechanical engineering design project by which the student is exposed to the design process from concept through analysis to layout and report. Projects are proposed from the different areas of study within mechanical engineering and reflect the expertise of instructing faculty. Two, four-hour design periods.

461. Automatic Control. ***Prerequisite: Mech. Eng. 340. I, II, and IIIa.*** (4).
Linear feed-back control theory with emphasis on mechanical systems; transient and frequency response; stability; system performance; control modes; compensation methods; analysis of hydraulic, pneumatic, inertial components and systems. Three one-hour lectures and one three-hour laboratory.

464. Computer Aided Mechanical Design. ***Prerequisite: Eng. 103, Mech. Eng. 340. I and II.*** (3).
Introduction to the use of the digital computer as a tool in engineering design and analysis of mechanical components and systems. Simulation of static, kinematic and dynamic behavior. Optimal synthesis and selection of elements. Discussion and use of associated numerical methods and application software. Individual projects.

465. Mechanical Analysis Laboratory. ***Prerequisite: Mech. Eng. 340. I and II.*** (3).
Laboratory use of instrumentation to measure forces, stresses, displacement pressure, etc., in mechanical devices; use of transducers, display and recording devices, and of the analog computer for experimental analysis; short experiments plus squad projects; lectures, laboratory, brief reports. Two three-hour periods per week.

470. (Nuc. Eng. 443). Heat Transfer. ***Prerequisite: Mech. Eng. 231 or 236, Math. 454 or 455. Not open to mechanical engineering majors. I.*** (3).
Mechanisms of heat transfer. Steady and transient conduction in solids; approximate and exact solution procedures. Convection processes; laminar and turbulent (dimensional analysis with experiment). Heat exchange design and performance. Thermal radiation. Introduction to diffusion and mass transfer between phases. Special emphasis on systems involving energy generation.

471. Computational Heat Transfer. ***Prerequisite: Mech. Eng. 371 or 470. II.*** (3).
Enclosure and gas radiation. Parallel flow and boundary layer convection. Variable property and odd geometry conduction. Technological applications. Individual term projects. Use of elementary spectral, similarity, local similarity, local (finite) difference and global difference (finite element) solution techniques.

474. Phase Change Dynamics in Energy Systems. ***Prerequisite: Mech. Eng. 336 and Mech. Eng. 371. II.*** (3).
Heat and mass transfer and fluid dynamics of phase change and two-phase flow. Basic laws, mechanisms and correlations for evaporation, boiling, condensation, pressure drop. Applications in areas of power plant boilers and condensors (conventional and nuclear), internal combustion engines (carburetion, diesel injection), freeze drying, bubble lift pumps, humidification/dehumidification.

475. Solar Thermal Systems—Fundamentals and Design. ***Prerequisite: Mech. Eng. 371 or permission of instructor. I and II.*** (4).
Review of status of solar thermal process and applications. Properties of sun and solar mechanics; solar resource models; analysis of solar thermal conversion systems; optics of cover/absorber system; thermal storage. Economic analysis, modeling and design considerations for solar thermal conversion systems. Four one-hour lectures.

476. (Bioeng. 476). Thermal-Fluid Sciences in Bioengineering. Not open to Mech. Eng. students. I. (3).
Fluid dynamics, thermodynamics, and heat transfer at micro- and macro-level. Systemic circulation, microcirculation, simulation of low regulation, artificial flow-regulating devices. First and second laws of thermodynamics. Conduction, metabolic heat generation, convection, radiation, regulation of body temperature, clothing, micro heat transfer, hyperthermia, hypothermia and cryogenic applications.

478. Dynamics and Control of Thermal-Fluid Systems. ***Prerequisite: Mech. Eng. 371. I.*** (3). ***P/F only.***
Application of fluid dynamics, heat transfer, and control theory to thermal-fluid equipment and processes in the mechanical engineering field. Methods for determination of dynamic characterization, controller types and applications of techniques of regulation.

480. Manufacturing Processes Laboratory. ***Prerequisite: Mat. Sci. & Eng. 250. I.*** (3).
Laboratory experience with basic machine tools to illustrate the geometric configurations, tolerances and surface finishes each can produce. Relationship of the manufacturing processes to design features and the design process. One three-hour period per week.

482. Machining Processes. ***Prerequisite: Mech. Eng. 381 or 252. II.*** (4).
Application of engineering fundamentals to design and analysis of machining operations. Special consideration is given to those facets of machine tool, cutting tool, and work material behavior which must be controlled in the use of computers, new electrical processes, and other modern and future facilities and techniques in manufacturing. Two recitations and two three-hour laboratories.

483. (I.&O.E. 471) Computer Control of Manufacturing Systems. ***Prerequisite: Mech. Eng. 381; I.&O.E. 373 and Mech. Eng. 252. II.*** (3).
Basic elements of numerical control of metal processing systems; programming languages for point to point and contouring machines; interaction between geometry and machinability decisions. Laboratory experiments in optimizing part-programming and equipment utilization. Computerized numerical control, adaptive control, industrial

robots, flexible manufacturing systems. Two one-hour lectures and two two-hour laboratories.

484.(EECS 467) (I& OE 494). Robot Applications. ***Prerequisite: (EECS 280 or 370 or I.&O.E. 373 or Mech. Eng. 340) and (Mech. Eng. 240 or EECS 360) and senior standing. Not open to students with previous credit for EECS 567. II.*** (3).
Basic concepts in the organization and operation of microcomputer-controlled manipulators. Experiments include kinematics, manipulation, dynamics, trajectory planning and programming language for robots. Applications of computer-controlled robots in manufacturing and programmable automation.

487. Welding. ***Prerequisite: Mech. Eng. 381. I.*** (3).
Study of mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting micro-structures, residual stresses and distortion, economics and capabilities of the various processes.

488. Microcomputer Applications in Manufacturing I. ***Prerequisite: Eng. 103 and preceded or accompanied by Mech. Eng. 461. I, II, and IIIa.*** (3).
Applications of microcomputers to problems in process control, quality control and mechanical analysis. Considers assembly level programming, input/output system, and conversion of mechanical characteristics to digital data. Emphasis on the complete microcomputer system through case studies of current application in manufacturing. Two one-hour lectures and one three-hour lab.

490. Experimental Research in Mechanical Engineering. ***Prerequisite: Permission of instructor. I, II, IIIa, and IIIb.*** (3). ***Not for graduate credit.***
Individual or group experimental research in a field of interest to the student under the direction of a member of the Mechanical Engineering Department. Topics may be selected from a list offered each term, including such areas as air conditioning, automotive engineering, fluids, heating, heat transfer, machine design, materials, processing, thermodynamics. The student will submit a report at the end of the term. Two four-hour laboratories per week. Time to be arranged. The first three hours are graded on a letter basis; any additional elections are graded on a pass-fail basis.

496. Internal-Combustion Engines I. ***Prerequisite: Mech. Eng. 336. I and II.*** (3).
Comparison of characteristics and performance of several forms of internal-combustion engines including the Otto and Diesel types of piston engines and the several types of gas turbines; thermodynamics of cycles, combustion, ignition, fuel metering and injection, supercharging, and compounded engines.

497. Automotive Laboratory. ***Prerequisite: preceded or accompanied by Mech. Eng. 496. I and II.*** (3).
Experimental study of automobile and aircraft engines, including horsepower, fuel economy, thermal efficiency, mechanical efficiency, energy balance, indicator cards, carburetion, compression ratio, electrical systems, and road tests for car performance. Laboratory and reports. One four-hour laboratory.

498. Automotive Engineering. ***Prerequisite: Mech. Eng. 362. I and II.*** (3).
Design of automobile and truck suspensions, steering, brakes, drive lines, axles, frames, bodies, and cabs. Acceleration, gradability, stability, and ride comfort. Power-weight ratio. Engine-transmission compatability. Problems of performance and economy.

505. (Appl. Mech. 505). Finite Element Methods in Mechanical Engineering and Applied Mechanics. ***Prerequisite: graduate standing. I and II.*** (3).
Theoretical and computational aspects of finite element methods. Examples from areas of thermal diffusion, potential/irrotational flows, lubrication, structural mechanics, design of machine components, linear elasticity, and Navier-Stokes flows problems. Program development and modification are expected as well as learning the use of existing codes.

515. (Appl. Mech. 515). Contact Mechanics. ***Prerequisite: Mech. Eng. 362 or Appl. Mech. 413. I. alternate and even years.*** (3).
Hertzian elastic contact; elastic-plastic behavior under repeated loading; shakedown. Friction; transmission of frictional tractions in rolling; fretting; normal and oblique impact. Dynamic loading. Surface durability in rolling. Surface roughness effects. Conduction of heat and electricity across interfaces. Thermal and thermoelastic effects insliding and static contact.

516. Special Topics in Mechanical Engineering. ***Prerequisite: Permission of instructor. I, II, IIIa, and IIIb. (To be arranged).***
Selected topics pertinent to mechanical engineering.

521. Fluid Mechanics. ***Prerequisite: Mech. Eng. 324. I, II, and IIIa.*** (3).
Principal concepts and methods of fluid mechanics. Special types of flow; methods of solution; applications to fluid machinery, fluidics, lubrication, propulsion systems and process industries.

526. (Appl. Mech. 526). Computational Fluid Mechanics. ***Prerequisite: Mech. Eng. 521 or Appl. Mech. 422. I.*** (3).
Application of finite differences and other numerical techniques to current problems in fluid mechanics, including high speed flow, boundary layer and separated flows. Problems in aerodynamics, combustion, and turbulent flow. Random choice, vortex, and panel methods. Visual presentation of numerical simulations.

528. Molecular Gasdynamics. ***Prerequisite: Mech. Eng. 324. I.*** (3).
Introduction to fluid flows from the molecular point of view. Molecular models and equilibrium kinetic theory of gases, classification of density regimes, and discussion of free molecule flows. Gas-surface interactions. Heat transfer in rarefied gases. Fundamentals of non-equilibrium kinetic theory with application to low density flows and vacuum technology.

531. Statistical Thermodynamics. ***Prerequisite: Mech. Eng. 231 or 336. II.*** (3).
Introduction to statistical methods for evaluating thermodynamic and transport properties. Elements of quantum mechanics, statistical mechanics, and kinetic theory, as applied to engineering thermodynamics.

535. Thermodynamics III. ***Prerequisite: Mech. Eng. 336. I and IIIa.*** (3).
Definitions and scope of thermodynamics; first and second laws. Maxwell's relations. Capeyron relations, equations of state, thermodynamics of chemical reactions, availability.

537. Power Generation Systems-Heat Sources. ***Prerequisite: concurrently with Mech. Eng. 470 or 371 or Nuc. Eng. 441 or 400. I.*** (3).
Problems associated with basic energy source for nuclear, fossil, hydroelectric, fusion, and other types of energy conversion systems. Present-day problems, including questions of safety, effluent disposition, pollution and economics as well as nuclear, thermodynamic, heat transfer, and mechanical restraints upon component and system design.

538. Power Generation Systems-Machinery. ***Prerequisite: concurrently with Mech. Eng. 470 or 371 or Nuc. Eng. 441 or 400. II.*** (3).
Nuclear, fossil, hydroelectric, fusion, and other types of energy conversion systems, with particular emphasis on peripheral machinery such as turbomachinery, heat exchangers, reactor systems, special heat engine systems, etc.

539. Cryogenics and Refrigeration. ***Prerequisite: Mech. Eng. 336 and preceded or accompanied by Mech. Eng. 371. II.*** (3).
Vapor compression refrigeration systems, properties of refrigerants, design of low temperature systems. Liquefaction, storage and handling of cryogenic fluids, including liquid natural gas, oxygen, nitrogen, hydrogen, and helium. Insulation problems. Applications of superconductivity. Emphasis placed on engineering practice, safety, and economics rather than low temperature physics.

541. (Appl. Mech. 541). Mechanical Vibrations. ***Prerequisite: Appl. Mech. 440 or Mech. Eng. 440. I.*** (3).
Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete nonconservative systems. Vibration of multi-degree-of-freedom systems. Small oscillation theory. Free vibration eigenvalue problem. Undamped system response. Viscously damped systems. Vibration of continuous systems. Modes of vibration of bars, beams, membranes, plates.

543. (Appl. Mech. 543) Analytical and Computational Dynamics I. ***Prerequisite: Mech. Eng. 440 or Appl. Mech. 443. I.*** (3).
Modern analytical rigid body dynamics equation formulation and computational solution techniques applied to mechanical multibody systems. Kinematics of motion generalized coordinates and speeds, analytical and computational determination of inertia properties, generalized forces, Gibb's function, Routhian, Kanes's equations, Hamilton's principle, Lagrange's equations homonomic and nonholonomic constraints, constraint processing, computational stimulation.

546. (Bioeng. 546) (Appl. Mech. 546). Biomechanics. ***Prerequisite: Mech. Eng. 210 or 211, 240. II.*** (3).
Definition of biological tissue behaviors, including elastic, viscoelastic and plastic properties, with emphasis on bone; dynamics of gait; impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

549. (Aero Eng. 549) (Appl. Mech. 549). Random Vibrations of Mechanical Systems. ***Prerequisite: Mech. Eng. 240. II.*** (3).
Random mechanical inputs; wind buffeting; earthquakes; surface irregularities. Engineering applications include response of linear spring-mass system and an elastic beam to single and multiple random loading. Failure theories. Necessary concepts such as ensemble averages, correlation functions, stationary and ergodic random processes, power spectra, are developed heuristically.

550. Rheology and Fracture. ***Prerequisite: Mech. Eng. 251. I.*** (3).
Mechanisms of deformation, cohesion, and fracture of matter. Unified approach to the atomic-scale origins of plastic, viscous, viscoelastic, elastic, and anelastic behavior. The influences of time and temperature on behavior. Stress field of edge and screw dislocations, dislocation interactions, and cross slip. Surface stress and energy states, wetting, solid adhesion, friction. Ductile, creep, brittle, and fatigue failure mechanisms.

552. (Mat Sci. & Eng. 523). Metal-forming Plasticity. ***II.*** (3).
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of work hardening and friction, temperature, strain rate, and anisotropy.

553. Friction and Wear. ***Prerequisite: Mech. Eng. 550 or Mat. Sci. & Eng. 351. II.*** (3).
The nature of solid surfaces, contact between solid surfaces, rolling friction, sliding friction, and surface heating due to sliding; wear and other types of surface attrition are considered with reference to practical combinations of sliding materials, effect of absorbed gases, surface contaminants and other lubricants on friction, adhesion, and wear; tire and brake performance.

555. Mechanics of Manufacturing. ***Prerequisite: Mech. Eng. 381. I.*** (3).
Development and evaluation of models for forming and machining processes. Applications to understanding causes of product defects, establishing conditions for quality, die/tool designs, and adding to the knowledge base of CAD/CAM systems.

556. Stress-Strain-Strength Considerations in Design. ***Prerequisite: Mech. Eng. 362. I and II.*** (3).
A broad treatment of stress, strain, and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects.

559. Failure Analysis Case Studies. ***Prerequisite: preceded or accompanied by Mech. Eng. 362. II.*** (3).
Detailed case study of a variety of service failures in engineering structures such as vehicles, medical implants, hoisting equipment, machinery, and consumer products such as ladders, mowers, and tools. Procedures for analysis include applications of optical and electron microscopy; load history, dynamics, and stress analysis; indentation hardness analysis; accident investigation and reconstruction techniques; specifications and standards; fracture mechanics. The expert's role in product liability litigation.

560. Modeling Dynamic Systems. ***Prerequisite: Mech. Eng. 340. I.*** (3).
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs.

561. Design of Automatic Control Systems. ***Prerequisite: Mech. Eng. 461 and Mech. Eng. 560. II.*** (3).
Topics from control theory are introduced in the context of control systems design. Topics such as state variable feedback, modal control, optimal control, and adaptive control are introduced for both continuous and discrete systems. Design application is emphasized through the use of selected case studies.

562. Dynamic Behavior of Thermal-Fluid Processes. ***Prerequisite: Mech. Eng. 478. II.*** (3).
Principles of transport processes and automatic control. Techniques for dynamic analysis; dynamic behavior of lumped- and distributed-parameter systems, nonlinear systems, and time-varying systems; measurement of response; plant dynamics. Experimental demonstration for dynamic behavior and feedback control of several thermal and fluid systems.

564. (I.&O.E. 564). Computer Aided Design Methods. ***Prerequisite: Mech. Eng. 464 or Appl. Mech. 460 or I.&O.E. 373.*** (3).
Generalized mathematical modeling of engineering systems, methods of solution and simulation languages. Analysis methods in design; load, deformation, stress and finite element considerations; non-linear programming. Computational geometry; definition and generation of curves and surfaces. Computer graphics; transformations; clipping and windowing; graphics systems; data structures; command languages; display processors.

566. Engineering Design Optimization. ***Prerequisite: graduate standing. II.*** (3).
Mathematical modeling of design problems for optimization. Emphasis on analytical techniques, monotonicity analysis, bounding functions, geometric programming and extensions. Students propose a design term project from various engineering disciplines and apply the theory to analyze their individual problem.

568. Design of Engineering Experiments. ***Prerequisite: Mech Eng. 362. II.*** (3).
Design of experiments and interpretation of test data; reliability of measurements, experiments of exploration, evaluation and comparison; evaluation and comparison; experiments to determine the effect of design changes, relationship between variables, and to establish optimum design; parametric and non-parametric tests; statistical tools.

570. Approximate Methods in Mechanical Engineering. ***Prerequisite: senior standing. II.*** (3).
Orthogonal and non-orthogonal expansions. Matrix algebra and algebraic eigenvalue problems. Finite difference formulation and solution. Integral and variational approaches to finite element formulation. Solution by electronic calculator and digital computer. Application to conduction, convection, and radiation heat transfer, and fluid and solid mechanics.

572. Convection Heat Transfer. ***Prerequisite: Mech. Eng. 371. II.*** (3).
Differential and integral formulations of convection. Parallel and nearly parallel laminar (boundary layer) flows. Similarity solutions. Periodic convection. Computational convection. Instability and turbulence. Kinetic and thermal scales and spectra. Flow prediction. Heat transfer prediction. Multiple scale dimensional analysis. Technological applications.

573. Radiative Heat Transfer. ***Prerequisite: Mech. Eng. 371. I.*** (3).
Electromagnetic, optical and quantum aspects of radiative equilibrium. Enclosure radiation including spatial, specular, and spectral distributions. Gas radiation including boundary affected thin gas and thick gas approximations. Averaged and spectral properties. Technological applications.

583. Sensing and Modeling for Manufacturing Control. ***Prerequisite: Mech. Eng. 381; preceded or accompanied by Mech. Eng. 461 or 483. I.*** (3).
Fundamental concepts in manufacturing with emphasis on welding, machining, and forming. Input and output variables for process control. Characteristics of sensors for feedback in manufacturing. Fiber optics, interferometry, infrared thermal imagery, tactile sensing, force/torque sensing for robots, force dynamometers, acoustic emission. Signal processing. Process modeling for control.

585. Time Series Analysis for Manufacturing Systems. ***Prerequisite: Mech. Eng. 461, or Stat. 402, Stat. 310, or EECS 401. II.*** (3).
Principles for identifying parametric time series models from discrete data and the relationship to autovariance, spectrum, and the Green's function from linear system theory are considered. Theory is developed for application to prediction, characterization, signature analysis, and process identification and control.

586. Materials in Manufacturing and Design. ***Prerequisite: Mech. Eng. 381. I and II.*** (3).
Material selection on the basis of cost, strength, formability and machinability. Advanced strength analysis of heat treated and cold formed parts including axial, bending, shear and cyclic deformation. Correlations of functional specifications and process capabilities. Problems in redesign for productibility and reliability.

590. Master's Thesis Proposal. ***Prerequisite: graduate standing in Mechanical Engineering. I, II, IIIa, IIIb, and III.*** (3). ***(Not for credit unless 6 hrs of Mech. Eng. 690 satisfactorily completed.)***
A course devoted to literature search, analysis, design of experiments and other related matters prior to completion of a master's degree thesis. A thesis proposal clearly delineating the proposed research and including the above items is required at the conclusion of the course.

594. Internal-Combustion Engines II. ***Prerequisite: Mech. Eng. 496. I.*** (3).
Balancing of engines, advanced thermodynamic analysis of engines; chemical equilibrium, theory and control of combustion knock; combustion and air pollution problems; principles underlying recent advances in power development systems.

598. Vehicle Dynamics. ***Prerequisite: Mech. Eng. 440 or Appl. Mech. 440. II.*** (3).
Dynamic behavior of vehicles supported on pneumatic tires. Static and dynamic aspects of tire behavior; mechanical models of the pneumatic tire. Directional stability and response of double- and single-track vehicles; ride phenomena treated as a random process. Aerodynamics of bluff bodies.

600. Study of Research in Selected Mechanical Engineering Topics. ***Prerequisite: graduate standing: permission of instructor who will guide the work should be obtained before registration. I, II, IIIa and IIIb. (Credit to be arranged; a maximum of six credit hours will be allowed toward graduate degrees; three hours per term.)***
Individual or group study, design, or laboratory research in a field of interest to the student. Topics may be chosen from any of the areas of mechanical engineering. The student will submit a report on his project and give an oral presentation to a panel of faculty members at the close of the term. Course grade will be reported as "Satisfactory".

605. (Appl. Mech. 605). Advanced Finite Element Methods in Mechanics. Prerequisite: Mech. Eng. 505. or Appl. Mech. 505. II. (3).
Recent developments in finite element methods; mixed, hybrid, mixed-hybrid, reduced integration penalty, singular, boundary integral elements. Emphasis on the methodology for developing elements by using calculus of variations. Applications selected from various branches of solid and fluid mechanics.

626. (Appl. Mech. 626). Singular-Perturbation and Approximate Mechanics of Fluids I. ***Prerequisite: Appl. Mech. 422 or Mech. Eng. 521. I.*** (3).
Application of asymptotic methods to fluid mechanics, with special emphasis on the method of matched expansions. Regular perturbation solutions, suppression of secular terms, method of multiple times, boundary layer and low Reynolds number flows by inner and outer expansions, phenomena in rotating flows, asymptotic solutions on the Orr-Sommerfeld equation.

635. Thermodynamics IV. ***Prerequisite: Mech. Eng. 535. II.*** (3).
Discussion of thermodynamic systems including surface phenomena, external fields, and relativistic effects. Study of complex equilibrium calculations including effect of heterogeneous reactions and real substance behavior. Introduction to the thermodynamics of irreversible processes with applications to heat and mass transfer, relaxation phenomena and chemical reactions.

641. (Appl. Mech. 641). Advanced Vibrations of Structures. ***Prerequisite: Mech. Eng. 541 or Appl. Mech. 541. II.*** (3).
Energy formulation for nonconservative gyroscopic systems. Spectral methods for free and forced vibrations. Eigenvalue and boundary value problems. Non self-adjoint systems. Variational methods of approximation: Bubnov-Galerkin. Perturbation theory for the eigenvalue problem. Dynamics of rotating systems. Dynamics of constrained dynamical systems.

643. (Appl. Mech. 643). Analytical and Computational Dynamics II. ***Prerequisite: Mech. Eng. 543 or Appl. Mech. 543. II.*** (4).
Kinematical and dynamical equation formulation for rigid and flexible mechanical multibody systems undergoing large overall motion and small elastic deformation. Energy principles, higher and lower pair joint parameterizations, sparse and dense equation formulation and solution techniques, numerical integration, generalized impluse and momentum, collisions, and computational elastodynamics. Course project.

661. Adaptive Control Systems. ***Prerequisite: Mech. Eng. 561. I.*** (3).
Introduction to control of systems with undetermined or time varying parameters. Theory and application of self-tuning and model reference adaptive control for continuous and discrete-time deterministic systems. Model based methods for estimation and control, stability of non-linear systems, adaptation laws, and design and application of adaptive control systems.

672. Turbulent Transport of Momentum, Heat and Mass. ***Prerequisite: Mech. Eng. 572. I.*** (3).
Introduction to laminar flow stability. Statistical and phenomenological theories of turbulence. Turbulent transport of momentum, heat and mass in steady and unsteady internal, boundary layer, and free flows. Skin friction, heat and mass transfer coefficients. Discussion of experimental results.

674. Special Topics in Phase Change Dynamics. ***Prerequisite: Mech. Eng. 474. II.*** (3).
Advanced topics in mechanisms and dynamics of phase change: nucleation, bubble dynamics, cavitation, flow boiling heat transfer, condensation, hydrodynamics of two-phase flow.

690. Master's Thesis Research. ***Prerequisite: Mech. Eng. 590*** (3). ***I, II, IIIa, IIIb, and III.*** (3). ***(Student must elect 2 terms of 3 hrs./term. No credit if student has had Mech. Eng. 600.)***
Student is required to present a seminar at the conclusion of the second election as well as prepare a written thesis.

772. Special Topics in Laminar Transport of Momentum and Heat. ***Prerequisite: Mech. Eng. 572. II.*** (3).
Thermal problems associated with visco-elasto-plastic fluids and solids; electromagnetic and radiation effects.

820. Fluid Mechanics Seminar. ***Prerequisite: graduate standing and permission of instructor. I and II. (To be arranged).***
Reports and discussions on library study and laboratory research in selected topics.

835. Seminar in Thermodynamics. ***Prerequisite: graduate standing and permission of instructor. I and II. (To be arranged).***
Reports and discussions on library study and laboratory research in selected topics.

850. Rheology and Fracture Seminar. ***Prerequisite: graduate standing and permission of instructor. I or II. (To be arranged).***
Selected topics for study and discussion relating atomic mechanisms to mechanical behavior of materials.

990. Dissertation/Pre-Candidate. ***I, II, and III.*** (1-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as candidate.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral Candidate. I, II, and III.*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

Naval Architecture and Marine Engineering

Department Office:
222 Naval Architecture and Marine Engineering Building
phone (313) 764-6470.
See Page 60 for statement on Course Equivalence.

Faculty

Michael G. Parsons, Ph.D., Professor of Naval Architecture and Marine Engineering and Chairman of the Department of Naval Architecture and Marine Engineering

Robert F. Beck, Ph.D., Professor of Naval Architecture and Marine Engineering

Movses Kaldjian, Ph.D., Professor of Naval Architecture and Marine Engineering

William S. Vorus, Ph.D., Professor of Naval Architecture and Marine Engineering

John Woodward, Ph.D., Professor of Naval Architecture and Marine Engineering

Raymond A. Yagle, M.S.E., Professor of Naval Architecture and Marine Engineering

Harry Benford, B.S.E., Professor Emeritus of Naval Architecture and Marine Engineering

Richard Couch, Ae.E., Professor Emeritus of Naval Architecture and Marine Engineering

Amelio M. D'Arcangelo, M.S., Professor Emeritus of Naval Architecture and Marine Engineering

Klaus-Peter Beier, Dr. Ing., Associate Professor of Naval Architecture and Marine Engineering

Michael M. Bernitsas, Ph.D., Associate Professor of Naval Architecture and Marine Engineering

Terry E. Brockett, Ph.D., Associate Professor of Naval Architecture and Marine Engineering

Howard M. Bunch, M.S.E., C.M.A., Associate Professor of Transportation Management

Guy A. Meadows, Ph.D., Associate Professor of Physical Oceanography

Armin W. Troesch, Ph.D., P.E., Associate Professor of Naval Architecture and Marine Engineering

Anastassios N. Perakis, S.M. (M.B.A.), Ph.D., Assistant Professor of Naval Architecture and Marine Engineering

102. (NS102). Introduction to Ship Systems. II. (3).
Types, structures, and purposes of ships. Ship compartmentation, propulsion systems, auxiliary power systems, interior communications, and ship control. Elements of ship design to achieve safe operations, and ship stability characteristics. Not open for credit to students in Naval Architecture and Marine Engineering.

270. Ship Design I. ***Prerequisite: preceded or accompanied by Mech. Eng. 101. I and II.*** (3).
Overall view of the ship design process. Weights, buoyancy, stability, powering, and economics. Each student designs a simple ship to satisfy a set of performance specifications. Hull lines are created and faired.

302. Static Stability of Marine Vehicles. ***Prerequisite: Nav. Arch. 270., Eng. 103. II.*** (3).
Calculation of areas, volumes, centers. Statical stability, damaged stability, launching. Use of digital computer is emphasized in all problems.

310. Ship Strength I. ***Prerequisite: Mech. Eng. 210. I.*** (4).
Quasi-static analysis of hull loading. Hull primary response. Introduction to the probabilistic approach. Strength of plated structures and ship's structural components. Combined stresses and failure theories. Framing systems. Brittle fracture and fatigue failure modes; structural details. Midship section synthesis, including classification society rules and techniques of stress superposition. Material and fabrication considerations.

320. Ship Resistance and Propulsion I. ***Prerequisite: Nav. Arch. 270 and Mech. Eng. 325. I.*** (4).
Ship resistance components: skin friction, form drag, wave resistance. Resistance prediction from standard series. Propeller geometry and design. Hull-propeller interaction, propeller charts, powering prediction. Model testing in the towing tank: hull resistance, wake survey, open water propeller test, shaft horsepower.

330. Ship Power Systems I. ***Prerequisite: Mech. Eng. 235; preceded or accompanied by Mech. Eng. 325. I.*** (4).
Principles of steam turbine, gas turbine,

and diesel marine power systems including power cycles, operating characteristics, and limitations. Engine-propeller matching and propulsion power transmission. Selection of propulsion systems. Introduction to marine boilers and nuclear reactors. Principles of electric power generation. Electric load analysis. Electric drive operating principles and characteristics. Introduction to heat transfer, including conduction and heat exchange design. Principles of fluid system design.

340. Ship Dynamics I. ***Prerequisite: Nav. Arch. 302; preceded or accompanied by Mech. Eng 325 and Nav. Arch. 380. II.*** (4).
Periodic motion. Free and forced vibration for multi-degree of freedom systems. Coupling. Hull vibration. Propeller excitation. Rigid body motions of floating structures. Response operators. Absorbers. Hydrodynamic added mass and damping. Random processes and time series. Fourier series. Response functions. Spectral density functions and wave spectra.

350. (A.O. & S.S. 350). Ocean Engineering. ***Prerequisite: Mech. Eng. 325. II.*** (3).
Engineering analyses of work systems for operation in and on the ocean. Offshore drilling platforms, submersibles and semi-submersibles. Cables and moorings. Buoy systems, pipe laying, salvage and rescue systems, ocean mining. Selected aspects of physical oceanography, underwater acoustics and instrumentation.

380. Maritime Management I. ***Prerequisite: junior standing. II.*** (4).
Probability and statistics for marine problems. Engineering economics in ship design and operation. Shipping and ship-building industries. Cost estimates, contracts, specifications. Ship production methods, planning, inventory, quality control.

401. Small Craft Design. ***Prerequisite: preceded or accompanied by Nav. Arch. 320.*** (3).
Design of planing craft, hydrofoils, and other small high performance craft.

403. Sailing Craft Design Principles. ***Prerequisite: preceded or accompanied by Nav. Arch. 320.*** (3).
Application of hydrodynamic and aerodynamic principles to the design of sailing craft.

410. Ship Strength II. ***Prerequisite: Nav. Arch. 310; preceded or accompanied by Nav. Arch. 340. I and II.*** (3).
Equilibrium methods, energy methods and matrix methods are applied to problems in linear elastic beam theory. Solutions for classic beam problems include static bending, buckling, and vibration. Example problems in ship structural design and modeling techniques are reviewed.

411. (Aero. Eng. 411) (Appl. Mech. 411) (Civ. Eng. 411). Finite Element Applications. ***Prerequisite: Eng. 103, Mech. Eng. 211. I.*** (3).
The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and interpret results. A short introduction to the underlying theory is also presented.

420. Ship Resistance and Propulsion II. ***Prerequisite: Nav. Arch. 320. I.*** (3).
Viscous fluid theory applied to ships. Navier-Stokes equations, boundary layer theory, separation, form drag. Ideal fluid theory, Laplace and Bernoulli equations, method of singularities, numerical hydrodynamics. Two-dimensional and three-dimensional airfoil theory. Theoretical propeller design.

421. Ship Model Testing. ***Prerequisite: Undergraduates only and permission of instructor. I, II, and IIIa, (To be arranged.) Undergraduates only.***
Individual or team project, experimental work, research or directed study of selected advanced topics in ship model testing.

425. Physics of the Oceans. ***Prerequisite: senior or graduate standing. II.*** (3).
Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on thermodynamics and equations of state of sea water, optical and acoustical properties of sea water, currents, tides, waves and turbulent phenomena.

430. Ship Power Systems II. ***Prerequisite: Nav. Arch. 330. II.*** (3).
Review of heat exchanger design, and of thermodynamic topics pertinent to marine energy use. Alignment of reduction gears and propulsion shafting. Electric power topics, including characteristics of motors and generators, generators in parallel.

440. Ship Dynamics II. ***Prerequisite: Nav. Arch. 340. I.*** (3).
Theory of random processes, probability density functions. Wave spectra formulations, determination of ship motions and loads in a seaway. Linearized equations of motion for a ship in six degrees of freedom. Damping. Analytical treatment of added mass, introduction to strip theory. Hull surface forces and vibratory response.

450. (A.O. & S.S.450). Coastal and Offshore Engineering. ***Prerequisite: Nav. Arch. 340 or A.O. & S.S. 335. I.*** (3).
Dynamics of ocean waves. Deep and shallow water waves. Mechanics of sediment movement due to waves and current. Effect of sediment transport on off-shore structures. Loading and motions of offshore structures. Morison's equation. Current and wind loads. Wave loading. Absolute and relative motions of buoys and platforms in head seas.

460. Ship Production Planning and Control. ***Prerequisite: Nav. Arch. 380, preceded or accompanied by Nav. Arch. 470. II.*** (3).
Overview of ship production systems; shipyard organization and arrangement; product standardization and work simplification systems; performance measurement; use of models and composites; PERT/CPM and other control techniques; the design and use of Information Systems for Production Control.

469. (A.O. & S. S. 469). Underwater Operations. ***Prerequisite: permission of instructor. II.*** (3).
Survey of manned undersea activities in oceanography and ocean engineering. The tools of underwater operations: decompression chambers, habitats, submarines, diving apparatus; pertinent design criteria and applications as based on human hyperbaric physiology and performance. Topics in research diving for engineering and oceanographic studies.

470. Ship Design II. ***Prerequisite: senior standing. I and II.*** (3).
Preliminary design methods, general arrangements and outfitting of ships. Given the owner's general requirements, the student blocks out initial design characteristics for the ship.

474. Optimization and Numerical Methods in Marine Design. ***Prerequisite: Nav. Arch. 302, Eng. 103. I.*** (3).
Preliminary design models. Numerical methods for curve fitting, interpolation, integration, linear equations, regression, eigen values. Optimization methods applied to marine design problems.

475. Design Project. ***Prerequisite: Nav. Arch. 470. I, II, and IIIa.*** (3).
Completion of a design project begun in Nav. Arch. 470. This will usually be the preliminary design of a ship with an emphasis on hull and/or machinery. Team or individual study.

485. Maritime Management II. ***Prerequisite: Nav. Arch. 380. I.*** (3).
Structural analysis of industries. Measures of merit. Risk; utility theory. Tradeoff analysis; optimization (linear, integer, dynamic

programming) applications in maritime management. Fleet deployment. International trade theory. Tariffs, quotas and other barriers. OPEC and tanker shipping. The basing point system. Rate formation in conference systems. Maritime policy, tax law, and admiralty law.

490. Directed Study, Research and Special Problems. ***Prerequisite: undergraduate only and permission. I, II and IIIa. (To be arranged).***
Individual or team project, experimental work or study of selected topics in naval architecture or marine engineering. Intended primarily for students with senior standing.

510. Ship Structure Analysis I. ***Prerequisite: Nav. Arch. 410. I.*** (3).
Analysis of continuous frames, curved beams and variable cross-section structural members. Stiffened plates and cylindrical shells. Bulkheads and other grillage structures. Buckling strength.

511. Special Topics in Ship Structure. ***Prerequisite: prior arrangement with instructor. (To be arranged).***
Individual or team project, experimental work, research or directed study of selected advanced topics in ship structure. Primarily for graduate students.

518. Strength Reliability of Ship and Offshore Structures. ***Prerequisite: Nav. Arch. 410, Aero. Eng. 452. I.*** (3).
Stress versus strength analysis. Deterministic stress analysis, safety factor approach. Random nature of loads, geometry material and construction. Random variables and random functions. Reliability of structures described by one or more random variables. Introduction to random vibration of discrete and continuous structural systems.

520. Ship Resistance and Propulsion III. ***Prerequisite: Nav. Arch. 420. II.*** (3).
Ideal fluid theory. Surface distribution of singularities. Green's theorem, sources, dipoles, vortices. Numerical hydrodynamics using boundary integral methods. Two-dimensional unsteady airfoil theory. Ship wave resistance, Michel's integral, wave cut analysis, and hull form optimization.

521. Directed Study and Research in Marine Hydrodynamics. ***Prerequisite: permission of instructor. (To be arranged).***
Individual or team project, experimental work, research or directed study of selected advanced topics in ship hydrodynamics. Primarily for graduate students.

528. (A.O. & S. S. 528). Remote Sensing of Ocean Dynamics. ***Prerequisite: Nav. Arch. (A.O. & S. S.) 335 or permission of instructor. II.*** (3).
The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means.

530. Automatic Control in Naval Architecture and Marine Engineering. ***Prerequisite: EECS 460 or Aero. Eng. 471. I.*** (3).
Applications of classical and modern control design methods. Emphasis on ship steering and ship motions control. Review of classical methods and their use in design. Describing functions. State variable design methods using pole placement, deterministic observers, and multivariable integral control. Optimal stochastic control and Kalman filter design. Model reference adaptive control.

531. Marine Propulsion Plant Dynamics. ***Prerequisite: Nav. Arch. 340 and Nav. Arch. 430. II.*** (3).
Vibration of marine propulsion systems and machinery. Torsional analysis of turbine and diesel propulsion systems. Longitudinal analysis of shafting systems. Coupling of longitudinal and torsional modes. Lateral analysis of propulsion shafting. Simulation of marine propulsion systems using digital and analog computers.

540. Ship Dynamics III. ***Prerequisite: Nav. Arch. 440. II.*** (3).
Motion of ships in calm water and waves. Forces on stationary bodies in waves and moving at constant speed. Statistical analysis of ship motion.

550. (A.O. & S.S. 550). Offshore Engineering Analysis. ***Prerequisite: Nav. Arch. 410, 420, 440, and 450. (A.O. & S. S. 450) II.*** (3).
Prediction of hydrodynamic loading of large offshore structures. Three dimensional source-sink distribution methods. Calculation of drift forces due to waves and currents. Empirical analysis of viscous forces on structural members. Morison's equation. Static and dynamic analysis and design of risers, cables and pipelines. Spectral fatigue analysis of offshore structures.

560. Ship Production II. ***Prerequisite: Nav. Arch. 460. I.*** (3).
Selected areas of ship production, including group technology, welding processes, accuracy control, production planning and control, human resource development. Specialized production; naval vessels, workboats, recreational boats.

571. Ship Design III. ***Prerequisite: prior arrangement with instructor (To be arranged).***
Individual (or team) project, experimental work, research or directed study of selected advanced topics in ship design. Primarily for graduate students.

574. Computer-Aided Hull Design and Production. ***Prerequisite: graduate standing or permission. II.*** (3).
Hull surface representation, creation, distortion, fairing. Computer-aided arrangement, piping, structures. Computer systems for structural detailing, production, manufacturing.

575. Computer-Aided Marine Design Project. ***Prerequisite: Nav. Arch. 574. I, II, IIIa, IIIb, and III.*** (2-6).
Development of computer-aided design tools. Projects consisting of formulation, design, programming, testing, and documentation of programs for marine design and constructional use.

582. Marine Reliability and Tradeoff Analysis. ***Prerequisite: EECS 401. I.*** (3).
Review of probability, statistics, and elements of financial management. Tradeoff analysis. Reliability, availability, maintenance, replacement, and repair decisions. Fault tree and event tree analysis. Marine applications.

590. Reading and Seminar. ***Prerequisite: permission. I, II, IIIa and IIIb. (To be arranged).***
A graduate level individual study and seminar. Topic and scope to be arranged by discussion with instructor.

592. Master's Thesis. (3).

610. (Civ. Eng. 610). Finite Element Methods. ***Prerequisite: Eng. 103, and Nav. Arch. 510 or Civ. Eng. 512. II.*** (3).
Influence coefficients and stiffness matrices. Formulation and calculation of the finite element matrices using the principles of virtual displacements. Preparing computer programs. Introduction to the isoparametric family of elements. Familiarization with and use of existing finite element programs and pre-and post-processor for data processing and graphic display.

615. Ship Structure Analysis III. ***Prerequisite: Nav. Arch. 510 and prior arrangement with instructor. (To be arranged).***
Advances in specific areas of ship structure analysis as revealed by recent research. Lectures, discussions, and assigned readings.

621. Experimental Marine Hydrodynamics. ***Prerequisite: Nav. Arch. 520 and 540. IIIa.*** (3).
Non-steady state ship model testing to compare hydrodynamic theory to experimental results, to develop experimental techniques, and to illustrate advanced applications. Propellers, seakeeping, vibrations, waves, resistance, etc.

622. Real Flows of Marine Hydrodynamics. ***Prerequisite: Nav. Arch. 520. I.*** (3).
Review of the basic equations: Stokes equations, Helmholtz vorticity equation, Biot-Savart law. Boundary layer theory, Stability considerations. Simple models for turbulence: eddy viscosity and mixing length theories. The integro-differential velocity-vorticity formulation. Degeneration to the Green's theorem formulation of ideal flows at infinite Reynolds number; some approximate solutions.

624. Marine Propulsors. ***Prerequisite: Nav. Arch. 420, Nav. Arch. 520, and graduate standing. II.*** (3).
Propeller series, momentum analysis, geometry, hull/propeller interaction. Lifting line and lifting surface theory. Operation in non-uniform flow. Propeller noise. Compound propulsors: tandem, contra-rotating, preswirl, ducted.

625. Special Topics in Marine Hydrodynamics. ***Prerequisite: permission. I and II. (To be arranged).***
Advances in specific areas of marine hydrodynamics as revealed by recent research.

635. Special Topics in Marine Engineering. ***Prerequisite: permission. I and II. (To be arranged).***
Advances in specific areas of marine engineering as revealed by recent research. Lectures, discussions, and assigned readings.

655. Special Topics in Offshore Engineering. ***Prerequisite: permission. I. and II. (To be arranged).***
Advances in specific areas of offshore engineering as revealed by recent research. Lectures, discussions, and assigned readings.

685. Special Topics in Marine Systems. ***Prerequisite: permission of instructor. I and II. (To be arranged).***
Advances in specific areas of marine systems engineering as revealed by recent research. Lectures, discussions, and assigned readings.

792. Professional Degree Thesis. I, II and III. (2-8); ***IIIa and IIIb.*** (1-6).

990. Dissertation/Pre-Candidate. I, II, and III. (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III.*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

Nuclear Engineering

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phone (313) 764-4261
See Page 60 for statement on Course Equivalence.

Faculty

Glenn F. Knoll, Ph.D., Professor of Nuclear Engineering and Chairman of the Department of Nuclear Engineering

A. Ziya Akcasu, Ph.D., Professor of Nuclear Engineering

James J. Duderstadt, Ph.D., Professor of Nuclear Engineering, President of the University

Terry Kammash, Ph.D., Stephen S. Attwood Professor of Nuclear Engineering

William Kerr, Ph.D., Professor of Nuclear Engineering

John S. King, Ph.D., Professor of Nuclear Engineering

Edward W. Larsen, Ph.D., Professor of Nuclear Engineering

John C. Lee, Ph.D., Professor of Nuclear Engineering

William R. Martin, Ph.D., Professor of Nuclear Engineering

George C. Summerfield, Ph.D., Professor of Nuclear Engineering

Dietrich H. Vincent, Dr. Rer. Nat., Professor of Nuclear Engineering

Michael M.R. Williams, Sc.D., Professor of Nuclear Engineering

Ronald M. Gilgenbach, Ph.D., Associate Professor of Nuclear Engineering

Gary S. Was, Sc.D., Associate Professor of Nuclear Engineering

Michael Atzmon, Ph.D., Assistant Professor of Nuclear Engineering

Mary L. Brake, Ph.D., Assistant Professor of Nuclear Engineering

David K. Wehe, Ph.D., Assistant Professor of Nuclear Engineering

100. Nuclear Energy in Modern Society. ***I and II.*** (2).
Nuclear power, as an example of introducing new technology for societal use. Human energy needs vs. consumption, alternative energy technologies (solar, fossil, and nuclear), natural and man-made radiation environment, nuclear medicine, nuclear energy, and the Green Revolution. Guest lecturers.

311. Elements of Nuclear Engineering I. ***Prerequisite: Physics 242, preceded or accompanied by Math. 450.*** (3).
Properties and structure of nuclei. Radioactivity; alpha-, beta-, and gamma-decay. Nuclear reaction. Interaction of neutron, gamma rays, and charged particles with matter. Nuclear fission.

312. Elements of Nuclear Engineering II. ***Prerequisite: Nuc. Eng. 311. II.*** (3).
Neutron physics; the four-factor formula for the multiplication constant for the infinite reactor; neutron generation time; one-speed neutron diffusion with elementary solutions; space-independent slowing down theory. Nuclear fusion.

315. Nuclear Instrumentation Laboratory. ***Prerequisite: preceded or accompanied by Nuc. Eng. 312. II.*** (4).
An introduction to the devices and techniques most common in nuclear measurements. Topics include the principles of operation of gas-filled, solid state, and scintillation detectors for charged particle, gamma ray, and neutron radiations. Techniques of pulse shaping, counting, and analysis for radiation spectroscopy. Timing and coincidence measurements.

317. Radiation Detection and Measurement. ***Prerequisite: Nuc. Eng. 311, EECS 314 or equivalent. No Nuclear Engineering credit for both Nucl. Eng. 315 and 317. I.*** (3).
A general coverage of the instruments and techniques of importance in radiation measurements. Sources, interactions, and units of ionizing radiation. Counting statistics and measurement errors. Ion chambers, proportional counters, Geiger tubes, scintillators, semiconductor diodes, Ge(Li) detectors, and neutron detectors. Pulse processing and multichannel analysis. Background and shielding.

400. Elements of Nuclear Energy. ***Prerequisite: junior standing. I and II.*** (3).
Ideas and concepts important to the development of nuclear energy for peaceful purposes—designed for those in fields other than nuclear engineering. Principal emphasis upon fission reactors and fusion reactor research. History of the nuclear energy program, elementary nuclear physics, radiologic health physics, and nuclear medicine.

421. Nuclear Engineering Materials. ***Prerequisite: Nuc. Eng. 312. I.*** (3).
An introduction to materials for nuclear fuels, nuclear reactors, and nuclear radiation detection, including radiation effects in these materials due to neutrons, charged particles, and gamma radiation.

425. Applied Nuclear Radiation. ***Prerequisite: Nuc. Eng. 315. I.*** (4).
Nuclear methods for materials analysis, including activation analysis, neutron diffraction and neutron radiography, tracer methods, ion beam analysis, Mössbauer spectroscopy. Lectures and laboratory.

441. Introduction to Nuclear Fission Reactors. ***Prerequisite: Nuc. Eng. 312 and Math. 454 or Math. 455. I.*** (4).
An introduction to the theory of nuclear fission reactors including such topics as neutron diffusion, the one-speed theory of nuclear reactors, reactor kinetics, multigroup diffusion theory and criticality calculations, and neutron slowing down and thermalization.

442. Nuclear Power Reactors. ***Prerequisite: Nuc. Eng. 441. II.*** (3).
Analysis of nuclear fission power systems including an introduction to nuclear reactor design, reactivity control, core thermal-hydraulics and feedback, fuel depletion, nuclear fuel management, environmental impact and plant siting, and nuclear systems analysis.

443. (Mech. Eng. 470). Heat Transfer ***Prerequisite: Mech. Eng. 231 or 236, Math. 454 or 455. Not open to Mech. Eng. Majors. I.*** (3).
Mechanisms of heat transfer. Steady and transient conduction in solids; approximate and exact solution procedures. Convection processes; laminar and turbulent (dimensional analysis with experiment). Heat exchanger design and performance. Thermal radiation. Introduction to diffusion and mass transfer between phases. Special emphasis on systems involving energy generation.

445. Nuclear Reactor Laboratory. ***Prerequisite: Nuc. Eng. 315 and Nuc. Eng. 441. II and IIIa.*** (4).
Measurements of nuclear reactor performance: activation methods, rod worth, critical loading, power and flux distributions, void and temperature coefficients of reactivity, xenon transient, diffusion length, pulsed neutrons.

462. Reactor Safety Analysis. ***Prerequisite: preceded or accompanied by Nuc. Eng. 441. II.*** (3).
Analysis of those design and operational features of nuclear reactor systems that are relevant to safety. Reactor siting, reactor containment, engineered safeguards, transient behavior and accident analysis for representative reactor types. NRC regulations and procedures. Typical reactor hazards analyses.

471. Introduction to Plasmas and Fusion. ***Prerequisite: Nuc. Eng. 312. I.*** (3).
Introduction to the requirements and operation of fusion systems. Reaction cross sections. Plasmas and plasma containment. Wave phenomena in plasmas. Analysis of simple laboratory plasmas and devices, including glow discharges, probes and simple pinches.

472. Fusion Reactor Technology. ***Prerequisite: Nuc. Eng. 471. II.*** (3).
Study of technological topics relevant to the engineering feasibility of thermonuclear fusion reactors as power sources; including energy and particle balances in fusion reactors; neutronics including tritium breeding and neutron damage; various approaches to plasma fueling and heating; adiabatic compression and reactor ignition; dynamics and control; and special topics including environmental aspects.

481. (Bioeng. 481). Engineering Aspects of Radiology and Nuclear Medicine. ***II.*** (2).
An introduction to the physical principles, instrument systems, and analytical methods of importance in radiation-related medical procedures. Topics are drawn from research and clinical activities in diagnostic radiology, nuclear medicine, and radiation therapy.

490. Special Topics in Nuclear Engineering I. ***Prerequisite: permission of instructor. (To be arranged).***
Selected topics offered at the senior or first-year graduate level. The subject matter may change from term to term.

499. Research in Nuclear Engineering. ***Prerequisite: permission of instructor.*** (1-3).
Individual or group research in a field of interest to the student under the direction of a faculty member of the Nuclear Engineering Department.

511. Quantum Mechanics in Neutron-Nuclear Reactions. ***Prerequisite: Nuc. Eng. 312 and Math. 450. I.*** (3).
An introduction to quantum mechanics with applications to nuclear science and nuclear engineering. Topics covered include the Schroedinger equation and neutron-wave equations, neutron absorption, neutron scattering, details of neutron-nuclear reactions, cross sections, the Breit-Wigner formula, neutron diffraction, nuclear fission, transuranic elements, the deuteron problem, masers, and lasers.

512. Interaction of Radiation and Matter. ***Prerequisite: Nuc. Eng. 511. II.*** (3).
Classical and quantum-mechanical analysis of the processes by which radiation interacts with matter. Review of nuclear structure and properties. Nuclear models. Nuclei as sources of radiation. Interaction of electromagnetic radiation with matter. Interaction of charged particles with matter. Radiative collisions and theory of bremsstrahlung. Interaction of neutrons with matter. Interaction mechanisms and cross sections are developed.

515. Nuclear Measurements Laboratory. ***Prerequisite: permission of instructor. I.*** (4).
Principles of nuclear radiation detectors and their use in radiation instrumentation systems. Characteristics of important devices with applications in nuclear science. Gamma ray spectroscopy, fast and thermal neutron detection, charged particle measurements, pulse analysis, nuclear event timing, and recent development in nuclear instrumentation.

521. Radiation Effects in Nuclear Materials. ***Prerequisite: permission of instructor. I.*** (3).
Radiation effects in crystalline solids; defect production, spike phenomena, displacement cascades, interatomic potentials, channeling, focusing, slowing down. Radiation effects on mechanical behavior of reactor components; creep, hardening, fracture, fatigue. Applications to pressure vessel steels, in-core components, and fusion reactor wall materials.

522. Nuclear Fuels. ***Prerequisite: permission of instructor. II.*** (3).
Nuclear reactor fuels; physical properties, radiation damage, thermal response. Fuel behavior; densification, fission-gas release, swelling, burn-up. Cladding; metallurgy, mechanical properties, corrosion behavior, radiation effects. Fuel design and fabrication, fuel behavior. Fusion reactor fuels.

541. Nuclear Reactor Theory I. ***Prerequisite: Math. 454 or 455 and Nuc. Eng. 312 or Nuc. Eng. 511 concurrently. I.*** (3).
A graduate level course on the principles of nuclear fission reactors including neutron transport theory, the P_n approximation, multigroup diffusion methods, fast and thermal group constant generation, core lattice analysis. A strong emphasis will be placed on numerical analysis and computer methods.

542. Nuclear Reactor Theory II. ***Prerequisite: Nuc. Eng. 541. II.*** (3).
A continuation of Nuc. Eng. 541 including neutron resonance absorption and thermalization, perturbation and variational methods, flux synthesis, and numerical methods for solving the neutron transport equation including S_n and B_n methods, collision probabilities, and Monte Carlo methods.

551. Nuclear Reactor Kinetics. ***Prerequisite: preceded or accompanied by Nuc. Eng. 441. II.*** (3).
Derivation and solution of point reactor kinetic equations; concept of reactivity and inhour equation; reactor transfer function; physical origin and mathematical description of feedback. Linear and non-linear stability of reactors, and the derivation of the stability criteria. Lyapunov's theory with reactor applications. Space-dependent reactor kinetics and xenon oscillations, coupled core analysis, introduction to reactor noise analysis.

554. Radiation Shielding. ***Prerequisite: preceded or accompanied by Nuc. Eng. 441. I.*** (3).
A macroscopic study of the absorption of nuclear radiation in dense material with applications to radiation shielding. Topics considered include radiation sources, permissible radiation levels, gamma-ray attenuation, neutron attenuation, shield optimization, heat generation and removal in shields, and other related problems.

561. Nuclear Core Design and Analysis I. ***Prerequisite: preceded or accompanied by Nuc. Eng. 542. II.*** (3).
Analytical investigation of areas of special importance to the design of nuclear reactors. Includes development, evaluation, and application of models for the neutronic, thermalhydraulic, and economic behavior of both thermal and fast reactors. Typical problems arising in both design and operation of nuclear reactors are considered. This course includes extensive use of digital computers.

562. Nuclear Core Design and Analysis II. ***Prerequisite: Nuc. Eng. 561. IIIa.*** (3).
Continuation of subject matter covered under Nuc. Eng. 561 with emphasis on applications of analytical models to the solution of current problems in reactor technology.

571. Plasmas and Controlled Fusion I. ***Prerequisite: permission of instructor. I.*** (3).
Fundamentals of the physics of fusion and of ionized gases. The basic equations describing the collective behavior of charged particles are formulated. General physical implications of these equations are examined.

572. Plasmas and Controlled Fusion II. ***Prerequisite: Nuc. Eng. 571. II.*** (3).
Investigations in plasma dynamics based on the Boltzmann and Fokker-Planck equations of magneto-hydrodynamics. Study of problems of containment, pinch effect, plasma oscillation, diffusion.

575. (EECS 519). Plasma Dynamics and Particle Optics Laboratory. ***Prerequisite: preceded or accompanied by a course in plasmas or physical electronics. II*** (3).
Experimental techniques for plasma dynamics, electron and ion beam technology, and vacuum technology. Experiments will be on microwave and probe diagnostics of plasmas, plasma instabilities, vacuum systems, plasma generation, electron and ion beam generation and optics, and other topics of current interest. Lectures will be given for background material.

576. Principles of Charged Particle Accelerators. ***Prerequisite: Phys. 242 and 405 or permission of instructor, EECS 314 and 315. I, alternate years.*** (3).
Study of electrostatic and electrodynamic accelerator principles and technology. Magnetic and electrostatic focusing of relativistic charged particles. Transient analysis of pulsed accelerators. Poisson/Laplace analysis of accelerator systems and components. Electron beam cathodes. Ion beam sources. Engineering aspects of field emission, insulator flashover, and vacuum arc phenomena.

590. Special Topics in Nuclear Engineering II. ***Prerequisite: permission of instructor. (To be arranged).***
Selected advanced topics such as neutron and reactor physics, reactor core design, and reactor engineering. The subject matter will change from term to term.

599. Master's Project. ***Prerequisite: permission of instructor. I, II, III, and IIIa or IIIb.*** (1-3).
Individual or group investigations in a particular field or on a problem of special interest to the student. The course content will be arranged at the beginning of each term by mutual agreement between the student and a staff member. This course may be repeated for up to 6 credit hours.

644. Transport Theory. ***Prerequisite: Math. 555. I.*** (3).
Mathematical study of linear transport equations with particular application to neutron transport, plasma physics, photon transport, electron conduction in solids, and rarefied gas dynamics; one-speed transport theory; Wiener-Hopf and singular eigenfunction methods; time-dependent transport processes; numerical methods including spherical harmonics, discrete ordinates, and Monte Carlo techniques; non-linear transport phenomena.

671. Theory of Plasma Confinement in Fusion Systems I. ***Prerequisite: Nuc. Eng. 572. I. (alternate years).*** (3).
Study of the equilibrium, stability, and transport of plasma in controlled fusion devices. Topics include MHD equilibrium for circular and non-circular cross section plasmas; magneto-hydrodynamic and microinstabilities; classical and anomalous diffusion of particles and energy, and scaling laws.

672. Theory of Plasma Confinement in Fusion Systems I. ***Prerequisite: Nuc. Eng. 671. II, alternate years.*** (3).
Study of the equilibrium, stability, and transport of plasma in controlled fusion devices. Topics include MHD equilibrium for circular and non-circular cross section plasmas; magneto-hydrodynamic and microinstabilities; classical and anomalous diffusion of particles and energy, and scaling laws.

673. (Aero. Eng. 673) (EECS 617). Topics in Theoretical Plasma Physics. ***Prerequisite: Nuc. Eng. 571 or EECS 517 or Aero. Eng. 726. I and II.*** (3).
This course may be taken for credit more than once. An advanced course in theoretical plasma physics covering topics of current research interest. Specific content will vary from year to year. Representative topics include: studies of weakly ionized plasmas with applications to gas lasers; space plasmas; laser fusion plasmas; and non-linear plasma dynamics and plasma turbulence.

674. Dynamics of Inertially Confined, Dense Plasmas. ***Prerequisite: Nuc. Eng. 571. I, alternate years.*** (3).
Coupling of radiation to electrons and collective modes in dense plasmas. Kinetic and hydrodynamic models for the description of the compression of plasmas to super-solid densities. Interpretation of the measurements of X-ray spectra; neutron, alpha, and mass spectra, etc., emitted by these hot, dense plasmas.

676. Physics of Intense Charged-Particle Beams. ***Prerequisite: Nuc. Eng. 572. I, alternate years.*** (3).
Generation of intense electron and ion beams, dynamics and transport of such beams in vacuum, neutral and ionized gases. Stability and erosion of intense beams with applications to inertial confinement fusion and high-power coherent radiation.

799. Special Projects. (1-6).
Individual or group investigations in a particular field or on a problem of special interest to the student. The project will be arranged at the beginning of the term by mutual agreement between the student and a staff member.

990. Dissertation/Pre-Candidate. ***I, II, and III.*** (2-8); ***IIIa and IIIb.*** (1-4).
Election for dissertation work by doctoral student not yet admitted to status as a Candidate. The defense of the dissertation, that is,

the final oral examination, must be held under a full term candidacy enrollment.

995. Dissertation/Candidate. ***Prerequisite: Graduate School authorization for admission as a doctoral Candidate. I, II and III.*** (8); ***IIIa and IIIb.*** (4).
Election for dissertation work by doctoral student who has been admitted to status as a Candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full term candidacy enrollment.

Physics*

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*College of Literature, Science, and the Arts

Professor H. A. Neal, Chairman; Professors Akerlof, Axelrod, Becchetti, Bretz, Chapman, Clarke, Coffin, Einhorn, Ford, Hecht, Hegyi, Janecke, Jones, Kane, Krimm, Krisch, Lewis, Longo, Meyer, Overseth, Parkinson, Rich, Roe, Ross, Sander, Sanders, Sands, Sinclair, Terwilliger, Thun, Tickle, Tomozawa, van der Velde, Veltman, Ward, Weinreich, Williams, Wu, Yao, Zorn; Associate Professors Gray, Merlin, Rand, Savit, Steel, Uher; Assistant Professors Akhoury, Ben-Jacob, Gidley, Orr, Snow, Tarle.

140. General Physics I. ***Prerequisite: Calculus and Physics 141 to be taken concurrently. I, II, IIIa.*** (3).
The normal course consists of two lectures and two discussions per week. However, there are Keller sections available that meet four hours per week in two-hour sessions. An Honors section may be taken by the well qualified student with permission of the Physics Department. This is the first of a three-term sequence in general physics for scientists and engineers, and the following topics are covered:

Classical Mechanics: Vectors, motion in one dimension, circular motion, projectile motion, relative velocity and acceleration, Newton's Laws, particle dynamics, work and energy, linear momentum, torque, angular momentum of a particle, simple harmonic motion, gravitation, planetary motion, pressure and density of fluids, Archimedes Principle.

141. Elementary Laboratory I. ***To be taken concurrently with Physics 140. I, II, IIIa.*** (1).
One two-hour period of laboratory per week, designed to accompany Physics 140.

240. General Physics II. ***Prerequisite: Physics 140 or equivalent: Physics 241 to be taken concurrently. I, II, IIIa.*** (3).
The normal course consists of two lectures and two discussions per week. However, there are Keller sections available that meet four hours per week in two-hour sessions. An Honors section may be taken by the well qualified student with permission of the Physics Department. This is the second of a three-term sequence in general physics for scientists and engineers, and the following topics are covered:

Electricity and Magnetism: Charge, Coulombs's Law, electric field, Gauss's Law, electric potential, capacitors and dielectrics, current and resistance, EMF and circuits, magnetic field, Biot-Savart Law, Amperes' Law, Faraday's Law of Induction.

Waves: Traveling wave equation, light waves, interference.

241. Elementary Laboratory II. To be taken concurrently with Physics 240. ***I, II, IIIa.*** (1).
One two-hour period of laboratory per week, designed to accompany Physics 240.

242. General Physics III. ***Prerequisite: Physics 240-241 or equivalent. I, II.*** (3).
This is the third of a three-term sequence in general physics for scientists and engineers, and the following topics are covered:

Relativity: Review of spacetime, energy-momentum transformation, invariant mass, mass-energy equivalence, energy-momentum conservation, and applications.

Atomic Physics and Quantum Effects: Rutherford scattering, atomic structure (Bohr, Sommerfeld, Goudsmit-Uhlenbeck), electron spin, Zeeman effect. Waves, Schrodinger equation and its application to free particles, bound states of square well potential, harmonic oscillator and the Hydrogen atom. Rotational spectrum, Band theory of solids, Fermi energy, etc.

250. Introduction to Quantitative Study of the Environment. ***Prerequisite: two and one-half years high school math or any college course in math or natural science. II.*** (3).
A course to develop some techniques and concepts of physics, such as the first and second laws of thermodynamics, in order to understand some environmental problems and their possible solution.

288. Physics of Music. ***II.*** (3).
Lectures, demonstrations, and laboratory designed to acquaint the student with the physical basis of music. Distribution of time between laboratory and demonstrations would depend on enrollment. While no prior formal knowledge of either physics or music theory is required, a reasonably strong interest in music is assumed, as well as a willingness to combine ear and mind in an attempt to analyze the phenomena involved. Topics to be covered include: nature of sound; properties of musical tones; dynamics of vibrating bodies, dynamics of continuous systems; harmonic series; pitch relationships; temperaments and their role as expressions of style; survey of musical instruments.

333. Keller Tutor 140. ***Prerequisite: permission of instructor. I and II.*** (1-3).
Student works as a tutor in Keller Physics 140.

334. Keller Tutor 240. ***Prerequisite: permission of instructor. I and II.*** (1-3).
Student works as a tutor in Keller Physics 240.

401. Intermediate Mechanics. ***Prerequisite: Physics 126 or 240-241 and Math. 216 or equivalent. I and II.*** (3).
The methods of Lagrange and Hamilton are introduced and compared with the Newtonian approach to solving problems.

Simple problems are introduced using the new methods: Simple harmonic motion, problems with springs and pulleys, projectile motion, spherical pendulum.

The theory of small oscillations for two or more dimensions: Secular determinant, eigenfrequencies, normal modes, normal coordinates, the double pendulum, resonance, CO2-like molecules, etc.

Problems with three or more dimensions: Central and planetary motions; the laws of Kepler; Newton's Law of universal gravitation, the theory of the motion of a rigid body, instantaneous angular velocity, the center of mass, the theory of moments of inertia, the theory of the motion of a free rigid body, and the symmetric top.

402. Light. ***Prerequisite: Physics 126 or 240-241 and Math. 216 or equivalent. I.*** (3).
The phenomena of physical optics, reflection, refraction, dispersion, interference, diffraction, polarization, etc., interpreted in terms of the wave theory of light.

403. Optics Laboratory. ***Prerequisite: Physics 242 or permission of instructor. I and II.*** (2).
Laboratory course covering geometrical and physical optics. It is intended for physics and other science majors. Lab experiments cover the following topics: lens equations, lens aberrations, light sources and detectors, polarization, interferometry, diffraction, electro-optical effects, light scattering, spatial filtering, holography, and spectroscopy.

Although no formal optics course is required, students are encouraged to take Physics 402 (Light).

405. Intermediate Electricity and Magnetism. ***Prerequisite: Physics 126 or 240-241 and Math. 216 or equivalent. I and II.*** (3).
The laws and principles of electrostatics, moving electric charges and electromagnetism; introduction to Maxwell's equation.

406. Statistical and Thermal Physics. ***Prerequisite: Physics 126 or 240-241 and Math. 216. I and II.*** (3).
Introduction to thermal processes, including the classical laws of thermodynamics and their statistical foundations: Basic probability concepts, statistical description of systems and particles, thermal interaction, microscopic basis of macroscopic concepts such as temperature and entropy, laws of thermodynamics, elementary kinetic theory of transport processes.

407. Thermodynamics Laboratory. ***Prerequisite: Physics 126 or 240-241. I and II.*** (2).
Laboratory course meeting four hours per week. Normally taken concurrently with Physics 406. Experiments in thermodynamics and heat transport.

409. Modern Laboratory. ***Prerequisite: admission primarily to science majors in the junior year by permission of instructor. I and II.*** (2).
Develops experimental skills as well as acquaints the students with some of the subject matter of modern physics. Experiments available include: electron charge to mass ratio, electron charge, photoelectric effect, optical interferometer, microwaves, velocity of light, and others.

415. Special Problems. ***Prerequisite: permission of instructor. I, II, III, IIIa and IIIb. (Arranged).***

417. Macromolecular and Bio-Physics I. ***Prerequisite: Math. 216, Physics 242, Physics 402, or equivalent or by permission of instructor. I.*** (3).
Introduction to physics techniques to study the ultrastructure of macromolecules and biomolecules: characterization of macromolecular structure; factors influencing conformational stability; an elementary study of structural techniques; scattering theory (x-ray diffraction, light scattering, etc.) and spectroscopic methods (infrared, Raman, UV, NMR, etc.) with application to macromolecules.

418. Macromolecular and Bio-Physics II. ***Prerequisite: Math. 216, Physics 242, 402, 417 or by permission of instructor. II.*** (3).
An intensive study of macromolecular structural problems and their solutions: thermodynamics and statistical mechanics of chain molecules; conformational transitions; denaturation; statistical nature of physical properties; nature of general organization and folding in macromolecules; case studies of structural problems in bio- and macromolecules.

438. Electromagnetic Radiation. ***Prerequisite: Physics 405. II.*** (3).
Electromagnetic waves in free space; propagation of electromagnetic waves in matter; reflection and refraction by dielectrics, conductors and ionized gases; dispersion; wave guides, cavity resonators, and transmission lines; absorption and scattering of light; radiation by dipoles and antennas; radiation by moving charges: bremsstrahlung; synchrotron radiation and Cerenkov radiation.

451, 452. Methods of Theoretical Physics. ***Prerequisite: Physics 401 and Math. 405 or equivalent. 451, I; 452, II. (3 each).***
Applications of matrix theory, vector and tensor analysis, boundary value problems approximation and variational methods, applications from theory of analytic functions. Fourier series and integrals, eigenvalue problems, spherical harmonics, Bessel functions and other special functions of mathematical physics. Green's functions. Other topics may include an introduction to integral equations or group theory with applications to physical problems.

453. Atomic Physics I. ***Prerequisite: Physics 242 or equivalent, 401 or 405, or permission of instructor. I and II.*** (3).
The course is an introduction to quantum mechanics.

Introduction: Bohr model, breakdown of classical mechanics, Stern-Gerlach experiment, probability amplitudes.

Schrödinger Equation: Application to a free particle, reflection at a potential discontinuity, barrier penetration, bound states of a square well, harmonic oscillation, qualitative discussions of solutions of the Schrödinger Equation for the hydrogen atom.

Electron spin and fine structure (hydrogen atom): The Stern-Gerlach experiment, angular momentum coupling for the one-electron atom; semi-quantitative (non relativistic) treatment of spin-orbit coupling and fine structure.

The many electron-atom: Pauli Principle, the periodic table, X-rays, Moseley's Law.

454. Electronic Acquisition and Processing of Physics Data. ***Prerequisite: basic knowledge of computer structure helpful. I.*** (3).
Open to students at the junior, senior, and graduate level. The external characteristics of analog and digital electronic elements are reviewed prior to their use in specific circuits for monitoring and collecting from physics experiments.

455. Electronic Devices and Circuits. ***Prerequisite: Physics 405. I.*** (5).
Physical principles and characteristics of semiconductor devices and vacuum tubes and their application in amplifiers, oscillators, and switching circuits. AC circuit analysis is introduced as required. Three lectures and one laboratory period.

457. Nuclear Physics. ***Prerequisite: Physics 453. II.*** (3).
The course is an introduction to nuclear physics. The basic elements of quantum mechanics are used.

Nuclear Structure: binding energies, size and shape, angular momentum, parity, isospin, magnetic moments, electric quadrupole moments; statistical, shell, and collective models for the nucleus.

Nuclear Decays: radioactivity, barrier penetration and alpha-particle decay, the weak interaction and beta-decay, electromagnetic transitions in nuclei.

Nuclear Interactions: Basic properties of the nuclear force, nucleon-nucleon scattering, the deuteron, nuclear reactions, and reaction models.

Nuclear Radiation: Interaction of charged particles, gamma rays and neutrons with matter, nuclear radiation detectors.

459. Nuclear Laboratory. ***Prerequisite: Physics 242 and one 400-level physics laboratory course, or by permission. I and II.*** (2).
Study of nuclear phenomena and instrumentation. Experiments available include: radioactivity; scintillation counter, angular correlation, Compton effect, Rutherford scattering, cosmic-ray muon lifetime, nuclear magnetic resonance, nuclear fission, neutron diffusion, and others.

460. Atomic Physics II. ***Prerequisite: Physics 453. II*** (2).
This is the second of a two-course sequence on quantum mechanics and atomic physics. The topics covered are:

The two-electron atom: The Pauli exclusion principle, energy levels of the helium atom.

Structure and spectroscopy of many-electron atoms: L-S land j-j coupling, the Zeeman, Stark, and Paschen-Bach effects, hyperfine structure; elementary treatment of transition probabilities and selection rules, line widths and broadening.

Lasers: Stimulated emission, pumping, output characteristics.

Interaction of light microwaves with atoms: Nuclear magnetic resonance, optical pumping, level-crossing spectroscopy.

461. Atomic Laboratory. ***Prerequisite: Physics 242 and one 400-level physics laboratory course or by permission. I and II.*** (2).
Intended for science majors. Covers atomic phenomena. Zeeman Effect, Faraday Effect, optical pumping and mass spectrometer, diffraction of electrons, atomic spectroscopy.

463. Introduction to Solid State Physics. ***Prerequisite: Physics 453 or permission of instructor. I.*** (3).
Structure and physical properties of crystalline solids. Ionic crystals; free electron theory of metals; band theory of solids; effects of impurities and imperfections; theories of magnetism. Introduction to the concepts of phonons, polarons, plasmons, etc. Interaction of radiation with crystalline materials.

464. Solid State Laboratory. ***Prerequisite: Physics 242 and Physics 406. Physics 463 to be taken concurrently or previously.*** (2).
Experimental work in x-ray diffraction from solids, electron transport in solids, phase transitions, the use of the electron microscopes and thermal mechanism in solids.

468. Elementary Particles. ***Prerequisite: Physics 453, or Physics 453 taken concurrently. I.*** (2).
A survey course, emphasizing the systematics of elementary particles, basic theory, and current experimental problems.

505, 506. Electricity and Magnetism. ***Prerequisite: Physics 405 and Math. 450. 505, I.*** (2); ***506, II.*** (3).
Electromagnetic theory; Maxwell's equations and the radiation from a Hertzian oscillator; connections with special relativity theory.

507. Theoretical Mechanics. ***Prerequisite: an adequate knowledge of differential equations: an introductory course in mechanics is desirable. I.*** (2).
Lagrange equations of motion; the principle of least action. Hamilton's principle, the Hamilton-Jacobi equations; Poisson brackets.

510. Statistical Physics. I. (3).
Kinetic and statistical methods of Boltzmann, and explanation of the second law; extension to the quantum theory; nonideal gases and the theory of the solid body; theory of radiation; fluctuation phenomena.

511. Quantum Theory and Atomic Structure I. ***Prerequisite: Physics 453. Physics 511 is a prerequisite for Physics 512. II.*** (3)

512. Quantum Theory and Atomic Structure II. ***Prerequisite: Physics 511. I.*** (3).
Physics 511 and 512 make up a two-term sequence on the quantum theory and its applications to the solution of problems in atomic physics.

513. Advanced Quantum Mechanics I. II. (3).
A review of time dependent perturbation theory, creation and destruction operator formalism, second quantization of the photon field, scattering of photons and atoms, and the Klein-Gordon and Dirac equations.

515, 516. Supervised Research. ***Prerequisite: permission. I and II.*** (4-6) ***each term.***

517. Graduate Physics Laboratory. ***Prerequisite: graduate standing. I.*** (3)
Experiments in atomic, optical, nuclear, condensed matter, and low temperature physics for the graduate student with limited experimental experience.

518. Microcomputers in Experimental Research. ***Prerequisite: graduate standing. II.*** (3).
A laboratory course in the application of microcomputers to experimental research: data acquisition, handling, analysis, and geographical presentation.

520. Solid State. ***Prerequisite: Physics 510, 511 or equivalent. II.*** (3).
Modern theory of solids with emphasis on fundamental interactions: electron states, band theory, electron-electron interactions; phonons; electron-phonon interactions; and topics from transport theory, superconductivity, and semi-conductor physics.

521. Elementary Particle Physics. ***Prerequisite: Physics 506, 512, or equivalent. II.*** (3).
Experimental aspects of the following topics will be covered in depth; particles and their quantum numbers; measurement techniques; basic symmetries, e.g., parity, charge conjugation, etc.; weak interactions; electromagnetic interactions; strong interactions.

522. Advanced Quantum Field Theory. ***Prerequisite: Physics 513 or its equivalent. I.*** (3).
Feynman rules of non-Abelian gauge theories will be derived. Higher-order effects, along with renormalization theory and methods will be considered. Applications of these theories to both solid state and particle physics will be given, including unbroken as well as spontaneously broken cases.

523. Advanced Quantum Mechanics II. ***Prerequisite: Relativistic Quantum Mechanics at the level of Physics 513. II.*** (3).
This course will assume a background of Relativistic Quantum Mechanics at the level of Physics 513 (Advanced Quantum Mechanics I). Among the topics explored will be: Group theory, spin, isospin, SU_2 and higher groups, the application of the Dirac equation to High Energy Physics, hyperfine splitting, etc. Topics in field theory will include Feynman diagrams and calculations of cross sections for simple processes.

601, 602. Particles and Fields.

605, 606. Group Theory.

615, 616. Advanced Mechanics.

617, 618. Continuous Media

619, 620. Solid State

621, 622. Quantum Theory of Fields

623, 624. Advanced Statistical Physics

625, 626. Theory of Elementary Particles

627, 628. Experimental High Energy Physics

631. 632. Advanced Mathematical Physics

633, 634. Fluid Dynamics

635, 636. Theory of Relativity

637, 638. Theory of Nuclear Structure

639, 640. Low Temperature Physics

643, 644. Advanced Atomic Physics

655, 656. Advanced Molecular Physics

665, 666. Contemporary Physics

667, 668. Astrophysics

670. Fundamentals of Plasma Physics

715. Special Problems

990. Dissertation/Pre-Candidacy

995. Dissertation/Candidacy

Statistics*

Department Office:
1444 Mason Hall
phone (313) 763-3519

*College of Literature, Science, and the Arts. Other courses in statistics are listed in the Bulletins of that College and the Horace H. Rackham School of Graduate Studies.

Professor Rothman, Chairman; Professors Ericson, Hill, Howrey, Hymans, Kmenta, Muirhead, Smith, and Woodroofe; Associate Professors Hoppe and Keener; Assistant

Professors Belisle, Faraway, Jeganathan, and Jhun; Adjunct Assistant Professor Thelen; Visiting Assistant Professor Hardwick.

300. Introduction to Statistical Reasoning. ***Prerequisite: none. I, II, and IIIa.*** (3).
Course is designed to expose a student to the basic ideas underlying statistical reasoning and modern statistical methodology. Topics covered include: rudiments of probability theory; critical discussion of alternative interpretations of probability; statistics as inference and/or decision making; basics of decision theory; the fundamental ideas underlying hypothesis testing and estimation; classical versus Bayesian idea; etc.

301. Introduction to Decision Theory. ***Prerequisite: Statistics 300. II.*** (3).
Models for decision making, including actions, states of nature, and consequences; using probability to measure uncertainty; the subjective and objective views of probability; Bayes and minimax solutions to decision problems with data; admissible and inadmissible strategies; relation to game theory; solutions to decision problems with data; quantifying the value of information; choosing among alternative experiments; special topics such as group and multipurpose decision making.

310. Elements of Probability. ***Prerequisite: taken concurrently with Math. 215. I and II.*** (3).
Basic concepts of probability; expectation and variance, covariance; distribution functions; bivariate marginal and conditional distributions. The binomial and related distributions, the Poisson process, the exponential and gamma distributions, the normal distribution, the distributions of sample statistics, the law of large numbers and the central limit theorem.

311. (I.&O.E. 365). Engineering Statistics. ***Prerequisite: I.&O.E. 315 or Stat. 310, and Math. 215, and Eng. 103. I and II.*** (4).
Analysis of engineering data associated with stochastic industrial processes. Topics include: fundamentals of distribution analyses; process model identification, estimation, testing of hypotheses, validation procedures, and evaluation of models by regression and correlation. Students are required to use the MTS computer system for problem solving.

402. Introduction to Statistics and Data Analysis. I, II and IIIb. (4).
A one-term course in applied statistical methodology from the analysis of data viewpoint. Frequency distributions; measures of location; mean, median, mode; measures of dispersion, the variance; graphic presentation; elementary probability; populations and samples; sampling distributions; one-sample univariate inference problems; two-sample problems; categorical data; regression and correlation; analysis of variance. Use of computers in data analysis. Three hours of lectures and one and one-half hour lab session each week.

403. Introduction to Statistics and Data Analysis II. ***Prerequisite: Statistics 402. I and II.*** (4).
This is a continuation of Statistics 402. Covers additional topics in the design and analysis of experiments (partially hierarchical, Latin squares, split plot; fixed, random, and mixed models, both parametric and nonparametric techniques); multiple regression including some discussion of model choice and evaluation, partial correlations, multicollinearity, etc.; analysis of covariance; analysis of categorical data from both a classical x^2 perspective and via linear models. Each technique presented with assumptions and illustrative examples.

404. Problem Solving in Medical Statistics. ***Prerequisite: enrollment in Inteflex or permission of instructor. I.*** (3).
This course is designed to introduce students in the medical sciences to the measurement and interpretation of clinically relevant variables. Applications to the design and analysis of clinical trials and diagnosis will be presented. The methodology includes some probability theory, classical inference, and curve fitting. Many of the topics are illustrated through current problems in medicine.

405. (Econ. 405). Introduction to Statistics. ***Prerequisite: Econ. 201 or 400, Math. 115. I and II.*** (4).
The purpose of this course is to provide students with an understanding of the principles of statistical inference. Topics covered include probability, experimental, and theoretical derivation of sampling distributions, hypothesis testing, estimation, and sample regression.

412. Introduction to Probability and Statistics. ***Prerequisite: taken concurrently with Math. 215 and either EECS 283 or Eng. 103. I, II and IIIa.*** (3).
An introduction to probability theory; statistical models, especially sampling models; estimation and confidence intervals; testing statistical hypotheses; important applications, including the analysis of variance and regression.

425. (Math. 425). Introduction to Probability and Mathematical Statistics. ***Prerequisite: Math. 215. I and II.*** (3).
Basic concepts of probability; expectation, variance, covariance; distribution functions; bivariate, marginal and conditional distributions.

426. Introduction to Probability and Mathematical Statistics II. ***Prerequisite: Statistics 425. I and II.*** (3).
Treatment of experimental data; normal sampling theory; confidence intervals and tests of hypotheses; introduction to regression and to analysis of variance. This course will serve as prerequisite for many 500-level statistics courses.

466. Statistical Quality Control. ***Prerequisite: Statistics 311. II.*** (3).
Design and analysis of procedures for forecasting and control of production processes. Topics include: attribute and variables sampling plans; sequential sampling plans; rectifying control procedures; charting, smoothing, forecasting, and prediction of discrete time series.

470. The Design of Scientific Experiments. ***Prerequisities: Statistics 311, 402 or 412 or 426 or permission of instructor. I and II.*** (4).
The course will cover the design of sample surveys, comparative observational studies and randomized experiments. Concepts covered will include: stratified and multistage samples, retrospective and prospective studies, design of multifactor experiments, optimal experimental designs, confounding and possible sources of bias. The course will include projects involving all aspects of a scientific study — from the design through the analysis of the data and the write-up of the results.

499. Honors Seminar. ***Prerequisite: permission of departmental honors adviser. I, II, IIIa, and IIIb.*** (2-3).
Advanced topics, reading and/or research in applied or theoretical statistics.

500. Applied Statistics I. ***Prerequisite: Math. 417 and a course in statistics (402 or 426 or permission of instructor). I.*** (3).
Review of matrices, multivariate normal and related distributions. Regression and general least squares theory, Gauss-Markov Theorem, estimation of regression coefficients, polynomial regression, step-wise regression, residuals. ANOVA models, multiple comparisons, analysis of covariance, Latin squares, and other designs, random and mixed-effects models. Applications and real data analysis will be stressed, with students using the computer to perform statistical analysis.

501. Applied Statistics II. ***Prerequisite: Statistics 500 or permission of the instructor. II.*** (3).
Topics in applied multivariate analysis including Hotelling's T^2, multivariate ANOVA, discriminant functions, factor analysis, principal components, canonical correlations, and cluster analysis. Analysis of qualitative data, measures of association in contingency tables, x^2 and likelihood ratio test, ANOVA for percentage data. Selected topics from: maximum likelihood and Bayesian methods, robust estimation and survey sampling. As in Statistics 500, applications and data analysis using the computer will be stressed.

502. Analysis of Categorical Data. ***Prerequisite: Statistics 426. I, II.*** (3).
Models of contingency tables, including the Poisson, multinomial, and hypergeometric models; additive and log linear models for cell probabilities; estimation of parameters, exact and asymptotic sampling distributions, and sufficient statistics; tests of hypotheses, including likelihood ratio tests, chi-square tests, and Fisher's exact test; special topics, such as quantal response problems, incomplete tables, tests for trend, and/or measures of association.

504. Seminar on Statistical Consulting. ***Prerequisite: Statistics 403 or 500. I, II.*** (1-4).
Applications of statistics to problems in the sciences and social sciences; students will be expected to analyze data and write reports.

505. (Econ. 673). Econometric Analysis. ***Prerequisite: permission of instructor.*** (3).
Theory and practice of hypothesis testing, statistical estimation, and the basic statistical theory underlying the linear model.

506. Statistical Computing. ***Prerequisite: Statistics 426 or Statistics 500 and Computer Science 380 or Computer Science 383 or permission of instructor. II.*** (3).
Monte Carlo procedures, generation of random numbers, computation of estimators, linear and non-linear problems, resampling algorithms, structural algorithms, splines, and other topics.

511. Probability and Mathematical Statistics. ***Prerequisite: Math. 450 or 451 and a course in probability or statistics, or permission of the instructor. I and II.*** (3).
Introduction to decision theory; competing approaches to estimation, including Bayes' and maximum likelihood; sufficient statistics; completeness; best unbiased estimators; critical discussion of confidence intervals; UMP tests; best unbiased tests; likelihood ratio tests; theoretical foundations of ANOVA and regression.

525. (Math 525). Probability. ***Prerequisite: Math 450 or 451 or permission of the instructor. I an II.*** (3).
Axiomatic treatment of probability, with emphasis on discrete sample spaces. Sums of independent random variables, random walks, limit theorems; Markov chains and other stochastic processes. Carries one credit for students with credit for Stat./ Math. 425.

526. (EECS 503) (Math. 526). Discrete State Stochastic Processes. ***Prerequisite: EECS 501 or Math. 525 or Stat. 510.*** (3).
Review of discrete distributions; generating functions; compound distributions; renewal theorem; systems as Markov chains. Properties of Markov chains: Chapman-Kolmogorov equations; return and first passage times; classification of states and periodicity; absorption probabilities; forward equation; stationary distributions; backward equation; ergodicity; limit properties. Branching and queueing processes, examples from engineering, biological and social sciences; continuous time Markov chains; embedded chains; the M/G/1 queue; Markovian decision processes; inventory problems.

531. Statistical Analysis of Time Series. ***Prerequisite: Statistics 426. I and II.*** (3).
Decomposition of series; trends and regression as a special case of time series; cyclic components; smoothing techniques; the variate difference method; representations including spectrogram, periodogram, etc.; stochastic difference equations, autoregressive schemes, moving averages; large sample inference and prediction; covariance structure and spectral densities; hypothesis testing and estimation; applications, and other topics.

550. (Stat. & Mgt. Sci. 576) (I.&O.E. 560). Bayesian Decision Analysis. ***Prerequisite: Stat. 425.*** (3).
Axiomatic foundations for personal probability and utility; interpretation and assessment of personal probability and utility; formulation of Bayesian decision problems; risk functions, admissibility; likelihood principle and properties of likelihood functions; natural conjugate prior distributions; improper and finitely additive prior distributions; examples of posterior distributions, including the general regression model and contingency tables; Bayesian credible intervals land hypothesis tests; applications to a variety of decision-making situations.

551. Bayesian Inference. ***Prerequisite: Statistics 550. II.*** (3).
Foundations; likelihood principle, noninformative stopping; sequential analysis; choice of priors; stable estimation; conjugate priors; invariance; estimation; credible intervals; hypothesis testing, the Lindley-Jeffreys paradox, the meaning of significance levels; unidentifiability; Behrens-Fisher problem; regression and multivariate problems.

552. Sequential Analysis and Design. ***Prerequisite: Statistics 426 or equivalent. I, II.*** (3)
Models for sequential sampling and sequential design; potential advantages and disadvantages of sequential methods, including their increased efficiency, ethical considerations and the effect on significance levels; the insensitivity of the likelihood function and posterior distributions to sequential sampling; fixed width confidence intervals; the Robbins Munro and related processes; some common sequential tests, including the sequential probability ratio test and restricted sequential procedures; decision theoretic formulation of sequential problems; Bayesian solutions of sequential problems by dynamic programming; applications to quality control and clinical trial; special topics.

560. (Biostatistics 560). Introduction to Non-parametric Statistics. ***Prerequisite: Statistics 426 and permission of the instructor. I and II.*** (3).
Confidence intervals and tests for quantiles, tolerance regions and coverages; estimation by U statistics and linear combination of order statistics; large sample theory for U statistics and order statistics; the sample distribution and its uses including goodness-of-fit tests; rank and permutation tests for several hypotheses including a discussion of locally most powerful rank and permutation tests; large sample and asymptotic efficiency for selected tests.

570. Experimental Design. ***Prerequisite: Statistics 426 and basic knowledge of matrix theory or permission of the instructor. I and II.*** (3).
The course will cover the basic topics and ideas in the design of experiments. That is, randomization and randomization tests, the validity and analysis of randomized experiments, randomized blocks, Latin and Graeco-Latin squares, and plot techniques; factorial experiments, the use of confounding, single and fractional replications, and other types of factorial arrangements; topics in split plot experiments, split plot confounding and response surface methodology; weighing designs, lattice and incomplete block and partially balanced incomplete block designs.

575. (Econ. 775). Econometric Theory. ***Prerequisite: Econ. 673 and 653 or equivalent.*** (3).
A course in econometric theory stressing the statistical foundation of the general linear

model. The course involves a development of the required theory in mathematical statistics and of derivations and proofs of main results associated with statistical inference in the general linear model.

576. (Econ. 776). The Econometric Theory. ***Prerequisite: Economics 775 or the equivalent. II.*** (3).
Generalized least squares, multivariate multiple regression, simultaneous equation models (Including problems of identification, estimation by equation and system methods, and forecasting), introduction to asymptotic theory, estimation problems in time series models.

580. Theory of Sampling. ***Prerequisite: statistics 426 and permission of . instructor., II.*** (3).
Mathematical foundations of sampling finite populations. Simple random sampling; stratification; ratio and regression estimates; systematic sampling, subsampling; cost functions and choice of optimal designs, estimation procedures.

600, 601. Advanced Topics in Applied Statistics. I and II. ***Prerequisite: Statistics 501 or permission. 600, I; 601, II.*** (3 each).
Advanced topics in applied statistics, such as cluster analysis, analysis of qualitative data, ranking and selection methods, sequential methods, etc. The course will study one or two advanced tôpics in detail with case studies.

610, 611. Mathematical Statistics I and II. ***Prerequisite: Math. 601 and 625. 610, I; 611, II.*** (3 each).
Decision theory, including: an introduction to subjective probability and utility, and finite decision problems, Bayes and minimax procedures, admissibility and completeness, exponential families, and the role of sufficiency. Point and interval estimation, including unbiasedness, invariance, large sample theory, maximum likelihood, Bayes, and empirical Bayes methods, and multiple comparisons. Hypothesis testing, including power, uniformly most powerful tests, Bayes tests, best invariant tests, best unbiased test, likelihood ratio tests. Special topics.

625, 626. (Math. 625, 626) Probability and Random Processes I and II. ***Prerequisite: Math 601 for I; Stat. 624 for II.*** (3 each).
Advanced introduction assuming knowledge of measure theory. Conditional expectation, characteristic functions, stochastic processes, limit theorems, selected topics.

630. Topics in Applied Probability. ***Prerequisite: Statistics 526 or Math. 626. I.*** (3).
Advanced topics in applied probability, such as queueing theory, inventory problems, branching processes, stochastic difference and differential equations, etc. The course will study one or two advanced topics in detail rather than attempting to study several in a (necessarily) superficial manner.

Technical Communication

Office:
111 Technical Information Design and Analysis Laboratory
phone (313) 764-1427

Faculty

Leslie A. Olsen, Ph.D., Associate Professor of Technical Communication and Director of the Technical Communication Program

J. C. Mathes, Ph.D., Professor of Technical Communication

Dwight Ward Stevenson, Ph.D., Professor of Technical Communication

Webster Earl Britton, Ph.D., Professor Emeritus of Technical Communication

Thomas Mitchell Sawyer, Ph.D., Professor Emeritus of Technical Communication

David Edward Kieras, Ph.D., Associate Professor of Technical Communication

Peter Roberts Klaver, Ph.D., Associate Professor of Technical Communication

Marthalee S. Barton, Ph.D., Lecturer in Technical Communication

Normally Engineering College students will take a three-hour technical communication course in their senior year. However, students are expected to maintain satisfactory standards of English in all courses. Failing to do so, students may be reported to the Assistant Dean who, with the students' program advisers and technical communication or humanities faculty representatives, may prescribe additional study.

Directed Study Courses
Prerequisite: permission of Technical Communication faculty. (elective credit only).
Conferences and tutorial sessions that provide opportunities for students with special interests to work on a tutorial basis with a member of the Technical Communication faculty.

These courses are not intended as substitutes for regularly scheduled courses. Students who wish to elect Directed Study must confer with an instructor about the proposed study. If the instructor agrees to accept the student for this study, the two prepare a contract and submit it for approval. Directed study contracts must be approved before the student may enroll. (Directed Study contract forms and additional information are available from the Technical Communication office.)

400. Technical Information and Communication Resources. ***I and II*** (1).
Overview of information resources in printed, electronic, and verbal form; use of the information research process to explore communication among scientists and engineers.

490. Technical Information Resources and Research. ***I.*** (3).
This course describes and demonstrates all forms of technical information resources now available to engineers. It provides access to a wide variety of sources and systems, with primary emphasis on online networks, and uses conferencing and database systems.

492. Visual Communication of Technical Information. ***I.*** (3).
Theory and research on the effective design of visual representations in science and technology. Topics include the perceptual and cognitive bases of visual design; the relation of image and text, including layout and typography; and the analysis of assumptions underlying current industry design guidelines and representative graphics applications software.

497. Argument and Persuasion. ***Prerequisite: senior standing. I and II.*** (3).
A course in logical argument and its role in persuasive discourse, especially writing. The course focuses on the nature of a reasoned argument; the formulation and analysis of problems; and methods of selecting, arranging, writing, and editing information on the basis of the intended effect on a particular audience.

498. Technical and Professional Writing for Industry, Government, and Business. ***Prerequisite: senior or graduate standing. I, II, IIIa and IIIb.*** (3).
Development of the communication skills required of engineers and managers in industry, government, and business. Focus on (1) the design and writing of reports and memoranda that address the needs of diverse organizational audiences and (2) the preparation and delivery of organizational oral presentations and briefings.

499. Scientific and Technical Communication. ***Prerequisite: senior or graduate standing.*** (3).
The goal of this course is to train students of science and engineering to write and speak about design and research problems in

terms that will satisfy both specialists and non-specialists. The student will present a series of short explanatory papers and speeches leading up to a final formal report and public lecture.

475. Directed Study. ***Prerequisite: permission of instructor. I, II, IIIa and IIIb. (To be arranged).***
Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor.

575. Directed Study. ***Prerequisite: permission of instructor. I, II, IIIa and IIIb. (To be arranged).***
Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor.

675. Directed Study. ***Prerequisite: graduate standing and permission of instructor. I, II, IIIa and IIIb. (To be arranged).***
Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor.

Selected Topics
Study of selected topics. When offered, the course or courses will be announced in the Time Schedule.

401. Selected Topics. ***Prerequisite: junior standing. I and II. (To be arranged).***
Study of selected topics. May be taken for 1-4 credit hours as arranged by the instructor.

501. Selected Topics. ***Prerequisite: graduate standing. (To be arranged).***
Study of selected topics. May be taken for 1-4 credit hours as arranged by the instructor.

601. Selected Topics. ***Prerequisite: graduate standing. (To be arranged).***
Study of selected topics. May be taken for 1-3 credit hours as arranged by the instructor.

The following courses provide senior and graduate students with intensive training in communication. One of the following courses must be elected to satisfy the requirement for a writing course in the senior year: 497, 498, or 499.

Graduate Courses in Technical Communication

520. Technical and Scientific Editing. ***II.*** (3).
A general overview of the roles, responsibilities, and practices of an editor of technical and scientific information. Application of these variables to editing proposals, scientific and technical papers, design reports, users' manuals and group-writing projects. Includes practice and applications in computer-based editing.

570. Comprehension of Technical Prose. ***II.*** (3).
A survey of research literature from cognitive psychology, psycholinguists, and artificial intelligence on how written text is comprehended, with emphasis on technical text, such as scientific writing, computer documentation, and equipment manuals.

585. Theory of Documentation. ***I.*** (3).
A survey of the scientific research and theory that yields principles and guidelines for effective documentation for equipment such as computer systems. Topics covered include the choice of documentation content, effective presentation, and readability. Emphasis on science base rather than design experience.

586. Design of Documentation. ***II.*** (3).
This is a design course which applies theories of documentation to actual development and testing of documentation, especially computer documentation. It presents a brief review of documentation theory; analysis of current industry guidelines and procedures for producing documentation; actual writing of documentation; and testing of documentation in a laboratory environment.

590. Internship in Technical and Professional Communication. ***Prerequisite: Tech. Comm. 498 or 499 and permission of instructor. I, II, IIIa and IIIb. (To be arranged).***
Advanced instruction and on-the-job experience in technical writing for students interested in preparing for careers as technical communicators or in enhancing their qualifications for administrative roles in industry and government.

595. Communication, Technology, and Public Policy. ***I.*** (3).
Analysis of the public policy decision making process involving technology management. The structure and techniques of policy discussions from the engineering management perspective. Communication in social decision analysis for engineering projects. Design of specific types of policy statements such as the position paper, legislative testimony, and environmental impact statement.

598. Management and Administrative Communication Processes. ***Prerequisite: Tech. Comm. 498 or equivalent, or permission of instructor. II.*** (3).
Description, analysis, and assessment of written and oral communication processes in organizations. Establishing and managing effective communication procedures and practices. The role of communication in organizational and decision making processes. The contribution of communication to production efficiency and productivity

610. Dissertation, Dissertation Proposal, and Thesis Writing. ***I and II.*** (1-3).
Intended for American and foreign students writing their dissertations, dissertation proposals or theses. Presents writing guidelines and their scientific base for problem definition and literature review; argument structures for the discussion of problem, criteria, methodology, results, and conclusions; selection and ordering of information; editing visual aids; and special grammatical problems.

620. Teaching and Supervising Technical Writing. ***Prerequisite: graduate standing. I.*** (3).
This course is for graduate students of two types: those planning academic careers in technical contexts; and those planning administrative and project management careers in industry. It covers the objectives, methods, and resources necessary to teach technical writing and to supervise technical personnel who write.

Committees

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R. I. Carr
R. M. Howe
A. W. Naylor
J. O. Wilkes

Standing Committee +
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F. L. Bartman
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G. Smith

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Committee on Program Counseling +
B. H. Karnopp, *Chairman*
all undergraduate program advisers

Listed for the 1988 - 89 academic year
+ By arrangement, this committee meets with representatives of the student body appointed by the Student Engineering Council.

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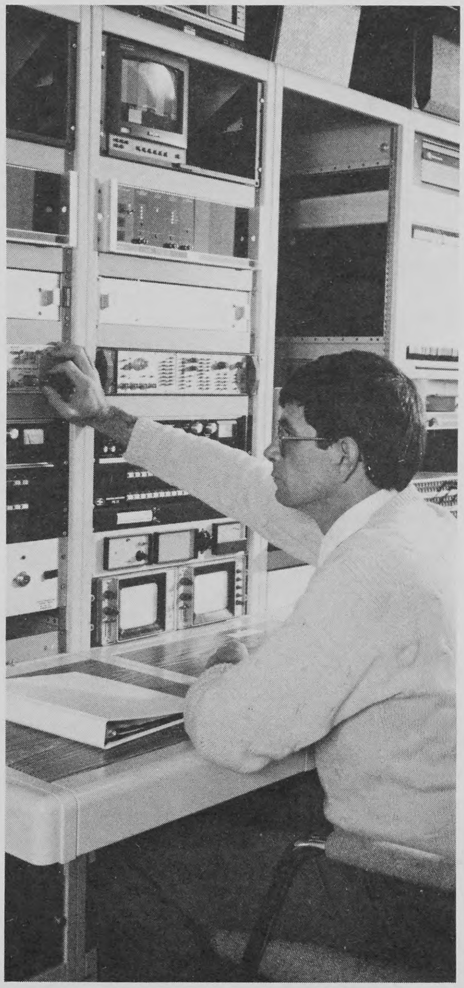

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