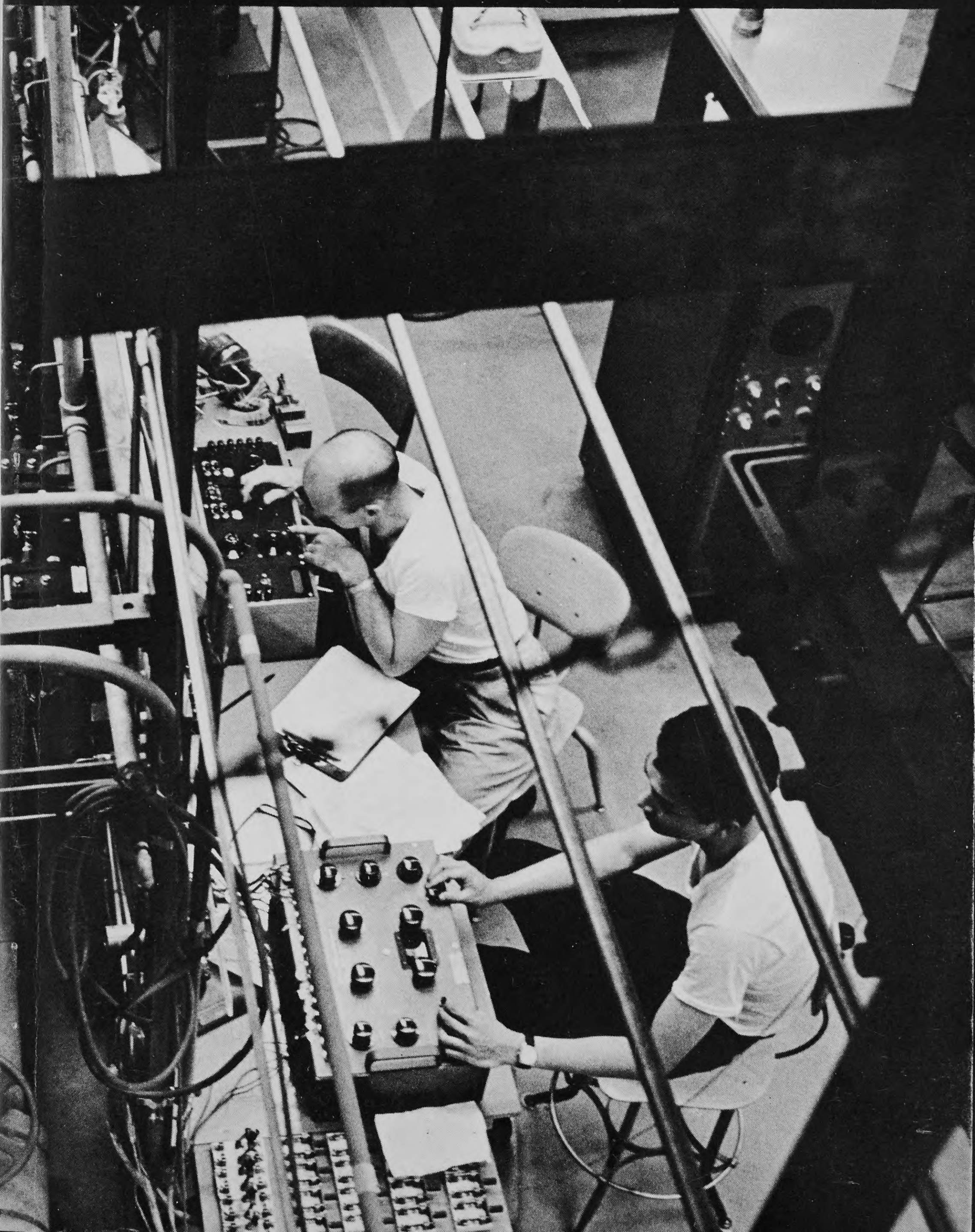
official publication

# The University of Michigan College of Engineering 1965-66



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University of Michigan Official Publication

# College of Engineering

# 1965-1966

# Announcement

Published by the University Ann Arbor

# Office Directory

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| Examination period for full term and summer-half term | August 17-18, Tuesday-Wednesday |
| Full term and summer-half term (summer session) end | August 18, Wednesday |

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| | |
|---|---|
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| Classes begin | August 30, Monday |
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| Midyear Graduation | December 18, Saturday |

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| | |
|---|---|
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| Examination period | April 19-26, Tuesday-Tuesday |
| Commencement | April 30, Saturday |

### Spring-Summer Term, 1966

| | |
|---|---|
| Orientation and registration for full term and spring-half term. | May 2-3, Monday-Tuesday |
| Classes begin | May 4, Wednesday |
| Examination period for spring-half term | June 23-24, Thursday-Friday |
| Registration for summer-half term (summer session) | June 23-24, Thursday-Friday |
| Summer-half term (summer session) classes begin | June 27, Monday |
| Examination period for full term and summer-half term | August 16-17, Tuesday-Wednesday |
| Full term and summer-half term (summer session) end | August 18, Thursday |

This calendar is subject to change without notice.

# COLLEGE OF ENGINEERING

HARLAN HATCHER, Ph.D., Litt.D., LL.D., *President of the University*
MARVIN L. NIEHUSS, LL.B., *Executive Vice-President of the University*
ROGER W. HEYNS, Ph.D., *Vice-President for Academic Affairs*
STEPHEN S. ATTWOOD, M.S., *Dean of the College of Engineering*
GLENN V. EDMONSON, M.E., *Associate Dean of the College of Engineering*
JAMES C. MOUZON, Ph.D., *Associate Dean of the College of Engineering*
WALTER J. EMMONS, B.S., A.M., *Associate Dean Emeritus and Secretary Emeritus of the College of Engineering*
ARLEN R. HELLWARTH, M.S., *Assistant Dean and Secretary of the College of Engineering*
RAYMOND E. CARROLL, B.A., *Assistant to the Dean*
ROBERT H. HOISINGTON, M.S., *Assistant to the Dean*
IRA K. MCADAM, B.S.E. (M.E.), *Assistant to the Dean*
JOHN G. YOUNG, B.S.E. (M.E.), *Assistant to the Dean*

## General Information

Engineering is the profession that applies the laws of physical science to the efficient and economic conversion of natural resources for the benefit of man.

To design and produce the structures, machines, and products of industry requires the application of scientific and mathematical knowledge, the utilization of natural resources and capital, and the management of men.

The engineer is generally a practitioner. He brings to bear on each problem all available science and experience or judgment to arrive at the best or most economical solution. He combines knowledge of what to do and how to do it with understanding of why he is doing it and of the significant results that he may expect of his actions. He becomes not only an interpreter of science in terms of material human needs but also a manager of men, money, and materials in satisfying these needs.

An ever-present challenge in engineering work is to search for something better. The successful engineer is never satisfied with the existing design. He uses his ingenuity further to improve quality or performance, to increase efficiency, to decrease cost, or to facilitate production and construction. Often motivated by competition, he strives for some optimum goal that will reward him with new and exciting opportunities for service.

The educational objective of the College of Engineering is to prepare its students to take positions of leadership commensurate with their abilities in a world where science, engineering, and human relations are of basic importance. The programs are specially planned to prepare them, according to their aptitudes and desires, to become practicing engineers, investigators, administrators, or teachers. The useful knowledge and mental discipline gained from such educational programs, however, are so broad and fundamental as to constitute excellent preparation for other careers.

Some qualified graduates will continue their formal education at the graduate level leading to a master's or doctor's degree. One of the opportunities for continued growth and development after college is registration as a professional engineer. In each state of the United States, after a specified length of experience, usually four years, the young engineer may pass qualifying examinations to attain this status.

The student will have the opportunity of associating with teachers who have professional experience, gained through research, consultation, and engineering employment. The University of Michigan believes that engineering experience improves the ability of teachers, both in the classroom and laboratory. Members of the faculty are encouraged to be active in professional practice in order to keep informed on new developments in their respective fields. Facilities at the University provide for its teachers not only an atmosphere of research but also convenient opportunities for continuing their professional development, increasing their understanding of the subjects taught, and passing on to their students the benefit of their investigations and firsthand experiences.

Teaching is often at its best when the student and teacher work together in developing new relationships of a fundamental nature, or better and more economical ways of applying scientific knowledge to the problems of industry and the public welfare. Graduate and undergraduate students are given an excellent opportunity to take part in such activities in the well-equipped engineering laboratories, at several field locations, and on a variety of engineering projects.

An excellent criterion for predicting success is good performance in high school, particularly in mathematics, science, and English. Other important factors are: an interest and curiosity in the "why" of things, an ability to visualize objects well in three dimensions, sound habits of work and study, a persevering spirit, and good health. A serious mistake is frequently made in regarding manual dexterity, or an interest in mechanical things, as the only standards for judging abilities important for high achievement in the profession of engineering.

The choice of a career is a most important one and should be based on sound and complete information. If at all possible, a prospective student should discuss his interests and abilities with practicing engineers. In many communities, professional engineering societies provide counseling services. The Admissions Office of the University and the officers and program advisers of the College of Engineering will gladly be of service in assisting students with career planning.*

Successful completion of undergraduate work leads to the degree Bachelor of Science in Engineering for each of thirteen programs offered by the College of Engineering; they are listed in the Contents. A program in meteorology and oceanography leads to the degree Bachelor of Science. A student should select a program near the completion of his second semester, or of approximately 30 credit hours, as explained under Freshman Program.

By careful planning, an additional bachelor's degree (B.S. or A.B.) can be earned in the College of Literature, Science, and the Arts in approximately one year beyond the time required for any one of the degrees referred to above. Refer to Undergraduate Degree Programs, page 37.

* A vocational booklet entitled *Engineering—A Creative Profession* may be obtained (25 cents per copy) from Engineers' Council for Professional Development, 345 East 47th Street, New York 17, N.Y. It answers many questions commonly experienced by high school students who are considering engineering as a career and describes in particular several general fields of the engineering profession.

## Accreditation

The following degree programs offered on the Ann Arbor Campus have been accredited by the Engineers' Council for Professional Development: Aeronautical and Astronautical, Chemical, Civil, Electrical, Engineering Mechanics, Industrial, Materials, Mechanical, Metallurgical, Naval Architecture and Marine Engineering, Physics, Sanitary (first degree M.S.E.), and Science.

## Facilities

The physical facilities of the University for instruction, housing, health care, recreation, physical education, and athletic activities are described briefly in the bulletin *General Information,* available upon request.

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

- West Engineering Building
- East Engineering Building
- Aeronautical and Astronautical Engineering Laboratories
- Automotive Engineering Laboratory
- Fluids Engineering Laboratory
- Magnetofluiddynamics Laboratory
- Mortimer E. Cooley Building
- Phoenix Memorial Laboratory

The description of each of the undergraduate degree programs includes a reference to the facilities for the respective programs.

The **Computing Center** provides an IBM 7090, IBM 1410, and two IBM 1401 computers for use by the educational and research programs of the University. Engineering students prepare problems for solution on this equipment as a regular part of more than eighty different courses. Each instructor exercises administrative control over the use of these computers as required for his course. In addition, several small digital computers and many analog computers are located within the College. Every student may expect to become familiar with the theory and application of modern computing methods during his course of study.

The **Engineering Library**, located on the third floor of the Undergraduate Library, is one of the more than twenty divisional libraries in the University Library system. Its collection of approximately 138,000 volumes covers all fields of engineering. The library subscribes to almost 900 periodicals and maintains large collections of pamphlets, technical reports, and industrial catalogues.

The Engineering Library also maintains two special collections: the Phoenix Library, located in the Phoenix Memorial Laboratory on the North Campus, containing an AEC depository collection of approximately 86,000 reports as well as almost 3,500 volumes on atomic energy; and the

Transportation Library, containing more than 122,000 volumes on all phases of the subject of transportation.

Trained staffs are available to assist the student in making effective use of these libraries, as well as of the University Library system as a whole.

## Co-operative Programs With Industry

In certain fields a desirable combination of theory and practice is available, to a limited extent, through the medium of co-operative courses with industry. To be eligible for acceptance in a co-operative program a student must have completed a substantial part of his program, at least one year in residence, with good grades. He must be acceptable to the company with which he plans to work. He will devote alternate terms to study at the University and in the employ of the company. He will receive regular compensation for his work and will be subject to the regulations of the company by which he is employed. When accepted in a co-operative program, he is expected to continue in it until he graduates or leaves the University.

Co-operative programs have been established with several companies and public organizations. The College is willing also to consider the proposals of students who find it possible to arrange for alternate terms of study and work with any organization offering opportunities for experience which will contribute to their educational progress.

Credit is not granted for work experience, but a co-operative program, when approved, is entered upon the student's official record.

## Dearborn Campus

The Dearborn Campus, an integral part of The University of Michigan, provides the newest and one of the most unusual educational opportunities of the University. It offers a full-fledged co-operative program in electrical, industrial, and mechanical engineering, and engineering mathematics. Students seeking admission must have completed the requirements of the first two years for the program elected either on the Ann Arbor campus, at an accredited junior college, or at another accredited college or university. A student desiring further information should write: Admissions Office, Dearborn Campus, 4901 Evergreen Road, Dearborn, Michigan.

## Placement

The College of Engineering considers the proper placement of its graduates to be very important, since it is recognized that the first years of professional experience are of great significance in developing the full capabilities of the young engineer. For this reason the College provides an engineering placement service for both students and alumni in Room 128H, West Engineering Building. This service includes the arranging of employment interviews on campus, the announcement of openings received by mail, and the providing of career and placement information through counseling and published material.

Summer and other short-term training positions in industry 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 very valuable adjunct to formal technical education.

Meetings for students are conducted by the placement service at the beginning of the first and second terms on subjects of placement interest, such as the nature and availability of engineering opportunities, techniques for effective interviewing and plant visits, and considerations of engineering practice and professional development.

## Extracurricular Opportunities

Students at The University of Michigan enjoy many privileges outside of their classes as indicated in the bulletin *General Information.* Living a full life is an art, acquired by practice. The *Michigan Technic,* debating societies, orchestras, bands, glee clubs, sports groups, and other organizations provide excellent opportunities for self-development. They constitute an important part of the University life, and engineering students are encouraged to take an active part in them after the day's work is well done.

The following organizations, many of them related to scholastic or professional interests, are among those available to students of the College of Engineering upon meeting the respective requirements for membership or participation.

**Alpha Pi Mu,** national industrial engineering honor society
**American Institute of Chemical Engineers,** student chapter
**American Nuclear Society,** student branch
**American Rocket Society,** student branch
**American Society of Civil Engineers,** student branch
**American Society of Mechanical Engineers,** student branch
**Chi Epsilon,** national civil engineering honor fraternity
**Engineering Student Council**
**Eta Kappa Nu,** national electrical engineering honor society
**Institute of Electrical and Electronics Engineers,** student branch
**Michigan Metallurgical Society**
**Michigan Technic,** a monthly magazine containing articles on technical subjects and other matters of interest to the College, staffed by engineering students
**Phi Eta Sigma,** national honor society for freshman men
**Phi Kappa Phi,** national honor society for seniors of all schools and colleges
**Pi Tau Sigma,** national mechanical engineering honor fraternity
**Quarterdeck Society,** honor-technical society for students in naval architecture and marine engineering
**Sailing Club,** an organization for dinghy sailing, iceboating, intercollegiate competition
**Scabbard and Blade,** national ROTC honor fraternity
**Sigma Xi,** a national society devoted to the encouragement of research
**Society of Automotive Engineers,** student branch
**Society of Women Engineers**
**Tau Beta Pi,** national engineering honor society

**Triangles,** junior honor society
**Vulcans,** senior honor society

Students interested in exploring other opportunities may review a complete list of campus organizations in the Office of Student Affairs, 2011 Student Activities Building.

## Scholarships, Fellowships, Prizes, Loans, and Employment

Numerous scholarships, fellowships, and prizes, as well as loan funds, are available to engineering students. A list of these, with the conditions governing them, appears in the special bulletin *University Scholarships, Fellowships, and Prizes,* which is available upon request to the Office of Student Affairs, Student Activities Building. February 15 is the deadline for applying for scholarships.

The Committee on Scholarships and Loans of the College has under its jurisdiction those scholarships and aid funds which have been established for the special benefit of undergraduate students in engineering. In general, such assistance is awarded on the basis of high scholastic performance and of demonstrated need. Applications may be addressed directly to this committee at the office of the Dean.

A number of qualified seniors are employed each term as student assistants for assigned work in the several departments. Qualified graduate students are frequently provided assistance to continue their studies toward master's or doctor's degrees either through fellowships or a variety of employment opportunities in teaching or research.

## Veterans

The University of Michigan welcomes veterans and provides information, guidance, and counseling to those eligible for educational benefits under Public Laws 634, 815, and 894.

All students who are eligible for and elect to receive education and training benefits while attending the University are required to register with the Veterans Affairs Office, 2059 Administration Building, as an integral part of the registration process.

## Fees and Deposit

The following fees for the academic full terms (fall, winter, spring-summer), spring-half term, and the summer-half term (summer session) are subject to change without notice:

### Academic Term Fees

| | *Michigan Residents* | *Non-Residents* |
|---|---|---|
| Freshman-Sophomore | | |
| Eight hours or more | $140 | $450 |
| Six or seven hours | 115 | 365 |
| Four or five hours | 85 | 285 |
| One to three hours | 60 | 190 |

| | *Michigan Residents* | *Non-Residents* |
|---|---|---|
| Junior-Senior | | |
| Eight hours or more | $155 | $480 |
| Six or seven hours | 120 | 385 |
| Four or five hours | 90 | 290 |
| One to three hours | 65 | 205 |
| Graduate (Rackham) | | |
| Eight hours or more | 175 | 500 |
| Six or seven hours | 145 | 415 |
| Four or five hours | 110 | 315 |
| One to three hours | 75 | 215 |

**Spring-Half or Summer-Half Term (Summer Session) Fees**

| | | |
|---|---|---|
| Freshman-Sophomore | | |
| Five hours or more | 80 | 235 |
| Four hours | 60 | 190 |
| Three hours | 55 | 165 |
| Two hours | 45 | 135 |
| Junior-Senior | | |
| Five hours or more | 90 | 250 |
| Four hours | 70 | 200 |
| Three hours | 60 | 170 |
| Two hours | 50 | 140 |
| Graduate (Rackham) | | |
| Five hours or more | 100 | 260 |
| Four hours | 80 | 210 |
| Three hours | 70 | 180 |
| Two hours | 60 | 150 |

Students enrolled as special students or guest students in the College of Engineering will be assessed the junior-senior fees. Any question on residence regulations may be referred to the Assistant Dean.

Term fees are payable prior to registration, at registration, or in installments during the term. The number and dates of the installments will be specified in advance for each term. Requirements on the enrollment deposit are stated below.

Students are urged to provide themselves with money orders or bank drafts to cover term fees. For the convenience of students, the Cashier's Office will cash or accept, in payment of term or other University fees, money orders or bank drafts. Personal checks will not be cashed but will be accepted for the exact amount of fees.

Term fees are the student's contribution to the cost of class instruction, library services, physical education privileges, membership in the Michigan Union or Michigan League, and medical attention from the University Health Service in accordance with regulations of the Health Service as given in the bulletin *General Information.*

Foreign students who are not provided with health-hospitalization insurance by their sponsors are required to purchase Student Group Health Insurance. The cost of this coverage (approximately $30) *must* be paid at the time of registration. This coverage extends for a full twelve months.

**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, most recent grades are not released, no transcript of academic record will be issued, nor will future registration be permitted.

**Enrollment Deposit.** In order to manage its over-all enrollment more efficiently and to guarantee each bona fide student a place in that enrollment, the University requires a $50 deposit for all students, including special nondegree candidates. Information will be supplied at the time of admission.

# Admission

Applicants for admission should be at least sixteen years of age and officially recommended graduates of accredited high schools. They must present acceptable evidence of good moral character, and must satisfy requirements as explained under Health Service Approval. General policies and requirements are stated in the bulletin *General Information.*

Applications for admission for the fall term should be submitted by the preceding February 1 to receive equal consideration with other applicants. However, qualified students who seek admission after this date will always be given consideration. Since there is no application fee, no money should be sent when making application for admission.

## Admission as a Freshman

High school students who have begun the senior year are invited to write to the Director of Admissions, Student Activities Building, for application forms and instructions for admission to the College of Engineering. Early application will make it possible to inform students of the probability of their admission and to call attention to any requirements still unfulfilled. Admission, when granted to a high school student, is contingent upon satisfactory completion of his high school program.

Both the Office of Admissions and the College of Engineering welcome the opportunity to interview prospective freshmen, but recommend that appointments be arranged in advance.

### Criteria

The admission requirements are designed to ensure that each student who is granted an 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 his 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.

Applicants for admission as freshmen without entrance deficiency must present a minimum of fifteen units of acceptable high school credit in accordance with the following schedule:

| | |
|---|---|
| *English* | |
| At least three units are required | 3 |
| *Mathematics Group* | |
| At least three and one-half units are required, including algebra, two units; geometry (including some solid geometry), one unit; trigonometry, one-half unit | 3½ |
| *Science Group* | |
| Two units are required. These should consist of one unit of physics and one unit of chemistry, but botany, zoology, or biology may be offered. | 2 |
| *Required Group* | |
| Three units are required from a group consisting of foreign languages, botany, zoology, biology, history, economics, or additional English, mathematics, or chemistry. Not less than one full unit of a foreign language will be accepted. | 3 |
| The remaining units required to make up the necessary fifteen units may be elected from among the subjects listed above and any others which are counted toward graduation by the accredited school | 3½ |
| Total | 15 |

Four units of English, four units of mathematics, one unit of chemistry, and one unit of physics should be presented whenever feasible. With excellent preparation, some acceleration is possible at the University, as stated under "Planning the Student's Program."

An applicant who does not meet the preceding requirements for admission is advised to consult the Director of Admissions concerning his particular problem. Deficiencies may be removed before the anticipated date of entrance. When conditions warrant such action, provisional admission may be granted if not more than two units are lacking.

**2. Scholastic Performance.** The student's grades—particularly in English, mathematics, and science—together with his standing in his class, are considered important in determining eligibility for admission to the study of engineering. Interest and high achievement in these subjects will also help the student to decide whether or not he is making the right choice of a career, and to predict his likelihood of success in the engineering profession.

**3. Scholastic Aptitude Test.** Applicants are required to take during their junior or senior year in high school the College Entrance Examination Board Scholastic Aptitude Test (SAT).

When a senior desires a decision before the SAT test results are known, preliminary admission may be made if other acceptable test data are submitted to the Director of Admissions along with his application.

For information and time schedules on the Scholastic Aptitude Test, the student should consult his high school counselor or write to College Entrance Examination Board, Box 592, Princeton, New Jersey, or to Box 1025, Berkeley 1, California.

**4. High School Recommendation.** A statement by an authorized representative of the applicant's high school is required, relating to the character and seriousness of purpose of the applicant, his interests and attainments (both scholastic and extracurricular), his intellectual promise, and his potential for success. Such information provides additional background that may not be evident from the other criteria listed above.

### Advanced Placement

Many high schools throughout the country are offering work of such caliber that an incoming freshman may receive college credit for some subjects provided he has performed satisfactorily on Advanced Placement Program examinations conducted nationally by the College Entrance Examination Board. Such a student may significantly accelerate his education or he may enrich his stay in the College of Engineering by covering more material than does the normal student.

For information and time schedules on the tests referred to above, write to College Entrance Examination Board, Box 592, Princeton, New Jersey, or to Box 1025, Berkeley 1, California.

High school graduates desiring to be excused from taking courses in engineering graphics may be required to pass a comprehensive examination and to submit for approval appropriate drawings completed previous to entrance.

## Admission with Advanced Standing

An applicant desiring to transfer from an approved college in the United States with advanced credit should write to the Assistant Dean, College of Engineering, for an application form and instructions. He will be required to arrange for an official transcript of both his secondary school and college work, together with evidence of honorable dismissal from his college. This applies also to students planning to transfer from another unit in the University.

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.

The history of an applicant must demonstrate that he has the ability to meet the requirements of the College of Engineering for graduation.

An over-all scholastic average satisfactory for good standing at his 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 his ability to succeed. As a minimum requirement, his scholastic record as interpreted by the College of Engineering must be such that he would be considered in good standing if his work had been taken at this College.

A male 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 ROTC Advanced Course. As early as possible, he should contact the unit on the campus to make the necessary arrangements for basic training during the summer. See ROTC section for details.

**Program with Basic Courses Taken in Another Institution.** Basic pre-engineering courses in English, mathematics, chemistry, and physics are offered by many liberal arts colleges and community or junior 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, he should weigh the advantages of completing the required basic program before seeking a transfer.

In many institutions a student is able to satisfy the requirements of physical education, economics, and nontechnical subjects; he may also be able to complete his work in engineering graphics and engineering materials and to start engineering mechanics if his institution offers adequate instruction in these fields.

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

**Combined Programs With Other Institutions.** The College of Engineering co-operates 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: Albion College, Alma College, Calvin College, Central Michigan University, Eastern Michigan University, Emmanuel Missionary College, and Kalamazoo College. Normally an interested student would enroll at one of these institutions for his first three years and include in his 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 a combined program with the College of Literature, Science, and the Arts of the University, refer to Undergraduate Degree Programs, pages 35–39.

**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 the satisfactory completion of the prescribed courses, covering at least two terms enrollment and a minimum of 30 hours of credit, the student will be recommended for the appropriate degree.

**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 number of credit hours on a term basis 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 with his election because of an inadequate preparation. In general, credit will not be allowed for a course with a D or equivalent low grade. Class standing is determined by the number of credit hours transferred. (See under Class Standing).

In general, only those credit hours presented that contribute to the completion of the student's degree requirements will be recorded on his academic record. Grades earned in the courses transferred are not recorded, and the student's grade-point average is determined solely by the grades earned while he is enrolled in this College.

Credit for experience is not granted. When experience in industry closely parallels the content of a required course, however, the student may be excused by his program adviser from taking such course.

If at any time a transfer student has any question regarding the adjustment of his credit, he should consult the Office of the Assistant Dean.

## Student Not a Candidate for a Degree

**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.

Request for admission as a special student and supporting evidence of qualifications should be addressed to the Assistant Dean. 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 courses for which his preparation is sufficient.

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

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

**Guest Students.** A student regularly enrolled in another college is permitted to elect appropriate college courses as a guest student. He must apply for enrollment before the beginning of each term he desires to attend.

## Foreign Students

Foreign students whose native language is other than English are required to complete basic college subjects (English, mathematics, chemistry, physics, engineering graphics) 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 his proficiency in English.

An applicant must submit an official copy in English of the scholastic record of his 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 he must maintain the same scholastic standards. In order that he may know that his control of the English language is adequate to carry on his studies without serious handicap, each student whose native language is not English is required to pass an English proficiency examination before he is admitted. This test is prepared and administered abroad by the English Language Institute of the University. If the applicant is informed that his scholastic record is satisfactory, he will then be instructed to make arrangements for the test with the English Language Institute. The charge for this test taken abroad is $10.00, or its equivalent in the local currency.

For students who need to improve their control 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, Michigan.

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. When a student wishes to transfer to this College, he is encouraged to submit an application for admission with advanced standing during the final 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 he is living in an unfamiliar environment and is studying under an educational system which may be new to him. If he fails in his studies and if, in the judgment of his instructors and adviser, his failure is due primarily to his lack of proficiency in the English language, his record will be disregarded and he will be required to pursue additional remedial study of English as may be deemed necessary before resuming his professional studies.

For statement on health insurance requirements for foreign students, see Fees and Deposit.

**International Center.** A foreign student with financial, immigration, housing, or personal adjustment problems is assured of careful and understanding counseling at the University's International Center. Students also have opportunities to plan and participate in social activities under the sponsorship of the Center.

## Academic Counseling

To plan his educational program wisely and efficiently each student should understand his own aptitudes, abilities, and interests and their relationship with his future. A student with some question in this regard, or any other personal problem on which he feels the need of counseling, is urged to consult University people who are qualified to help him.

Engineering students who are uncertain regarding procedures, or who have special problems, may seek advice from the Office of the Assistant Dean, 259 West Engineering Building.

**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 details include testing, a call at the Health Service, preparation of the student's identification card, consultation with academic counselors, selection of courses, assignment of fees, and attendance at the necessary orientation group meetings.

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

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

**Academic Counseling for Freshmen.** Freshman counselors, consisting of a group of well-qualified members of the professional teaching staff, are available in a central freshman counseling office for interviews at all times throughout the year.

Each entering freshman meets with a counselor to determine his schedule of courses for his first term. The necessary counseling takes into account his entrance credits, level of high school achievement, test results, and other information made available to the counselor.

Developing self-reliance and ability to appraise his own performance and intellectual growth is an important part of the student's education. Nevertheless, freshmen are encouraged to consult with counselors at any time concerning their career plans and academic programs and to discuss any matter of interest or concern. A particularly appropriate time to examine progress is at the time of the midterm grade report.

**Program Adviser.** At the beginning of each of the statements on the fourteen undergraduate programs (given later in this *Announcement*) is the name of a member of the faculty designated as program adviser. This person is available primarily to counsel students above the freshmen level on their academic program and other matters such as changes in objectives and choices of subject electives. Program advisers will also assist each student with career planning and other decisions that are necessary to make a proper selection of a particular program. A freshman who needs additional help in this respect may attend group meetings or, by appointment, consult with the several program advisers.

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

**Academic Counselor.** 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 counseling as covered under Election of Studies or as specifically delegated.

**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 Bureau of Psychological Services 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, the Mental Health Clinic of the Health Service is available. Training in reading speed and comprehension is provided for students especially in need of such assistance. Remedial training in speech is offered by the Speech Clinic. The churches in Ann Arbor provide counselors on religious problems. The Office of Student Affairs provides counsel and assistance on housing, financial, employment, and other nonacademic 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.

## Planning the Student's Program

By offering a variety of programs, the College provides opportunities for meeting the special needs and interests of each individual student. Students are admitted with varying degrees of ability and with differences in high school or other pre-engineering preparation. These variations, and the student's choice of an engineering field, necessitate considerable flexibility in arranging schedules and programs. Hence, every effort is made to plan a schedule for the newly admitted student so that his college experience will be more effective for him.

### Freshman and Sophomore Program

The program for each freshman is planned with the objective of placing him in courses commensurate with his previous preparation and his ability, so that he may reach the level of attainment required for graduation as efficiently as possible. At the same time, his schedule should not include courses which the student is judged to be unable to handle successfully. The high school performance record and results of various tests will help in planning a program that meets these objectives.

Students are required to remove all admission deficiencies during their first year, unless granted an extension of time. A student who does not present three and one-half units in the mathematics group (see Admission as a Freshman) will find it to his advantage to remove the deficiency during the summer preceding the first term of the freshman year.

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.

**Studies of the First Year.** The schedules for the first year will generally include courses from among the following subjects: mathematics, English, engineering graphics, chemistry, physics, and an elective subject in a nontechnical field. For courses common to all degree programs, see Undergraduate Degree Programs—Group A.

Physical education (twice a week through the year without credit in hours) is required of all first-year students unless enrolled in one of the three Reserve Officers Training Corps programs.

Opportunities are offered for reserve officer training in air, military, and naval science. Enrollment in one is not required, but those who choose to enroll are excused from taking physical education (see statement concerning conditions of voluntary enrollment under Reserve Officers Training Corps).

If Reserve Officers Training Corps enrollment is elected, hours of credit and the grades earned will be recorded and included in the computation of average grades. The only hours that may be applied to degree requirements are for those advanced courses in the third and fourth year that are permitted in the schedule of requirements of the respective programs.

While many variations in freshman schedules are possible, the following will serve as a guide to each student in planning his own personal program:

| *First Term* | *Credit Hours* | *Second Term* | | *Credit Hours* |
|---|---|---|---|---|
| English 111 and 121 | 4 | English 112 | | 2 |
| Mathematics 115 | 4 | Mathematics 116 | | 4 |
| Chemistry | 4 or 5 | Physics 145 | | 5 |
| Eng. Graphics 101 | 3 | Eng. Graphics | 3 or 2 | 2 to 7* |
| *or* | | Chemistry | 4 | |
| Elective | 3 or 4 | Elective | 2 to 7 | |
| Physical Education | 0 | Physical Education | | 0 |
| *or* | | *or* | | |
| ROTC | 1 or 3 | ROTC | | 2 or 3 |

Usual combinations of the subjects listed above will result in a term schedule with 15 to 18 hours credit. The appropriate number for each student will depend on a number of factors: past scholastic record, placement tests, extracurricular activities, and need for partial self-support through outside work.

* Explanations regarding the several possibilities or combinations in this group of subjects appear in the following discussions.

**Studies of the Second Year.** A part of the normal schedule for the third and fourth terms consists of the remainder of the Group A courses common to all fourteen programs:

| *Third Term* | *Credit Hours* | *Fourth Term* | *Credit Hours* |
|---|---|---|---|
| Mathematics 215 | 4 | Mathematics 315 | 2 |
| Physics 146 | 5 | Mathematics 316 | 2 |

The remainder will be made up of appropriate courses from the list of professional and advanced subjects and electives (Group B) specified for the program selected by the student.

**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. He should consult with his freshman counselor, with program advisers, and others for assistance and counsel in planning his career. During the second term, he will be asked to select the degree program in which he plans to graduate. From this point on, the degree programs differ in their requirements. The differences are not so pronounced, however, as to make difficult a transfer from one program to another in the second year should the student change his career plans.

**Opportunity to Attain Two Bachelor's Degrees.** Through careful planning of his course elections throughout his college enrollment, a student with interests in more than one field of engineering may work for two bachelor's degrees concurrently. Inasmuch as he must satisfy the subject requirements of both programs as specified by the two program advisers, he will find that he can accomplish this in a minimum of time by starting his plans early. (See under Requirements for Graduation, paragraph 4.)

## Variations and Acceleration Possibilities

The following discussions and outlines will serve as additional guides. They include a number of variations and possibilities for accelerating the progress of qualified students. A number of factors are taken into account, but other variations not covered here may be arranged in consultation with counselors and program advisers according to the needs and qualifications of each student.

**English.** English 111, Composition, and English 121, Speech, are usually prescribed for the first term. Generally, a student will take English 112 during the second term and prior to electing courses from Group II. If a student has met the English 112 requirement during the first term, or has been excused from the course on the basis of proficiency, he may elect a course from Group II during the second term. Courses in Group 1-A are also available to freshmen to satisfy part of the requirements for non-technical electives. See page 151.

**Mathematics.** The mathematics sequence of 115, 116, 215, 315, and 316 provides an integrated sequence in college mathematics, sixteen hours credit, that includes analytic geometry, calculus, and elementary differential equations.

While most freshmen elect Mathematics 115 in their first term, it is in the best interest of the student to place him in the mathematics course which most closely matches his previous preparation and his ability.

A student having an especially high level of mathematical preparation and ability may accelerate his training, with deeper penetration, through one of the honors-level sequences starting with Mathematics 185 or 195. See also the Unified Science sequence below.

A student who has completed a full year calculus course in high school, and whose preparation in this subject has been validated by College Board Advanced Placement scores, may receive eight hours credit in mathematics and be eligible for placement into Mathematics 215. Other students who have 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 Branch Office, 347 West Engineering Building.

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

| | *Those Students Who:* | *Elect* | *Credit Hours* |
|---|---|---|---|
| I. | Are deficient in trigonometry. | Math. 107 (May accompany Math. 115) | 2* |
| II. | Are deficient in both algebra and trigonometry. | Math. 105 | 4* |
| III. | Have no deficiencies but whose high school record and SAT scores indicate possible difficulties in mathematics. | Math. 115 (A section meeting 6 times a week) | 4 |
| IV. | Have no deficiencies and are qualified by high school record and SAT scores. | Math. 115 (A section meeting 4 times a week) | 4 |
| V. | Qualify for Unified Science sequence (see below) or have special permission of the Department of Mathematics. | Math. 185 or 195 | 4 |

Transfer students from other colleges who have completed college algebra, and plane and solid analytic geometry without calculus, normally will be allowed six hours credit and will be required to take Mathematics 213 and 214 (four hours credit each) and Mathematics 316 (two hours credit) to complete the Group A requirements.

**Engineering Graphics.** The freshman schedule includes a three-hour engineering drawing course in the first term, Engineering Graphics 101.

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

The several programs vary with respect to additional requirements in engineering graphics. The student should refer to Group B of the departmental program in which he plans to enroll and should consult with his counselor before electing further graphics courses. Graphics 101 is usually followed by Graphics 102, 3 hours credit, or Graphics 104, 2 hours credit.

**Chemistry.** Chemistry is not required as a science unit for admission, although it is strongly recommended.

A number of factors determine the proper elections in chemistry. These are best covered in outline form as follows:

| *Those Students Who:* | *Elect* | *Credit Hours* |
|---|---|---|
| I. Have not had chemistry in high school (*a*) and who plan to elect a program requiring advanced chemistry; | Chem. 103 and 106 | 8 |
| (*b*) others | Chem. 103 and 105 | 8 |
| II. Have had chemistry in high school but do not qualify for Chemistry 107 or Unified Science sequence (*a*) and who plan to elect a program requiring advanced chemistry; | Chem. 104 and 106* | 8 |
| (*b*) others | Chem. 104 and 105* | 8 |
| III. Have shown proficiency in chemistry in high school and on chemistry tests. | Chem. 107 (given fall term only) | 5 |
| IV. Qualify for Unified Science sequence (see below) | Chem. 194 and 195 | 8 |

A student planning to elect a program requiring additional chemistry should refer to the schedule of the selected program and consult with the program adviser to determine the most suitable sequence of advanced chemistry.

**Physics.** Physics is not required as a science unit for admission, although it is strongly recommended.

The freshman schedule includes Physics 145 in the second term. This course assumes knowledge of calculus and follows Mathematics 115. Transfer students placed in Mathematics 213 may elect Physics 145 concurrently. Physics 145 is followed by Physics 146, making a total of 10 hours.

Those students who qualify for Unified Science sequence will elect Physics 153 and 154 for a total of 8 hours (see below).

**Unified Science Sequence.** The Unified Science sequence consists of special honors-level courses in introductory college mathematics, physics, and chemistry designed for students with strong backgrounds in science

* A student with a high record in Chemistry 104 may be invited to elect Chemistry 191, 5 hours, instead of Chemistry 105 or 106. This combination provides the student with additional background in chemistry and may permit him to take succeeding courses at a saving of credit hours.

and mathematics who have demonstrated outstanding academic abilities in high school. These courses are taken in the following order:

| | |
|---|---|
| First Term: | Math. 185 (4 hours) and Physics 153 (4 hours) |
| Second Term: | Math. 186 (4 hours) and Chem. 194 (4 hours) |
| Third Term: | Math. 285 (4 hours) and Chem. 195 (4 hours) |
| Fourth Term: | Physics 154 (4 hours) |

An example of this sequence appears in the representative schedule for the Science Engineering program.

These courses emphasize the use of mathematics and laboratory experimentation in developing the fundamental principles and concepts of the physical sciences. In addition, they are highly integrated, with each course building on the material taught in all previous courses. This approach allows each subject to be treated in a more rigorous manner and at a more advanced level than would otherwise be possible, and it provides a superior background in science and mathematics that is especially valuable for students in engineering.

Because of their integrated character, these courses can normally be taken only in the order given above, and it is necessary for students to enroll in them as freshmen and to complete the full two-year sequence to obtain maximum benefit from them. In the College of Literature, Science, and the Arts, the Unified Science courses are part of the Honors Program, and only students qualifying for this program are selected for the Unified Science courses. Students of comparable ability are selected from freshmen entering the College of Engineering. Preliminary selection of students is made during the freshman orientation period by special counselors, based on the students' high school records and their scores on the various examinations. The final decision to elect the sequence is made by the student after consultation with these counselors. No student is required to elect these courses; conversely, students who do not meet the minimum standards for honors-level work at the time of admission will not be admitted to the sequence.

**Other Possibilities for the First-Year Schedule.** A student who satisfies his chemistry or engineering graphics requirements during his first term has an opportunity to select appropriate hours from a number of subjects during his second term. A student who plans to select a program requiring additional chemistry, should elect an appropriate chemistry course. If he plans to select the chemical or metallurgical engineering program, he may elect Chemical and Metallurgical Engineering 200.

Acceptable nontechnical subjects may be elected that will apply against the requirements for nontechnical electives in Group B. For example, see English, page 155, Group I-A.

## Transfer Students

Students who transfer from another college enter with a wide variety of previous preparation. After tentative adjustment of advanced credit, usually they will be counseled as follows:

*a*) A student with less than 25 hours of credit applicable to an engineering degree will be assigned to a freshman counselor;

*b*) A student with 25 hours or more will be referred to the program adviser of the program he elects.

In any case, the student's courses for his first term will be determined by this College's evaluation of his past work and by his program adviser. If he finds at any time during the first two weeks that he has not been properly classified, he should report immediately to his program adviser.

# Rules and Procedures

## Honor Code

"Honesty, justice, and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers, and clients, and with fairness and impartiality to all."

In 1916, thirty years before this statement was published by the Engineers' Council for Professional Development and adopted as part of the Canons of Ethics by the national professional engineering societies, the students of the College of Engineering, with the approval of the faculty, established and adopted the following procedure:

All examinations and written quizzes in the College are held under the Honor Code, the object of which is to create the high standard of honor which is essential to a successful engineer and a good citizen. Students are expected to uphold the code or declare their unwillingness to do so after having been duly instructed in all its rules. The instructor does not remain in the room during an examination. The students are placed upon their honor to refrain from all forms of cheating and to reprimand a fellow student who acts suspiciously and, in case he does not take heed, to report him to the Student Honor Committee. Every student must write and sign the following at the end of his examination paper, if he had not asked for an examination under a proctor:

*"I have neither received nor given aid during this examination."*

Either a student or the instructor may report a violation that is then investigated by the Student Honor Committee, which makes a recommendation to the faculty Committee on Discipline.

The principles on which the Honor Code depends for its success apply to all facets of a student's life on the campus. Enrollment in the College carries with it obligations in regard to conduct outside the classroom as well as inside and students are expected to conduct themselves in such a manner as to be a credit to themselves, to the University, and to the community.

## Health Service Approval

Health Service approval is a prerequisite for final admission. This approval is granted when the report of a physical examination is submitted by a physician of the applicant's choice upon a form provided by the University. It is not intended to establish standards of physical requirements for admission and the nature of the physician's report will not affect the eligibility of the applicant. It is essential, however, that the Health Service be provided with information with respect to the physical condition of each student in the best interest of the student himself and his associates. Vaccination for small pox and tetanus is strongly urged.

Physical examinations are not required of those applicants who intend to enroll only for the summer session or who are on campus for limited periods.

All new students will report to the Health Service for a chest X ray as a part of the normal registration procedure.

Students who have been out of residence for health reasons will go to the Health Service for clearance, as will those students who have received notice that special Health Service approval is required for readmission.

Treatment by the Health Service of those students entitled to that service is optional on their part, except when in the opinion of the Director they may be a source of danger to student health. The type and amount of service is in conformity with the rules and regulations of the Health Service.

Foreign students should observe the regulation regarding health insurance under Fees and Deposit.

## Physical Education

Each student entering the University from a secondary school is required to satisfactorily complete a one-year course in physical education suited to his health condition, unless exempted by service in the Marching Band (one term) or official freshman sports. A transfer student with less than sixty hours of advanced credit, and without a year of physical education elsewhere, will be required to elect one year of physical education at the University unless excused by the Health Committee.

Veterans who have completed a regular tour of duty (minimum of 20 months of service), or its equivalent, are excused from the regular requirements of physical education. Students who enroll in a Reserve Officers Training Corps also fulfill the requirements of physical education.

All *unexcused absences* must be made up. Health Service statements will be accepted only for illness of more than twenty-four hours. All excuses for absences from required physical education classes must be presented to the Waterman Gymnasium office for approval.

## Definitions

**Term.** A term is a period of enrollment extending over approximately four months, including examinations. Schedule, by months, of the University's year-round calendar is 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-Summer | 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* |

Summer half-term is synonymous with the University's Summer Session. In the following rules and procedures, the word "term" also applies to half-term (and summer session) unless otherwise indicated.

**Credit Hour.** A credit hour represents, generally, one hour of recitation or lecture per week for one term, preparation for which should require two hours of study; generally, one period of laboratory work is considered equivalent to one hour of credit. (An explanation of the time requirement for graduation will be found under Undergraduate Degree Programs and Requirements.)

**Counselor.** The word "counselor" as used in the following rules means freshman counselor for freshmen and academic counselor for other undergraduates.

## Election of Studies

**Course Offerings.** The annual and Summer Session *Announcements* 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 six persons.

**Program Selection.** A student is required to select his program of study during the second term of his freshman year and is referred to the appropriate program adviser at the completion of approximately thirty hours of Group A credits. A tentative program established at this time, will be helpful as a guide to the student and his elections counseling through the completion of the student's degree requirements.

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

**Election Considerations.** At any time, a student's elections must take into account his preparation (including deficiencies), demonstrated ability and performances, 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 of his work in the College of Engineering shall be reported to the Assistant Dean. After consultation with the Department of English and the program adviser, the student may be required to elect such further work in English as may be deemed necessary.

**Work Load.** Minimum full schedule is twelve credit hours during a term or six during a half term.

Unless approved by his program adviser (for freshmen, the Assistant Dean), a student may not elect courses (or change his elections) for which the total number of hours for a term is less than twelve or more than eighteen, 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 eighteen hours.

A student may be required to drop part of his course work at any time he appears to be undertaking too much, or to take additional work if he is not carrying a sufficient work load. If he is required to work to support himself wholly or in part, he should elect a schedule of courses consistent with his ability to earn grades that qualify for graduation and at the same time retain his health.

**Classification and Registration.** Each term, the Classification Committee will prepare necessary instructions to program advisers, counselors, and students relating to election of courses, classification (including assignment to sections), and registration.

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

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

**Dropping a Course.** During the first eight weeks of the term, a course may be dropped without record when there is a justifiable reason, and when the student has the approval of his counselor after conference with the instructor in the course. See Work Load, above.

After the first eight weeks of the term, a student must obtain the approval of his program adviser (or the Assistant Dean for freshmen) to officially drop a course; approval without grade of E will depend on satisfactory evidence of extraordinary circumstances.

A student enrolled in an ROTC program must have approval also of the professor in charge of the unit before he can drop an ROTC course or relieve himself of the obligation he assumed when he enrolled in the program.

The grade for any course dropped without permission will be recorded as U (unapproved drop) and computed as E in the averages.

**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 on a form available at the Records Office, and is subject to review by the Curriculum Committee.

**Electives.** In order that a student may explore areas other than his chosen field of engineering, he is required to complete a minimum number of credit hours of elective studies. For details, refer to Group B subjects, pages 36–37.

A student may elect courses in addition to those required for his degree.

He may not register in the Engineering College and elect courses offered by another college if such elections do not contribute to a goal of a bachelor's degree in the Engineering College, except when approved by the Assistant Dean.

## 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 his final grade.

All students are required to account to their instructors for their absences. An instructor may report to the Assistant Dean when he considers that the number of absences of an underclassman is excessive, and he 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 his adviser to determine the advisability of reducing his 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.

Any student absent from an examination is required to report to his instructor as soon thereafter as possible. If a student presents a valid excuse for his absence, he may take the examination at such time as may be arranged by the instructor.

## Grades and Scholastic Standing

**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 his academic record. The grades are valued per credit hour on the basis of:

| | | | |
|---|---|---|---|
| A—excellent | 4 points | D—passed | 1 point |
| B—good | 3 points | E—not passed | 0 points |
| C—satisfactory | 2 points | | |

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 credit hours represented by all the courses elected. The word "average" is synonymous with grade-point average.

**Academic Record.** Each student's "Academic Record" is that cumulative record maintained by the Records Office of his courses elected, grades, averages, and other matters relating to his progress. A copy is given to the student's program adviser after each term's grades and averages are recorded.

Upon request by the student at the Records Office, first official copy of his academic record is provided without charge, and additional copies at $1.00 each except as restricted under "Indebtedness to the University."

**Good Scholastic Standing.** To be in good scholastic standing at the end of any term, a student must have an average of 2.00 or more for the term and a cumulative average of 2.00 or more. (See Rules Governing Scholastic Standing below.)

In order to attain a bachelor's degree, a student's final cumulative average must be 2.00 or more for all courses taken while enrolled in this College.

Degree candidates who carry a full schedule and earn a 3.50 term average or better, attain the distinction of the Dean's Honor List for the term.

**Unsatisfactory Performance.** Three degrees of scholastic deficiency identify a student's unsatisfactory performance resulting from D and E grades: (1) on warning, (2) on probation, and (3) required to withdraw.

**D Grades.** While a grade of D is passing, it is not considered satisfactory performance. Any deficiency of grade points (below 2.00 average) resulting from one or more D grades must be made up while enrolled in this College before the student is restored to good standing.

A student on warning or probation must repeat as soon as possible each course for which he earned a grade of D if the course is required by his program; in exceptional cases, this requirement may be waived by the student's program adviser (for freshmen, the Assistant Dean).

A student in good standing may choose to repeat a D provided he does so during the next two terms that he is enrolled. As a general principle, any student is well-advised to repeat a D immediately if the course is an important prerequisite for other courses.

Credit is not transferable for courses in which D grades, or equivalent, were earned in another college.

**E Grades.** Neither credit nor grade points are allowed for a course in which a student earns the grade of E. Any deficiency of grade points (below 2.00 average) resulting from one or more E grades must be made up while enrolled in this College before the student is restored to good standing.

A student earning a grade of E in a course required by his program must repeat it as soon as possible.

**Rules Governing Scholastic Standing.** The following chart defines the rules that govern scholastic standing:

| *Scholastic Standing at Beginning of Term* | *Student's Achievement Record for the Term* | | *Resultant Standing* |
|---|---|---|---|
| | *Term Average* | *Cumulative Average* | |
| In good standing | 1.70 to less than 2.00<br>1.10 to less than 1.70<br>less than 1.10 | | Placed on warning<br>Placed on probation<br>Required to withdraw† |
| On warning | 2.00 or more<br>2.00 or more*<br>1.70 to less than 2.00<br>less than 1.70 | less than 2.00 | Continued on warning<br>Continued on warning<br>Placed on probation<br>Required to withdraw† |
| On probation | 2.00 or more<br>2.00 or more*<br><br>less than 2.00 | less than 2.00 | Placed on warning<br>Continued on probation<br>Required to withdraw† |
| In good standing, but on probation twice previously | less than 1.70 | | Required to withdraw† |
| On warning or probation | 2.00 or more for full schedule | 2.00 or more | Restored to good standing |

* For a schedule of courses less than a minimum full schedule.
† See Conditions for Reinstatement below.

**On Warning or Probation.** A student on warning or probation may continue his enrollment but should consult immediately with his counselor or program adviser to review his status and goals, and arrange any necessary adjustments in his program, work load, or plans for the future. See under D and E Grades above on repeating courses.

In cases of extenuating circumstances, a student on warning or probation may be restored to good standing at the discretion of the faculty Committee on Scholastic Standing.

**Conditions for Reinstatement.** When a student is required to withdraw because of poor scholarship, his further enrollment is contingent upon reinstatement on probation by the faculty Committee on Scholastic Standing. He has the privilege of presenting the associated circumstances, and the reasons for his low record, to the Committee in a manner specified by the Committee, normally in an interview. On sufficient and convincing evidence of the extenuating circumstances, and of the student's ability and motivation to improve his performance, the Committee may reinstate him on probation and specify the credit-hour load and expected performance. Upon being reinstated, his achievement will be judged by the rules that cover "On Probation" (above).

A student reinstated after an absence of one term or more must also re-establish his enrollment with the Assistant Dean's Office.

**Incompletes.** When a student is prevented by illness, or by any other cause beyond his control, from taking an examination or from completing any part of a course, or if credit in a course is temporarily withheld, the mark I with a qualifying grade may be given to indicate that the course has not been completed. An incomplete course is thus reported IA, IB, IC, ID, or IE. The grade indicates the quality of work done in the part of the course which has been completed.

The qualifying grade is used to compute temporary averages. If an incomplete is reported without a qualifying grade, it is considered temporarily as a D grade.

In order that credit may be allowed, the required work must be completed before the end of the eighth week of the first term (not including half terms) that the student is enrolled after the term in which the incomplete grade was recorded, unless an extension is granted by the Assistant Dean. When completed, the final grade will be based upon all of the work done in the course and may or may not be the grade reported for the partly completed course.

If the student does not meet the above stated requirements, the I grade will be changed to E by the Records Office and averages computed accordingly.

**Other Irregularities.** Irregularities associated with failure to submit change in classification to the Records Office are identified on the student's Academic Record by an appropriate designation such as U (unapproved drop), or N (no report). No credit will be allowed a student for work in any course unless the election of that course is entered officially on his classification record.

The student must consult the Assistant Dean's Office on the necessary procedures for resolving such cases, if there has been an error.

**Repeating Courses.** For D and E grades, see above. Except as provided for D grades, a student may not repeat a course which he 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.

Any time a course is repeated in accordance with the rules, both grades will be used in computing the student's cumulative average, but the hours of credit are used only once in computing the hours credit towards his degree.

**Grade Reports.** Unless withheld for infringement of rules, each term's grades are reported to the student. When he is not in good scholastic standing, a status report is sent to both the student and the parent.

## Class Standing

The number of credit hours achieved toward graduation at the close of the term in which a student was most recently enrolled, plus "incompletes," "no reports," and "unapproved drops," will be used to determine his class standing for purposes of assessing fees and the necessary statistics. Appeals concerning class-level designations should be made at the Assistant Dean's Office.

| *Class* | *Credit Hours* |
|---|---|
| *Underclassmen* | |
| Freshman | 0 to 29 |
| Sophomore | 30 to 61 |
| *Upperclassmen* | |
| Junior | 62 to 99 |
| Senior | 100 or more |

A transfer student is classified in this manner in terms of the tentative adjustment of credit hours applicable to his elected program. When, in the opinion of his program adviser, there is a reasonable expectancy that a transfer student will graduate within one year, he will be classified as a senior.

Special students, guest students, and students on a prescribed program are considered upperclassmen for purpose of assessing fees.

## Transferring Out, Withdrawal, and Readmission

**Transferring Out.** A student who wishes to pursue his studies in another unit of the University must apply for admission to that unit and be accepted in order to continue his enrollment in the University. In general, a student's scholastic standing determines his eligibility for admission to other colleges.

The Assistant Dean may be consulted for procedures to effect a transfer.

**Withdrawal.** Withdrawal from the College for a justifiable reason at any time during a term requires the approval of the Assistant Dean. A student under twenty-one may be required to present evidence of parent's approval.

After the eighth week of a term, or fourth for a half term, a student requesting withdrawal without record must present evidence of extraordinary circumstances.

When a student plans not to return the next term, his attention is called to the regulations on enrollment deposit.

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

**Readmission.** When a former student wishes to re-enroll, he must apply to the Assistant Dean for readmission and should do so at least two months before the date of desired enrollment.

A student who was required to withdraw must first be reinstated on probation by the Committee on Scholastic Standing.

## Convocations

The College of Engineering holds a convocation near the end of the winter term giving recognition to students with high scholastic achievement, and with records of service to the college and its student organizations. In addition, those students who have earned distinguished academic records participate in the University's Honors Convocation.

## Diploma and Commencement

To be recommended for a degree a student must file formal application for the diploma in the Records Office, 263 West Engineering Building. This should be done early in the term in which the student is reasonably certain of completing his work for the degree. If he does not complete his work in that term, it will be necessary for him to renew his application early in the succeeding term.

All students who are entitled to receive diplomas are expected to be present at the Commencement exercises appropriate to the date of graduation.

## 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 nonengineer, the state establishes standards and provides the legal processes associated with the registration of individuals and their practice as professional engineers.

In Michigan, the State Board of Registration for Architects, Professional Engineers, and Land Surveyors provides an opportunity for senior engineers while on the campus to take the first examination to begin planning for registration. It 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 engineer-in-training will take an examination in his chosen field and one in a general area relating to business and professional practices and ethics.

On completing his registration, an engineer receives authority to practice his profession before the public and establishes his professional standing on the basis of legal requirements. 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.

## Requirements for Graduation

The scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student rather than in terms of a total number of credit hours.

In order to secure a degree in the College of Engineering, a student must meet the following requirements:

1. (*a*) He must demonstrate a basic level of attainment in the fundamental fields common to all degree programs, equivalent to the satisfactory completion of the courses as specified under Group A (next section), and (*b*) he must satisfactorily complete 95 hours of professional, advanced, and elective courses (or their equivalent) as specified in the program of his choice under Group B (next section).

2. His final cumulative grade-point average for all courses taken while enrolled in the College of Engineering, Ann Arbor campus, must be 2.00 or more.

3. A student who has earned 30 hours or more of credit in the College of Engineering, Ann Arbor campus, prior to the beginning of his last 30 hours required for graduation, may elect 6 hours of the last 30 hours at another recognized college. All other students must complete their last 30 hours of work enrolled in the College of Engineering, Ann Arbor campus.

4. To obtain two bachelor's degrees in the College of Engineering, a student must complete the requirements of both degree programs. He must complete, in addition to those credit hours which are used to satisfy the requirements of one of the degree programs, a minimum of 14 credit hours in pertinent technical subjects which must be used in satisfying the requirements of the other degree program. The credit hours used to satisfy each of the two program requirements must satisfy the cumulative grade-point average requirement of 2.00 or more.

5. To obtain an additional bachelor's degree (B.S. or A.B.) in the College of Literature, Science, and the Arts, a student must complete at least 90 hours of credit in the College of Literature, Science, and the Arts; satisfy the distribution requirements and the concentration requirements of the College of Literature, Science, and the Arts; satisfy the Group A and B requirements of the College of Engineering; and meet the scholastic requirements of each college. He must also make applications for diplomas to each college. For details refer to page 37.

## Undergraduate Degree Programs

Each of the fourteen undergraduate degree programs is composed of two groups of subjects that are identified under the program descriptions as Group A and Group B.

For information on credit for courses taken at other recognized colleges or universities, see Admission with Advanced Standing.

### Group A Subjects

Group A includes foundation subjects in those fundamental areas of communication, mathematics, and basic sciences that are common to all programs. The courses in the following schedule must be elected and passed or equivalent proficiencies must be demonstrated (see Requirements for Graduation):

| *Subject* | *Hours* | *Subjects to be elected or equivalent proficiencies to be demonstrated* |
|---|---|---|
| English Composition and Speech | 6 | English 111, 112, and 121 |
| Mathematics | 16 *or* 12 | Math. 115, 116, 215, 315, and 316 / Math. 185, 186, and 285 |
| Engineering Graphics | 3 | Eng. Graphics 101 |
| Chemistry | 5 or 8 | See Chemistry, page 23 |
| Physics | 10 *or* 8 | Physics 145 and 146 / Physics 153 and 154 |

NOTE—The number of hours elected by a student enrolled in the Unified Science sequence is generally 8 for chemistry and 8 for physics.

Appropriate college credit may be allowed a student for subjects in which he has qualified through the Advanced Placement Program as covered under Admission as a Freshman. Another possibility for attaining advanced credit is through demonstration of equivalent proficiency in any of the Group A subjects; this is done by observation of the extent of preparation, abilities, high school standing, and results of any placement examinations taken by the student. Such savings in credit hours resulting from careful planning of the high school program may serve either to materially decrease the time required for completing the degree requirements or to provide opportunity for special college elections.

Generally, suitable Group A subjects, with the possible exception of Engineering Graphics, are offered in liberal arts colleges and community colleges; under conditions of equivalency and satisfactory performance, they are transferable to any engineering program.

## Group B Subjects

Group B for each program is composed basically of those professional subjects, advanced subjects, and electives that will prepare the student for the particular field of engineering he selects. Included are courses in advanced mathematics and science, engineering sciences, engineering analysis and design, and elective studies in both technical and nontechnical areas as outlined below.

The requirements for each program, a total of 95 credit hours, are specified under the heading Professional and Advanced Subjects and Electives.

**Elective Studies.** Each program provides in Group B some freedom for the student to elect subjects that satisfy his particular interests and aptitudes. His counselor or program adviser is in a position to make helpful recommendations.

Subject to the limitations of his program and to the approval of his counselor or program adviser, a student may elect: courses within the field in which he is enrolled and courses for which he is qualified in other engineering departments; appropriate courses in other colleges or schools of the University (e.g., mathematics; the physical, biological, social, and management sciences; the humanities; fine arts; and languages); and advanced courses in air, military, or naval science.

This plan is designed to permit the greatest freedom of choice of subjects consistent with the acquisition of a sound background and a desirable breadth of education. It provides the student an opportunity to explore areas of cultural interest, and to plan for continued or advanced study in a selected field—either in engineering and physical sciences or in other areas such as business administration, patent law, or bioengineering.

**Nontechnical Electives.** The programs vary in their requirements of nontechnical electives and in some instances the subjects from which a student may make his choices are specified in the list of Group B requirements. For those programs in which the term "nontechnical electives" is used, the student may choose from the following:

1. English beyond the required courses
2. Courses in the College of Architecture and Design whose major emphasis is on the fine arts
3. Courses offered by any instructional department or unit of the University except the following:
   *a*) A department already represented by a required course in the student's degree program
   *b*) The departments of Air, Military, or Naval Science
   *c*) The College of Engineering (see (1) above)
   *d*) The School of Business Administration
   *e*) The College of Architecture and Design (see (2) above)

Anyone wishing to discuss suitable elections in the College of Literature, Science, and the Arts may consult the Junior-Senior Counseling office, 1223 Angell Hall.

## Time Requirement for the Bachelor's Degree

The time required to complete a degree program depends on the background, ability, and interests of the individual student. Eight terms plus a half term, or nine terms, can be used for planning purposes. Students who are admitted with advanced preparation, or with demonstrated ability to achieve at high levels, may materially accelerate their progress.

Students interested in the pursuit of graduate work may, under some conditions, receive credit for graduate level work taken in their last term as an undergraduate (refer to the *Announcement* of the Horace H. Rackham School of Graduate Studies).

## Additional Bachelor's Degrees from College of Literature, Science, and the Arts

*Program Advisers:* Professor W. C. Bigelow, 4213 East Engineering
Professor R. C. Taylor, 1044 Chemistry Building

Students enrolled in the College of Engineering or the College of Literature, Science, and the Arts who desire broader training and experience than is normally obtained in either college alone may participate in a Combined Degree Program leading to bachelor's degrees in both colleges. The regulations for this program are as follows:

1. Students enrolled in either the College of Engineering or the College of Literature, Science, and the Arts may participate in the Combined Degree Program.

2. A student considering the program should consult one of the program advisers as soon as his interest is firmly established, but preferably no later than during his second term of University work.

3. Admission to the program is subject to approval by the assistant deans and appropriate departmental program advisers in the two colleges. To qualify for admission, a student ordinarily must have completed at least 30 credit hours of work on this campus and have a grade point average of at least 2.40.

4. Once admitted, a student must meet the scholastic standards of both colleges to remain active in the Combined Degree Program; to permit most effective scheduling of the technical courses in the two colleges, he will not be required to meet the time limitations for completion of distribution requirements which are normally applicable to students in the College of Literature, Science, and the Arts.

5. Upon being admitted to the Combined Degree Program, a student must specify his intended field of specialization in each college. Thereafter, the corresponding program adviser in each college (or special counselors designated by the assistant deans), and the program advisers for the Combined Degree Program will assist the student in developing a schedule of courses that will effectively and efficiently meet the requirements of the Combined Degree Program.

**Program Requirements**

Candidates for bachelor's degrees in both the College of Engineering and the College of Literature, Science, and the Arts under the Combined Degree Program must (*a*) satisfy the Group A and B requirements of the College of Engineering; (*b*) satisfy the distribution and concentration requirements of the College of Literature, Science, and the Arts and take a minimum of 90 credit hours of work in that college; and (*c*) meet the scholastic standards of both colleges. These requirements are described in detail in the *Announcements* of the two colleges. Students interested in the Combined Degree Program should become thoroughly familiar with both *Announcements*.

Because of the variety of possible combinations of programs in the two colleges that might be chosen by students under the Combined Degree Program, it is not feasible to attempt to list course requirements in detail. Instead, it is recommended that each student consult with the program advisers for the Combined Degree Program to explore requirements for the particular combination of fields of specialization that is of interest to him.

In general, counselors working with students in the Combined Degree Program will attempt to minimize the total number of courses required by recommending courses which will contribute toward fulfilling requirements in both colleges whenever possible. Thus, many of the courses needed to fulfill the Group A 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 the College of Literature, Science, and the Arts; many of the concentration cognate courses can be selected from the Group B engineering science courses; likewise, the nontechnical electives and the Group B requirements in literature for the College of Engineering can be selected from among courses taken to fulfill the College of Literature, Science, and the Arts distribution requirements.

In this way, it should be possible for a student carrying an average load of 17 credit hours per term to complete the requirements of the Combined Degree Program in 10 or 11 terms.

## Aeronautical and Astronautical Engineering

*Program Adviser:* Associate Professor Eisley, 1503 East Engineering

The design of modern aircraft, missiles, and space vehicles involves problems in many branches of engineering and the sciences. The program in aeronautical and astronautical engineering, therefore, has been arranged to provide the student with a broad and fundamental background. It includes a study of subsonic and supersonic aerodynamics with applications to flight vehicles. A sequence of courses in propulsion considers theoretical aspects of aerothermodynamics and applications to jet and rocket motors. A sequence of courses in structural mechanics develops the fundamental equations of solid mechanics and applies them to static and dynamics problems of light weight structures. Another sequence considers the dynamic stability and control of flight vehicles. In the senior year a course in design is provided which draws on the experience gained in many of the earlier courses.

All theoretical work is co-ordinated with laboratory periods in which the student acquires a working familiarity with modern experimental equipment.

Electives are provided which enable the student to broaden his understanding of the various areas of aeronautical and astronautical engineering or to specialize in one of them.

### Facilities

The Department of Aeronautical and Astronautical Engineering provides laboratories for instruction and research in gasdynamics, guidance and control, and structures. The facilities for studies in gasdynamics include wind tunnels and channels covering wide speed and temperature ranges, as well as special pieces of equipment adapted to the study of specific problems. The instrumentation laboratory is equipped for studies of the fundamentals of guidance, automatic control, and instrumentation. This laboratory includes a number of electronic differential analyzers for teaching and research. The structures laboratory includes static testing machines and equipment for vibration excitation. Strain-measuring equipment includes strain gages and recording equipment for static or dynamic measurements.

**Requirements**

Candidates for the degree B.S.E. (Ae & Astrn.E.)—Bachelor of Science in Engineering (Aeronautical and Astronautical Engineering)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Groups II and III | 4 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Eng. Graphics 104, Geometry of Engineering Drawing | 2 |
| Econ. 401, Modern Economic Society | 3 |
| Math. 450, Advanced Mathematics for Engineers | 4 |
| Eng. Mech. 208, Statics | 3 |
| Eng. Mech. 210, Mechanics of Material | 4 |
| Eng. Mech. 212, Laboratory in Mechanics of Material | 1 |
| Eng. Mech. 343, Dynamics | 3 |
| Mech. Eng. 335, Thermodynamics I | 3 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Aero. Eng. 200, General Aeronautics and Astronautics | 2 |
| Aero. Eng. 314, Structural Mechanics I | 4 |
| Aero. Eng. 320, Aerodynamics I | 4 |
| Aero. Eng. 330, Propulsion I | 3 |
| Aero. Eng. 414, Structural Mechanics II | 4 |
| Aero. Eng. 420, Aerodynamics II | 4 |
| Aero. Eng. 430, Propulsion II | 4 |
| Aero. Eng. 441, Mechanics of Flight | 4 |
| Aero. Eng. 471, Automatic Control Systems | 4 |
| Aero. Eng. 481, Airplane Design | 4 |
| Electives in the Humanities and Social Sciences | 12 |
| Electives* | 12 |
| Total hours in Group B | 95 |

**Representative Schedule**

For studies of the first year, see page 20.

| *Third Term* | *Hours* |
|---|---|
| Math. 215 | 4 |
| Physics 146 | 5 |
| Aero. Eng. 200 | 2 |
| Eng. Mech. 208 | 3 |
| Elective | 3 |
| | 17 |

| *Half Term* | |
|---|---|
| Elective | 3 |
| English, Group II | 2 |
| Eng. Mech. 212 | 1 |
| | 6 |

| *Fourth Term* | *Hours* |
|---|---|
| Math. 315 | 2 |
| Math. 316 | 2 |
| Chem.-Met. Eng. 250 | 3 |
| Eng. Mech. 210 | 4 |
| Mech. Eng. 335 | 3 |
| Elective | 3 |
| | 17 |

* A maximum of 4 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

| *Fifth Term* | *Hours* | *Sixth Term* | *Hours* |
|---|---|---|---|
| Math. 450 | 4 | Aero. Eng. 314 | 4 |
| Aero. Eng. 320 | 4 | Aero. Eng. 330 | 3 |
| Eng. Mech. 343 | 3 | Aero. Eng. 420 | 4 |
| Elec. Eng. 316 | 4 | Aero. Eng. 441 | 4 |
| Elective | 2 | Elective | 2 |
| | 17 | | 17 |
| *Seventh Term* | | *Eighth Term* | |
| Aero. Eng. 430 | 4 | Aero. Eng. 471 | 4 |
| Aero. Eng. 414 | 4 | Aero. Eng. 481 | 4 |
| Econ. 401 | 3 | Electives | 6 |
| Electives | 5 | English, Group III | 2 |
| | 16 | | 16 |

## Chemical Engineering

*Program Adviser:* Professor G. B. Williams, 3213 East Engineering

"Chemical engineering is that portion of the field of engineering where materials are made to undergo a change of composition, energy content, or state of aggregation." So states a recent report on Dynamic Objectives for Chemical Engineering prepared by the American Institute of Chemical Engineers. The report also says, "The characteristic functions of chemical engineers are the examination, design, and operation of processes and equipment that accomplish changes in chemical composition." The chemical engineer is the designer of plants, the controller of reactions, the maker of chemicals, and the supervisor of developmental research. He brings to bear on his problems the principles of the physical sciences, economics, and human relations. In these tasks he must be a dynamic individual who keeps up with the latest developments that pertain in any way to his job responsibility.

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 following areas of specialization may be undertaken by the student in a regular chemical engineering program by electing the suggested groups of courses:

**Biochemical.** The combination of biological and chemical reactions to produce antibiotics, frozen foods, fermented products, vaccines, and even algae in space vehicles. Chem.-Met. Eng. 484, 485; Chem.-Met. Eng. 580.

**Combustion.** The oxidation of fuels to produce power, drive space craft, supply heat, or cause other chemical reactions. Chem.-Met. Eng. 445, 449; Aero. Eng. 632; Mech. Eng. 493, 495.

**Electrochemistry.** The use of electricity in promoting chemical reactions or the use of reactions to yield electricity directly. Chem.-Met. Eng. 510; Elec. Eng. 330.

**Electronic Materials.** The design, preparation, and properties of materials that find application in the electronics industry. Chem.-Met. Eng. 551; Elec. Eng. 419, 442; Math. 404; Physics 453, 463.

**Graduate Studies.** Preparation for a more intensive and penetrating study of the field of chemical engineering and of frontier problems of research. Chem.-Met. Eng. 400, 430, 445; Math. 450, and language preparation.

**Instrumentation.** The measurement and control of variables in physical and chemical processes encountered in industry or space-age research. Chem.-Met. Eng. 446; Math. 404, 448; Instr. Eng. 510, 570.

**Machine Computation.** The application of electronic computers to the solution of engineering problems. Chem.-Met. Eng. 501; Math. 404, 473, 474; Instr. Eng. 510.

**Materials.** A knowledge of the preparation, structure, and behavior of materials that are used in production or pilot plant work. Chem.-Met. Eng. 450, 451, 472, 479, 560; Eng. Mech. 413, 416.

**Molecular.** Concentration on the properties of molecules as they determine the macroscopic behavior of liquid or solid matter such as plastics or transistors. Chem.Met. Eng. 451, 560; Chem. 481, 482; Physics 425, 453.

**Nuclear.** A field closely allied to chemistry where nuclear reactions such as fission or spontaneous atomic disintegration occur. Nuc. Eng. 470, 550, 560.

**Polymers.** The field of large, long-chain molecules where new elastomers, synthetic fibers, or lubricants are designed or used. Chem.-Met. Eng. 451, 583; Chem. 538; Physics 418.

**Petroleum.** The production, transportation, refining, and chemical processing of oil and natural gas from the ground. Chem.-Met. Eng. 521, 522; Geol. 218.

**Propulsion and Rocketry.** The use of chemical, physical, and nuclear reactions to send machines through air, water, outer space, or across land. Chem.-Met. Eng. 449; Aero. Eng. 330, 430, 535, 632.

**Systems.** The methods of combining individual operations into a working whole with a maximum of efficiency and optimization. Chem.-Met. Eng. 481, 581; Instr. Eng. 570; Math. 448; Ind. Eng. 472.

## Facilities

The major facilities are located in the East Engineering Building, consisting of a foundry and melting laboratory; metalworking, welding, heat-treating, spectrographic (mass, infrared, ultra-violet, etc.), and metallographic laboratories; an X-ray laboratory for radiography and diffraction studies; an electron microscope; chemical, high-pressure, process dynamics, polymer, semiconductor, plasma, liquid metal, nuclear metallography, and thermodynamics laboratories; and in Fluids Engineering Laboratory, consisting of equipment for heat transfer and large-scale operations.

### Requirements

Candidates for the degree B.S.E.(Ch.E.)—Bachelor of Science in Engineering (Chemical Engineering)—are required to complete the program listed below. Since elective courses are nearly half the program, the student will be encouraged to plan the program which is best suited to his individual objectives with the advice and approval of the program adviser.

Only the level of attainment in the various areas of the academic program is specified, with the route to that level depending upon the preparation and ability of the individual student. Because of this and because of the large proportion of elective courses, a student may readily enter the chemical engineering program from an engineering science program or from a science curriculum taken outside the College of Engineering.

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*
(A typical sequence is shown in the first half of the representative schedule shown below.)

*B. Professional and advanced subjects and electives*

| **Basic Science** | *Hours* |
|---|---|
| Advanced chemistry to include Chem. 225, 226, 227, 265, 266, and 346, or Chem. 195, 225, 226, 227, 468, and 469, or equivalent | 20 |
| An electronic computer course such as Math. 273 | 1 |
| **Chemical and Metallurgical Engineering Science** | |
| Introduction to Engineering Calculations, Chem.-Met. Eng. 200 | 3 |
| Thermodynamics I, Chem.-Met. Eng. 230 | 5 |
| Rate Processes I, Chem.-Met. Eng. 341 | 3 |
| Rate Processes II, Chem.-Met. Eng. 342 | 4 |
| Separations Processes I, Chem.-Met. Eng. 343 | 4 |
| Structure of Solids, Chem.-Met. Eng. 350 | 3 |

**Electives**

1. Electives in humanities, social sciences, philosophy, languages, history of art, etc., including at least 4 credit hours of literature .... 14
   (See under English, and the *Announcement* of the College of Literature, Science, and the Arts for courses in these fields.)
2. Electives in law, economics, and business administration ... 6
   (Typical economics electives are: Econ. 203, 204, 271, 272, 401, 411, 412, 421, 431, and 475; and business administration electives are: Bus. Ad. 305 and 306, Accounting 271 and 272, Finance 300 and 301, Ind. Relations 300, Marketing 300, and Statistics 300.)
3. Electives in engineering science and analysis, such as mechanics of solids and fluids, network analysis, electronics, systems, energy conversion, electromagnetics, and thermodynamics 14
   (Typical electives are: Eng. Mech. 218, 219, 310, 324, 326, 343, 345, 400, 412, 422, 512, and 527; Elec. Eng. 210, 215, 220, 310, 315, 316, 320, 337, 418, 419, 422, and 425; Mech.-Eng. 421, 432, 437, 471, and 625; Chem.-Met. Eng. 430, 450, 470, 472, 560, and 580; Instr. Eng. 510, 530, and 570; Nuc. Eng. 400 and 470; Civ. Eng. 587.)

| | Hours |
|---|---|
| 4. Electives in advanced science and mathematics (Typical electives are: Math. 404, 447, 450, and 552; Chem. 403, 425, 447, 481, 482, and 538; Physics 305, 347, 406, 411, 418, 453, 455, 456, 457, and 463; Zool. 101, 105.) | 7 |
| 5. Electives in professional chemical engineering, to include laboratory, design, and materials (Minimum laboratory requirement is 2 hours) (Typical electives are: Chem.-Met. Eng. 390, 400, 430, 445, 446, 449, 450, 451, 460, 479, 480, 481, 484, 485, and 500-level courses where appropriate.) | 11 |
| Total hours in Group B | 95 |

A representative schedule is given below which shows one way in which the many elective alternatives may be chosen.

### Representative Schedule

The number in parentheses preceding course name designates typical electives from the group under Electives above.

| *First Term* | *Hours* |
|---|---|
| English 111 | 3 |
| Eng. Graphics 101 | 3 |
| Chem. 107 | 5 |
| Math. 115 | 4 |
| | 15 |

| *Second Term* | *Hours* |
|---|---|
| English 112 | 2 |
| English 121 | 1 |
| Physics 145 | 5 |
| Math. 116 | 4 |
| Chem. 225 | 3 |
| | 15 |

| *Third Term* | |
|---|---|
| Math. 273 | 1 |
| Physics 146 | 5 |
| Math. 215 | 4 |
| Chem. 226 | 3 |
| Chem. 227 | 2 |
| Chem.-Met. Eng. 200 | 3 |
| | 18 |

| *Fourth Term* | |
|---|---|
| Math. 315 | 2 |
| Math. 316 | 2 |
| Chem. 265 | 4 |
| Chem.-Met. Eng. 230 | 5 |
| (3) Eng. Mech. 310 | 4 |
| | 17 |

| *Fifth Term* | |
|---|---|
| Chem.-Met. Eng. 341 | 3 |
| Chem. 346 | 4 |
| Chem. 266 | 4 |
| (3) Elec. Eng. 316 | 4 |
| (1) English, Group II | 2 |
| | 17 |

| *Sixth Term* | |
|---|---|
| Chem.-Met. Eng. 342 | 4 |
| Chem.-Met. Eng. 350 | 3 |
| (3) Eng. Mech. 343 | 3 |
| (2) Acctg. 271 | 3 |
| (4) Math. 404 | 3 |
| (1) English, Group III | 2 |
| | 18 |

| *Seventh Term* | |
|---|---|
| Chem.-Met. Eng. 343 | 4 |
| (5) Chem.-Met. Eng. 479 | 3 |
| (2) Econ. 401 | 3 |
| (1) Russian | 4 |
| (3) Eng. Mech. 422 | 3 |
| | 17 |

| *Eighth Term* | |
|---|---|
| (5) Chem.-Met. Eng. 460 | 3 |
| (5) Chem.-Met. Eng. 480 | 3 |
| (5) Chem.-Met. Eng. 481 | 3 |
| (4) Adv. Math | 3 |
| (1) Russian | 4 |
| (1) Humanities | 2 |
| | 18 |

**Biochemical Engineering**

*Adviser:* Professor L. L. Kempe

Understanding of biological as well as physical sciences offers challenging opportunities to biochemical engineers in guiding the commercial development of products and processes required for human existence.

Current efforts in this exciting and progressive phase of chemical engineering involve work with antibiotics, freeze-dried foods, vaccines, marine plywood, tooth-hardening chemicals, DDT, potable water from the sea, detergents, algae in space vehicles, prosthetic metals, food yeast from industrial wastes, and frozen concentrated orange juice.

Electives adapted for the program in biochemical engineering: Group 3, Civ. Eng. 587, Chem.-Met. Eng. 580; Group 4, Chem. 228; Zool. 101 or 105; Group 5, Chem.-Met. Eng. 484 and 485.

**Combined Programs**

*Chemical, Materials, and Metallurgical Engineering*

Combined degrees may be obtained in chemical engineering and materials engineering, or chemical engineering and metallurgical engineering. A combined program is not recommended in metallurgical engineering and materials engineering because of their similarity.

Chemical engineering students who choose a second degree in metallurgical engineering will take a minimum of fourteen additional hours in the field of process, physical, and mechanical metallurgy. Those who choose materials engineering as a second degree will take at least fourteen additional hours in physical metallurgy, physical ceramics, and polymers.

Students in metallurgical or materials engineering who wish a second degree in chemical engineering must elect a minimum of fourteen additional hours in chemical engineering subjects. These must include Chem.-Met. Eng. 342 and 343, and any others chosen from Elective Group 5 in professional chemical engineering.

## Civil Engineering

*Program Adviser:* Associate Professor Harris, 313 West Engineering

Civil Engineering, originally named to distinguish it from military engineering, has always covered a wide field of engineering practice. Civil engineers plan, design, and supervise the construction of roads, railroads, harbors, buildings, tunnels, waterways, bridges, dams, airfields, canals, water supply and sewerage systems, and the many other facilities necessary for public works and industrial development. 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 he not only have a broad basic foundation in the physical sciences, but also that he be alert to the economic and social significance of what he plans and builds. This aspect of his educational foundation has been a strong contributing factor in qualifying him for positions of leadership in both industry and government. In the junior and senior years the curriculum provides an opportunity for elective courses in one of the following areas which exemplify the more important fields of civil engineering.

**Construction Engineering.** The methods and techniques of modern construction; fundamental principles of construction applicable to all types of engineering structures; business and legal principles of contracting as applied in the field of construction.

**Geodetic Engineering.** Theory and practical application of surveying and surveying techniques; theoretical and applied geodesy, figure of the earth, local and extended control surveys; precise measurements and the adjustment of observations; design and execution of municipal surveys, topographic mapping projects, boundary surveys and land subdivision; industrial applications of surveying techniques; research in fields of instrumentation, computation, mapping and photogrammetry, and the problems of land surveying and route location.

**Highway Engineering.** Location, design, construction, and maintenance of various types of roads and streets, including materials, surveys, plans, specifications, economics, financing, and administration.

**Hydraulic Engineering.** The application of the fundamental principles of hydraulics and hydrology to the development of water power, flood control, drainage, and improvement of rivers and harbors, and other hydraulic structures. Laboratory facilities and instruction are offered for students who wish to engage in research work in hydrology and hydraulics that will lead to advanced degrees.

**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.

**Railroad Engineering.** The design, construction, and operation of railroad properties, including metropolitan terminals, statistical analysis of operating data, freight and passenger traffic, economics, financing, administration and regulation.

**Sanitary Engineering.** The planning, construction, and operation of water works, sewerage and drainage systems, water-purification plants, and works for the treatment and disposal of city sewage and industrial wastes; improvement and regulation of natural waters for purposes of municipal and industrial use.

**Soils 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.

**Structural Engineering.** The theory, design, and construction of structures, such as bridges, buildings, dams, retaining walls, and reservoirs, involving the use of steel, reinforced concrete, and lumber; the testing and utilization of soils in foundations and subsurface construction.

**Transportation Engineering.** Methods of increasing the efficiency and safety of traffic movement; street and off-street parking; traffic surveys, geometrical design of urban and rural highways, traffic control devices, and other means of regulating and controlling the use of highways.

**Water Resources Engineering.** (See page 97).

## Facilities

The Civil Engineering Department has its departmental offices in the West Engineering Building. The laboratories for Sanitary Engineering and Structural Engineering are also located there. Equipment is available for both teaching and research in these laboratories.

The East Engineering Building houses the highway and soil mechanics laboratories of the Michigan State Highway Department which are used for instruction by the department.

The Fluids Engineering Laboratory on the North Campus contains space for the hydraulic engineering laboratory and the soil dynamics laboratory. The lake hydraulics laboratory, which is equipped with a 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 Automotive Engineering Laboratory houses the geodetic engineering instrument room and computation laboratory.

A concrete research laboratory, established to study new developments in concretes, is located in a building at the Willow Run Airport.

## Requirements

Candidates for the degree B.S.E.(C.E.)—Bachelor of Science in Engineering (Civil Engineering)—are required to complete the following:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| English, Groups II and III | 4 |
| Eng. Graphics 104, Geometry in Engineering Drawing | 2 |
| Eng. Mech. 208, Statics | 3 |
| Eng. Mech. 210, Mechanics of Material | 4 |
| Eng. Mech. 212, Laboratory in Mechanics of Material | 1 |

| | Hours |
|---|---|
| Eng. Mech. 324, Fluid Mechanics | 3 |
| Eng. Mech. 343, Dynamics | 3 |
| Advanced Mathematics | 3 |
| Math. 273, Elementary Computer Techniques | 1 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Mech. Eng. 333, Thermodynamics | 3 |
| Civ. Eng. 262, 263, Geodetic Engineering | 7 |
| Civ. Eng. 312, Theory of Structures | 3 |
| Civ. Eng. 313, Elementary Design of Structures | 2 |
| Civ. Eng. 350, Concrete Mixtures | 1 |
| Civ. Eng. 400, Specifications and Contracts | 2 |
| Civ. Eng. 415, Reinforced Concrete | 3 |
| Civ. Eng. 420, Hydrology | 2 |
| Civ. Eng. 421, Hydraulics | 2 |
| Civ. Eng. 445, Engineering Properties of Soil | 3 |
| Civ. Eng. 470, Transportation Engineering | 3 |
| Civ. Eng. 480, Water Supply and Treatment | 3 |
| Civ. Eng. 481, Sewerage and Sewage Treatment | 2 |
| Geol. 218 | 3 |
| Econ. 401 | 3 |
| Humanities and social sciences (see below) | 8 |
| Technical option group (see below) | 9 |
| Technical electives* (see below) | 5 |
| Total hours in Group B | 95 |

The electives in humanities and social sciences are to be approved courses in such fields as economics, history, law, literature, modern languages, philosophy, political science, psychology, and sociology.

The technical option group 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 his particular area of interest and confer with the adviser in that field regarding the electives required for the completion of his program. Groupings of subjects which meet the technical group requirements are available in the following areas:

1. Construction Engineering—Adviser: Associate Professor Harris
2. Geodetic Engineering—Adviser: Professor Berry
3. Highway Engineering—Adviser: Associate Professor Cortright
4. Hydraulic Engineering—Adviser:Professor Brater
5. Municipal Engineering—Adviser: Associate Professor Glysson
6. Railroad Engineering—Adviser: Associate Professor Cortright
7. Sanitary Engineering—Adviser: Professor Borchardt
8. Soils Engineering—Adviser: Professor Housel
9. Structural Engineering—Adviser: Associate Professor Harris
10. Traffic Engineering—Adviser: Associate Professor Cortright
11. Transportation Engineering—Adviser: Associate Professor Cortright
12. Water Resources Engineering—Adviser: Assistant Professor Weber

Technical electives will consist of approved subjects selected by the student in conference with his adviser to meet the individual needs of the student. Ordinarily these will be advanced courses in one of the branches of engineering, in mathematics, or in one of the natural sciences.

* A maximum of 3 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

**Representative Schedule**

| *First Term* | *Hours* | *Second Term* | *Hours* |
|---|---|---|---|
| Math. 115 | 4 | Math. 116 | 4 |
| Chem. 104 | 4 | Physics 145 | 5 |
| Eng. Graphics 101 | 3 | English 112 | 2 |
| English 111 | 3 | Chem. 106 | 4 |
| English 121 | 1 | | — |
| | — | | 15 |
| | 15 | | |

| *Third Term* | | *Fourth Term* | |
|---|---|---|---|
| Math. 215 | 4 | Math. 315 | 2 |
| Math. 273 | 1 | Math. 316 | 2 |
| Physics 146 | 5 | Eng. Graph. 104 | 2 |
| Eng. Mech. 208 | 3 | Eng. Mech. 210 | 4 |
| Civ. Eng. 262 | 3 | Eng. Mech. 212 | 1 |
| Civ. Eng. 350 | 1 | Geol. 218 | 3 |
| | — | Civ. Eng. 263 | 4 |
| | 17 | | — |
| | | | 18 |

| *Half Term* | |
|---|---|
| Civ. Eng. 312 | 3 |
| Eng. Mech. 343 | 3 |
| | — |
| | 6 |

| *Fifth Term* | | *Sixth Term* | |
|---|---|---|---|
| Eng. Mech. 324 | 3 | Advanced Math. | 3 |
| Chem.-Met. Eng. 250 | 3 | Civ. Eng. 415 | 3 |
| English, Group II | 2 | Civ. Eng. 421 | 2 |
| Mech. Eng. 333 | 3 | Civ. Eng. 470 | 3 |
| Civ. Eng. 420 | 2 | Civ. Eng. 480 | 3 |
| Civ. Eng. 445 | 3 | Elective | 3 |
| | — | | — |
| | 16 | | 17 |

| *Seventh Term* | | *Eighth Term* | |
|---|---|---|---|
| Elec. Eng. 316 | 4 | English, Group III | 2 |
| Civ. Eng. 313 | 2 | Econ. 401 | 3 |
| Civ. Eng. 481 | 2 | Civ. Eng. 400 | 2 |
| Options and electives | 9 | Options and electives | 10 |
| | — | | — |
| | 17 | | 17 |

## Electrical Engineering

*Program Adviser:* Professor Holland, 2511 East Engineering

The electrical engineer is concerned with electrical energy and its applications. In our homes we have electric refrigerators, electrically controlled heating and air-conditioning units, phonographs, radios, and television sets. In our communities are electric power plants and power distribution lines, electrical transportation, and communication systems. The modern automobile, and still more the modern aircraft, carries a bewildering array of electric controls, gauges, and instruments without which our present automobile and aircraft transportation would be impossible. Radar, lasers, masers, guided missiles, space vehicles, and scores of other such developments are all in the field of electrical engineering.

The program in electrical engineering emphasizes basic theory and provides the student with a broad and fundamental background. A student may achieve by careful selection of elective courses, however, a measure of specialization even within the basic undergraduate program. Extensive specialization should be reserved for graduate study.

### Facilities

The facilities of the Electrical Engineering Department include the following research laboratories: adaptive and control systems, Cooley electronics, digital computer engineering, electromagnetic materials, electron physics, information systems, plasma engineering, power systems, radiation, radio astronomy, and space physics research. The facilities of the Communicative Sciences Laboratory are available to students in electrical engineering for instruction and research.

### Requirements

Candidates for the degree B.S.E.(E.E.)—Bachelor of Science in Engineering (Electrical Engineering)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| Eng. Graphics 104, Geometry of Engineering Drawing | 2 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Math. 273, Elementary Computer Techniques | 1 |
| Math. 450, Advanced Mathematics for Engineers *or* Math. 404, Differential Equations | 4 or 3 |
| English, Groups II and III | 4 |
| Econ. 203, 204,* Principles of Economics | 6 |
| Eng. Mech. 310, Statics and Stresses | 4 |
| Eng. Mech. 324, Fluid Mechanics | 3 |
| Eng. Mech. 343, Dynamics | 3 |
| Mech. Eng. 252, Engineering Materials and Manufacturing Processes | 2 |
| Mech. Eng. 331, Classical and Statistical Thermodynamics | 4 |
| Mech. Eng. 343, Machine Design | 3 |
| Elec. Eng. 210, Circuits I | 4 |
| Elec. Eng. 220, Electromagnetic Field Theory I | 3 |
| Elec. Eng. 301, Introduction to Systems Engineering | 2 |
| Elec. Eng. 310, Circuits II | 4 |
| Elec. Eng. 330, Electronics and Communications I | 4 |
| Elec. Eng. 343, Energy Conversion and Control I | 3 |
| Elec. Eng. 360, Electrical Measurements | 3 |
| Elec. Eng. 380, Physical Electronics | 3 |
| Elec. Eng. 381, Physical Electronics Laboratory | 1 |

* Econ. 401 and Acctg. 271, or Econ 401 and three additional hours of nontechnical electives also will satisfy this requirement.

| | Hours |
|---|---|
| Elec. Eng. 410, Circuits III | 3 |
| Elec. Eng. 420, Electromagnetic Field Theory II | 3 |
| Elec. Eng. 444, Energy Conversion and Control II | 4 |
| Elec. Eng. 470, Electrical Design | 4 |
| Nontechnical electives | 6 |
| Electives* | 9 or 10 |
| Total hours in Group B | 95 |

### Representative Schedule

For studies of the first year, see page 20

| *Third Term* | Hours |
|---|---|
| Math. 215 | 4 |
| Math. 273 | 1 |
| Physics 146 | 5 |
| Elec. Eng. 210 | 4 |
| Nontechnical elective | 3 |
| | 17 |

| *Fourth Term* | Hours |
|---|---|
| Math. 315 | 2 |
| Math. 316 | 2 |
| Elec. Eng. 220 | 3 |
| Chem.-Met. Eng. 250 | 3 |
| English, Group II | 2 |
| Eng. Graphics 104 | 2 |
| Nontechnical elective | 3 |
| | 17 |

| *Half Term* | |
|---|---|
| Elec. Eng. 310 | 4 |
| Mech. Eng. 331 | 4 |
| | 8 |

| *Fifth Term* | |
|---|---|
| Elec. Eng. 360 | 3 |
| Elec. Eng. 380 | 3 |
| Elec. Eng. 381 | 1 |
| Eng. Mech. 310 | 4 |
| Math. 450 *or* Math. 404 | 4 or 3 |
| Econ. 203† | 3 |
| | 18 or 17 |

| *Sixth Term* | |
|---|---|
| Elec. Eng. 301 | 2 |
| Elec. Eng. 330 | 4 |
| Elec. Eng. 343 | 3 |
| Eng. Mech. 343 | 3 |
| Mech. Eng. 252 | 2 |
| Econ. 204* | 3 |
| | 17 |

| *Seventh Term* | |
|---|---|
| Elec. Eng. 410 | 3 |
| Elec. Eng. 444 | 4 |
| Eng. Mech. 324 | 3 |
| Electives | 6 or 5 |
| | 16 or 15 |

| *Eighth Term* | |
|---|---|
| Elec. Eng. 420 | 3 |
| Elec. Eng. 470 | 4 |
| English, Group III | 2 |
| Mech. Eng. 343 | 3 |
| Electives | 4 |
| | 16 |

* A maximum of four hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

† Econ. 401 and Acctg. 271, or Econ. 401 and three additional hours of nontechnical electives also will satisfy this requirement.

## Engineering Mechanics

*Program Adviser:* Professor Clark, 201 West Engineering

Rapid technological developments have brought about an increasing need for engineers who are exceptionally well-trained in the basic sciences. The need is acute throughout industry and government as well as in research institutions and in universities; to help fill this need is the purpose of the program in engineering mechanics. Men with training in the field of engineering mechanics are sought by organizations of all kinds, particularly by those working on modern developments. Most young men in the field are engaged in highly technical work, but many, like other engineers, enter supervision and management.

A student majoring in engineering mechanics gets the same first year program as most other students. He may, in fact, choose this specialty up to the beginning of the junior year without loss of time. The later years are filled mainly with more advanced mechanics and science courses which are designed to acquaint the student with the fundamental principles on which engineering science is based. The required mathematics exceeds that in most curriculums, but the engineering emphasis is always present.

The major areas of study in the bachelor's program are strength of materials, elasticity, plasticity, dynamics, vibrations, fluid mechanics, and thermodynamics. The department has modern laboratories, and computer and research facilities. The association of theory with the physical aspects of the work is very close. To gain practice in applying the fundamental principles of engineering, the program contains a group option in some other technical area chosen by the student. In addition, there are seven to nine hours of free electives.

Graduate work toward a master's degree is a natural sequence for many mechanics graduates who qualify. It is also open to graduates in other areas of engineering.

### Facilities

The departmental facilities in the West Engineering Building include the solid mechanics, fluid mechanics, and dynamics laboratories. In addition, laboratories for instruction and research in the basic mechanics of fluids are maintained in the Fluids Engineering Laboratories.

### Requirements

Candidates for the degree B.S.E.(E.M.)—Bachelor of Science in Engineering (Engineering Mechanics)—are required to complete the following program:

***A.*** *Subjects to be elected or equivalent proficiencies to be demonstrated* *(see page 35)*

***B.*** *Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Group II and III | 4 |
| Math. 404, Differential Equations | 3 |
| Math. 447, Modern Operational Mathematics, or an approved alternate | 2 |
| Math. 450, Advanced Mathematics for Engineers | 4 |

| | Hours |
|---|---|
| Civ. Eng. 312, Theory of Structures | 3 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Mech. Eng. 335, Thermodynamics | 3 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Eng. Graphics 102, Descriptive Geometry | 3 |
| Eng. Mech. 208, Statics, or Eng. Mech. 218 | 3 |
| Eng. Mech. 210, Mechanics of Material, or Eng. Mech. 219 | 4 |
| Eng. Mech. 212, Laboratory in Mechanics of Material, *or* Eng. Mech. 402 | 1 or 2 |
| Eng. Mech. 324, Fluid Mechanics, *or* Eng. Mech. 326 | 3 or 4 |
| Eng. Mech. 343, Dynamics, *or* Eng. Mech. 345 | 3 |
| Eng. Mech. 403, Experimental Mechanics | 2 |
| Eng. Mech. 412, Intermediate Mechanics of Material | 3 |
| Eng. Mech. 422, Intermediate Mechanics of Fluids | 3 |
| Eng. Mech. 442, Intermediate Dynamics | 3 |
| Eng. Mech., approved advanced courses | 7 |
| Econ. 401 | 3 |
| Nontechnical electives | 9 |
| Group options and electives* (see below) | 22 |
| Total hours in Group B | 95 |

Every student is required to elect a complete group option of 12 to 14 hours from some other program in the College of Engineering in order that his theoretical training may be correlated with engineering practice in that field. Electives, 8 to 10 hours, selected in conference with the adviser, will complete this group of requirements.

Suggested group options are:

Aerodynamics
Aeromechanics
Chemical Engineering
Dynamics
Electrical Engineering
Hydraulics
Instrumentation
Machine Design
Metallurgy
Meteorology and Oceanography
Naval Architecture
Nuclear Engineering
Physics
Propulsion
Structural Engineering
Others arranged

Details of these can be obtained from the program adviser, and options in other areas can be arranged in conference with him.

### Representative Schedule

The courses making up the group option are denoted by an asterisk; in this case, the suggested Electrical Engineering option is used as an example.

| *First Term* | *Hours* |
|---|---|
| Math. 115 | 4 |
| Chem. 103, 104, or 107 | 4 or 5 |
| Eng. Graphics 101 | 3 |
| English 111 | 3 |
| English 121 | 1 |
| | 15 or 16 |

| *Second Term* | *Hours* |
|---|---|
| Math. 116 | 4 |
| Physics 145 | 5 |
| Chem. 105 or Eng. Graphics 102 | 4 or 3 |
| English 112 | 2 |
| Nontechnical elective | 2 |
| | 17 or 16 |

* A maximum of six hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

| *Third Term* | *Hours* | *Fourth Term* | *Hours* |
|---|---|---|---|
| Math. 215 | 4 | Math. 315 | 2 |
| Physics 146 | 5 | Math. 316 | 2 |
| Eng. Mech. 208 or 218 | 3 | Chem.-Met. Eng. 250 | 3 |
| English, Group II | 2 | Eng. Mech. 210 | 4 |
| Nontechnical elective | 2 | Mech. Eng. 335 | 3 |
| | — | Eng. Mech. 343 | 3 |
| | 16 | | — |
| | | | 17 |

| *Half Term* | |
|---|---|
| Math. 404 | 3 |
| Eng. Mech. 324 | 3 |
| | — |
| | 6 |

| *Fifth Term* | | *Sixth Term* | |
|---|---|---|---|
| Math. 450 | 4 | English Group III | 2 |
| Elec. Eng. 210 or 316 | 4 | Elec. Eng. 310* | 4 |
| Elec. Eng. 220* | 3 | Eng. Mech. 403 | 2 |
| Eng. Mech. 412 | 3 | Eng. Mech. 442 | 3 |
| Nontechnical elective | 2 | Eng. Mech. 422 | 3 |
| | — | Elective | 3 |
| | 16 | | — |
| | | | 17 |

| *Seventh Term* | | *Eighth Term* | |
|---|---|---|---|
| Elec. Eng. 438* | 4 | Elec. Eng. 445* or 430* | 4 |
| Math. 448 | 4 | Econ. 401 | 3 |
| Civ. Eng. 312 | 3 | Eng. Mech. 522 | 3 |
| Eng. Mech. 402 | 2 | Nontechnical elective | 3 |
| Eng. Mech. 541 or 545 | 3 | Elective | 2 |
| | — | | — |
| | 16 | | 15 |

## Industrial Engineering

*Program Adviser:* Professor Gage, 242A West Engineering

Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design; to specify, predict, and evaluate the results to be obtained from such systems. The industrial engineer is primarily interested in problems which involve economy in the use of money, materials, time, human effort, and energy. The industrial engineer should combine the basic aptitudes of an engineer with an understanding of the reactions of people in business 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 plant flow analysis, scheduling and inventory systems, data processing systems, operations research, engineering economics, experimental design, resource allocation, and organizational and managerial control practices.

### 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 (calculators and small computers).

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

### Requirements

Candidates for the degree B.S.E.(Ind. E.)—Bachelor of Science in Engineering (Industrial Engineering)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Groups II and III | 4 |
| Econ. 401 | 3 |
| Eng. Mech. 310, Statics and Stresses | 4 |
| Eng. Mech. 343, Dynamics | 3 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Mech. Eng. 251, Manufacturing Processes I | 3 |
| Mech. Eng. 333, Thermodynamics | 3 |
| Mech. Eng. 343, Mechanical Design | 3 |
| Mech. Eng. 344, Mechanical Analysis Laboratory | 1 |
| Mech. Eng. 381, Manufacturing Processes II | 4 |
| Ind. Eng. 371, Stochastic Industrial Processes | 2 |
| Ind. Eng. 375, Engineering Linear Programming | 2 |
| Ind. Eng. 400, Industrial Management | 3 |
| Ind. Eng. 431, Management Control | 3 |
| Ind. Eng. 441, Production Control | 3 |
| Ind. Eng. 447, Plant Layout and Materials Handling | 3 |
| Ind. Eng. 451, Engineering Economy | 3 |
| Ind. Eng. 463, Work Methods and Measurements I | 4 |
| Ind. Eng. 473, Data Processing | 3 |
| Accounting 271 | 3 |
| Bus. Ad., General 454, Industrial Cost Accounting | 3 |
| Math. 273, Elementary Computer Techniques | 1 |
| Math. 465, 466, Introduction to Statistics I, II | 6 |
| Nontechnical electives | 8 |
| Technical electives* (including one Ind. Eng. course) | 13 |
| Total hours in Group B | 95 |

* All electives must receive the advance approval of the program adviser; a maximum of six hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

For studies of the first year, see page 20

**Representative Schedule**

| *Third Term* | *Hours* | *Fourth Term* | *Hours* |
|---|---|---|---|
| Math. 215 | 4 | Math. 315 | 2 |
| Acctg. 271 | 3 | Bus. Ad., General 454 | 3 |
| Math. 273 | 1 | English, Group II | 2 |
| Physics 146 | 5 | Math. 465 | 3 |
| Elective | 4 | Chem.-Met. Eng. 250 | 3 |
| | — | Ind. Eng. 400 | 3 |
| | 17 | | — |
| | | | 16 |

| *Half Term* | |
|---|---|
| Eng. Mech. 310 | 4 |
| English, Group III | 2 |
| | — |
| | 6 |

| *Fifth Term* | | *Sixth Term* | |
|---|---|---|---|
| Ind. Eng. 375 | 2 | Mech. Eng. 343 | 3 |
| Math. 466 | 3 | Mech. Eng. 344 | 1 |
| Eng. Mech. 343 | 3 | Ind. Eng. 371 | 2 |
| Ind. Eng. 473 | 3 | Math. 316 | 2 |
| Econ. 401 | 3 | Mech. Eng. 251 | 3 |
| Elective | 3 | Elective | 6 |
| | — | | — |
| | 17 | | 17 |

| *Seventh Term* | | *Eighth Term* | |
|---|---|---|---|
| Ind. Eng. 451 | 3 | Mech. Eng. 333 | 3 |
| Elec. Eng. 316 | 4 | Ind. Eng. 431 | 3 |
| Mech. Eng. 381 | 4 | Ind. Eng. 447 | 3 |
| Ind. Eng. 441 | 3 | Elective | 8 |
| Ind. Eng. 463 | 4 | | |
| | — | | — |
| | 18 | | 17 |

## Materials Engineering and Metallurgical Engineering

*Program Adviser:* Professor M. J. Sinnott, 4038 East Engineering Building

Materials engineering and metallurgical engineering have closely related curriculums, they are both based on the sciences of chemistry and physics and pertain to the development and utilization of the materials of all engineering. Both focus their attention on the internal structure of various materials around us, and the effect of this internal structure upon the properties of engineering and consumer interest.

Metallurgical engineering generally limits its attention to metals and alloys. Its professional area, however, directs its efforts to all phases of metallurgy from extraction, through chemical and mechanical processing, to property control and utilization.

Materials engineering pays attention to the selection, control, and engineering application of ceramics and polymers as well as to metals. We therefore find that a materials engineer usually gives less prominent attention to the initial processing of the raw materials than does the metallurgical engineer.

To obtain the necessary breadth, the basic program for these two curriculums consists of courses in mathematics, chemistry, physics, humanities, and the basic engineering sciences. In the upper class level, the metallurgical engineering student directs his efforts toward process, mechanical, and physical metallurgy. The materials engineering student gives comparable attention to physical ceramics, physical metallurgy, and to high polymers (i.e., plastics).

### Facilities

The facilities for the programs in materials and metallurgical engineering are housed in the East Engineering Building. These consist of metallographic, heat treatment, X-ray, electron microscope, cast metal, ceramic, semiconductor, polymer and plastic, liquid metal, corrosion, and high temperature laboratories. In addition extensive analytical facilities in the form of optical spectrographs, mass spectrometers, infrared and ultraviolet spectrometers are available.

### Requirements

Candidates for the degree B.S.E.(Mat.E.)—Bachelor of Science in Engineering (Materials Engineering), or B.S.E.(Met.E.)—Bachelor of Science in Engineering (Metallurgical Engineering)—are required to take the following program with the election of the appropriate option.

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*
*B. Professional and advanced subjects and electives*

#### Basic Science

| | *Hours* |
|---|---|
| Advanced chemistry, to include such subjects as physical chemistry and quantitative analysis | 12 |
| A course in electronic computers such as Math. 273 | 1 |
| **Thermodynamics and Rate Processes** | |
| Courses through Chem.-Met. Eng. 341, or Sci. Eng. 340 | 11 |
| **Metallurgy and Materials** | |
| Structure of Solids, Chem.-Met. Eng. 350, 472 | 6 |
| Physical Metallurgy, Chem.-Met. Eng. 470, 471 | 7 |
| **Electives** | |
| 1. Electives in English (to include 4 credit hours of literature), humanities, social sciences, philosophy, languages, etc. | 14 |
| 2. Electives in law, business administration, and economics | 6 |
| 3. Electives in engineering science and analysis, to include mechanics and electrical science | 14 |
| 4. Electives in advanced science and mathematics* | 10 |
| 5. Professional option leading to B.S.E. (Met.E.)† or B.S.E. (Mat.E.)* | 14 |
| Total hours of Group B | 95 |

* Option leading to B.S.E. (Mat. E.) must include at least 5 hours of organic chemistry among the basic science or advanced science electives. The professional electives must include physical ceramics, polymers, and a design course such as Chem.-Met. Eng. 480, Chem.-Met. Eng. 481, Elec. Eng. 470 or Mech. Eng. 460.

† Option leading to B.S.E. (Met. E.) must include professional metallurgical engineering subjects in the fields of process, mechanical, or physical metallurgy.

| *First Term* | *Hours* | *Second Term* | *Hours* |
|---|---|---|---|
| English 111 | 3 | Math. 116 | 4 |
| Eng. Graphics 101 | 3 | English 112, 121 | 3 |
| Chem. 107 | 5 | Physics 145 | 5 |
| Math. 115 | 4 | Group 1 Electives | 4 |
| | 15 | | 16 |
| *Third Term* | | *Fourth Term* | |
| Physics 146 | 5 | Math. 315 | 2 |
| Math. 215 | 4 | Math. 316 | 2 |
| Chem.-Met. Eng. 200 | 3 | Chem.-Met. Eng. 230 | 5 |
| Math. 273 | 1 | Chem. 265 | 4 |
| Group 3 Elective | 4 | Group 3 Elective | 3 |
| | | Group 1 Elective | 2 |
| | 17 | | 18 |
| *Fifth Term* | | *Sixth Term* | |
| Chem. 266 | 4 | Chem.-Met. Eng. 341 | 3 |
| Group 5 Elective* | 3 | Chem.-Met. Eng. 350 | 3 |
| Group 4 Elective* | 3 | Group 4 Elective* | 3 |
| Group 3 Elective | 4 | Group 4 Elective* | 4 |
| Group 2 Elective | 3 | Group 3 Elective | 3 |
| | 17 | | 16 |
| *Seventh Term* | | *Eighth Term* | |
| Chem.-Met. Eng. 470 | 4 | Chem.-Met. Eng. 471 | 3 |
| Chem.-Met. Eng. 472 | 3 | Group 5 Electives | 11 |
| Advanced Chem. | 4 | Group 1 Electives | 4 |
| Group 2 Electives | 3 | | |
| Group 1 Electives | 4 | | 18 |
| | 18 | | |

## Mathematics

*Program Co-advisers:* Assistant Professors Goldberg and Hedstrom, 347A West Engineering; Professor Hadley J. Smith, 312A West Engineering

The mathematics program in the College of Engineering provides the student with an opportunity to extend his knowledge of the language of the scientist, and to become more proficient in the application of mathematical reasoning to the formulation and solution of scientific problems in engineering. This program recognizes the ever-increasing demand that the changing physical and economic world imposes on the engineer. It therefore seeks to make available to him the knowledge with which he will be better able to understand and create the complex mathematical models which represent that world.

Many students, who are candidates for degrees in engineering programs of other fields, elect additional courses and qualify for the award of a degree in mathematics as well (see Requirements for Graduation).

* These electives must include the necessary option requirements for either B.S.E. (Met. E), or B.S.E. (Mat. E.).

## Requirements

Candidates for the degree B.S.E.(Math.)—Bachelor of Science in Engineering (Mathematics)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated* *(see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Groups II and III | 4 |
| Eng. Graphics 104 | 2 |
| Math. 273 | 1 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Mech. Eng. 252, Engineering Materials and Manufacturing Processes | 2 |
| Math. 450 or 451, Advanced Calculus | 4 |
| Electives in the humanities, social sciences, and philosophy (see the *Announcement* of the College of Literature, Science, and the Arts for the basic courses in these fields of knowledge) | 12 |
| Eng. Mech. 208 or 218 | 3 |
| Eng. Mech. 210 or 219 | 4 |
| Eng. Mech. 324 or 326 | 3 or 4 |
| Eng. Mech. 343 or 345 | 3 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Mech. Eng. 335, Chem.-Met. Eng. 230, or Sci. Eng. 330, Thermodynamics | 3 |
| Electives in mathematics, to include work in approved advanced mathematics having applications to problems in the physical sciences | 11 |
| Electives in engineering analysis and design | 15 |
| Electives in science and engineering science | 11 or 12 |
| Electives* | 9 |
| Total hours in Group B | 95 |

The fifteen hours of electives in engineering analysis and design must constitute a sequence of courses which provide an understanding and a useful knowledge in a specific area of engineering, and should include at least one course involving laboratory measurements. Suggested areas of engineering in which these electives may be chosen follow:

**Aeronautical and Astronautical Engineering**

Aerodynamics: Aero. Eng. 320, 330, 420, 520, or 525
Aeropropulsion: Aero. Eng. 320, 330, 420, 430
Flight Structures: Aero Eng. 314, 414, 441, 510
Mechanics of Flight: Aero Eng. 420, 441, 442, 471

**Civil Engineering**

Structures: Civ. Eng. 312, 313, 415, 514, 512 or 445 or 612 or 614 or 613 or 611

**Chemical Engineering**

Chem.-Met. Eng. 341, 342, 343, 480, 481

**Electrical Engineering**

Computers: Elec. Eng. 220, 380, 465, 466; Philosophy 414, 415
Electronics: Elec. Eng. 220, 310, 330, 380

**Industrial Engineering**

Ind. Eng. 400, 441, 472, 473, 527 or 541 or 571

* A maximum of six hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

**Instrumentation Engineering**

Math. 448, Elec. Eng. 418, Instr. Eng. 510, 570, 571

**Mechanical Engineering**

Automotive Engineering: Mech. Eng. 336, 343, 471, 493 or 496, 463 or 556
Energy Control: Mech. Eng. 336, 371, 421, 437, 535
Manufacturing: Mech. Eng. 381, 417, 483, 517, 567
Mechanical Design: Mech. Eng. 340, 362, 460, 463, 541

**Meteorology and Oceanography**

Meteor. and Ocean. 408, 440, 441, 462, 541

Further details of these options and of options in other areas, can be obtained from the program advisers.

All electives must be approved by a program adviser.

## Mechanical Engineering

*Program Adviser:* Associate Professor Quackenbush, 3305 East Engineering

The scope of activity 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 our space program, in the design of both conventional and nuclear power plants, in the automotive field, in heating and air conditioning, refrigeration and cryogenics, and in the fields of automation, fluid machinery, production, and processing machinery, 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 which 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 experience in measurement, and studies in design and manufacturing, will prepare him equally well for any of the fields of application. The program includes a number of both technical and nontechnical electives which permit the student to undertake further studies in an area of particular interest.

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. Some students may wish to work simultaneously for a second bachelor's degree in another program in accordance with the requirements presented under Requirements for Graduation.

## Facilities

The laboratories of the Department of Mechanical Engineering, in the Fluids Engineering and Automotive Laboratories on the North Campus and in the East Engineering Building on the Central Campus, provide facilities for both instruction and research.

The Fluids Engineering Building contains the thermodynamics, heat transfer, and fluid flow laboratories, a drop-tower for zero-g heat transfer studies and a large centrifuge for high-g investigations, cryostats for thermodynamic phase equilibrium studies down to 14 degrees K, and equipment for fluid amplifier research.

The Automotive Laboratory Building houses the mechanical analysis laboratory with a wide variety of electromechanical instrumentation and the analog computer in the experimental analysis of dynamics in mechanical systems; the combustion laboratory with a gas chromatograph and an infrared spectrometer; the lubrication laboratory; 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.

The machine tool laboratory is equipped for research in such areas as ultrasonics, high-speed machining, numerical control and vibrations and instruction in the fundamentals of manufacturing processes. The materials laboratory provides facilities for investigations in such areas as acoustic emission in metals, brittle fracture, heat treating, plasticity, and surface phenomena. A well-equipped welding laboratory is also a part of the East Engineering complex.

## Requirements

Candidates for the degree B.S.E.(M.E.)—Bachelor of Science in Engineering (Mechanical Engineering)—are required to complete the following:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| Electives in humanities, arts, and social sciences | 11 |
| English, Groups II and III | 4 |
| Econ. 401* Modern Economic Society | 3 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Eng. Graphics, 104 | 2 |
| Eng. Mech. 208, Statics | 3 |
| Eng. Mech. 210, Mechanics of Material | 4 |
| Eng. Mech. 212, Laboratory in Mechanics of Material | 1 |
| Eng. Mech. 324, Fluid Mechanics | 3 |
| Eng. Mech. 343, Dynamics | 3 |
| Math. 273, Elementary Computer Techniques | 1 |
| Mech. Eng. 251, Manufacturing Processes I | 3 |

* Econ. 203 and 204 may be substituted for Econ. 401 and 3 hours of electives in humanities, arts, and social sciences.

| | Hours |
|---|---|
| Mech. Eng. 324, Fundamentals of Fluids Machinery | 4 |
| Mech. Eng. 335, Thermodynamics I | 3 |
| Mech. Eng. 336, Thermodynamics II | 4 |
| Mech. Eng. 340, Dynamics of Machinery | 4 |
| Mech. Eng. 362, Mechanical Design I | 3 |
| Mech. Eng. 381, Manufacturing Processes II | 4 |
| Mech. Eng. 460 or 462,[1] Mechanical Design II*a* or II*b* | 4 |
| Mech. Eng. 471, Heat Transfer I | 4 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Elec. Eng. 442, Motor Control and Electronics | 4 |
| Technical electives* | 16 |
| Total hours in Group B | 95 |

The technical electives requirement permits the student to pursue a sequence of courses reflecting his interest in a particular field such as automotive engineering, automatic control, fluid flow, instrumentation, manufacturing, mechanical design, and thermal systems, including heat transfer and stationary or propulsive power plants.

The student is encouraged to formulate his own sequence of elective courses, with the advice, and subject to the approval, of his adviser; example elective sequences for the fields listed above are available in the Mechanical Engineering office, 225 West Engineering Building.

**Representative Schedule**

| *First Term* | Hours | *Second Term* | Hours |
|---|---|---|---|
| Math. 115 | 4 | Math. 116 | 4 |
| Chem. 104 | 4 | Chem. 105 | 4 |
| Eng. Graphics 101 | 3 | Physics 145 | 5 |
| English 111 | 3 | English 112 | 2 |
| English 121 | 1 | | 15 |
| | 15 | | |

| *Third Term* | | *Fourth Term* | |
|---|---|---|---|
| Math 215 | 4 | Math. 315 | 2 |
| Physics 146 | 5 | Math. 316 | 2 |
| Eng. Mech. 208 | 3 | Eng. Mech. 210 | 4 |
| Eng. Graphics 104 | 2 | Eng. Mech. 212 | 1 |
| English, Group II | 2 | Chem. Met. 250 | 3 |
| | | Mech. Eng. 335 | 3 |
| | 16 | Math. 273 | 1 |
| | | | 16 |

| *Fifth Term* | | *Sixth Term* | |
|---|---|---|---|
| Mech. Eng. 251 | 3 | Eng. Mech. 324 | 3 |
| Mech. Eng. 336 | 4 | Mech. Eng. 340 | 4 |
| Eng. Mech. 343 | 3 | Mech. Eng. 381 | 4 |
| Adv. Math. | 3 | Mech. Eng. 362 | 3 |
| Humanities | 4 | Humanities | 4 |
| | 17† | | 18† |

* This group of electives should include 3 credit hours of advanced mathematics, at least one advanced theory course, and one advanced laboratory in mechanical engineering. A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

† This program can be completed, as shown on the next page, in eight and one-half terms. As an alternative, the student may expand the half term to a full ninth term by transferring credits from other terms with high credit total or numerous courses, thereby adjusting the credit load per term.

| *Seventh Term* | *Hours* | *Eighth Term* | *Hours* |
|---|---|---|---|
| Mech. Eng. 324 | 4 | Mech. Eng. 471 | 4 |
| Econ. 401 | 3 | Elec. Eng. 442 | 4 |
| Elec. Eng. 316 | 4 | Technical Elective | 9 |
| Humanities | 3 | | — |
| Technical elective | 4 | | 17* |
| | — | | |
| | 18* | | |

| *Half Term* | *or* | *Ninth Term* | |
|---|---|---|---|
| Mech. Eng. 460 or 462 | 4 | *Load adjustment *or* extra credits | 6 |
| English, Group III | 2 | Mech. Eng. 460 or 462 | 4 |
| | — | English, Group III | 2 |
| | 6 | | — |
| | | | 12 |

## Meteorology and Oceanography

*Program Adviser:* Professor Dingle, 5062 East Engineering

Meteorology and oceanography are the two sciences concerned with the description and explanation of all phenomena in the atmosphere, the oceans, and the boundary between them. The two sciences encompass therefore both basic and applied problems. 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 which 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 top of the atmosphere. The qualified meteorologist or oceanographer will find employment in the official weather services, in the space sciences, in industry, government, teaching, research, and in private practice. The immediate need is great, and there is every evidence that the need will continue for years to come.

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 on them. Many important decisions in transportation, whether by land, water, or air, depends critically on meteorological factors. The

* This program can be completed, as shown above, in eight and one-half terms. As an alternative, the student may expand the half term to a full ninth term by transferring credits from other terms with high credit totals or numerous courses, thereby adjusting the credit load per term. Other representative schedules with different distributions may be found with the program adviser.

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, each of which leads to the degree B.S.(Meteor. & Ocean.)—Bachelor of Science (Meteorology and Oceanography); he thus acquires knowledge in depth in one discipline while obtaining good working knowledge in the rest. These options are:

**Option 1. Aeronomy** is the physics of the upper atmosphere. This field is treated separately because of the special electrical and magnetic properties of the upper layers of the atmosphere.

**Option 2. Meteorology** is the physics of the lower atmosphere, its dynamics, thermodynamics, radiation, cloud physics and precipitation processes, interaction with the ground and ocean, the general circulation of the atmosphere and physical weather forecasting.

**Option 3. Oceanography** is the physics of the oceans. In addition to basic disciplines which are rather parallel to those of Option 2, the program emphasizes geological and biological aspects of oceanography.

### Facilities

The Department of Meteorology and Oceanography include laboratories for atmospheric turbulence and scintillation, cloud and precipitation physics, a computer laboratory containing a hybrid analog-digital computer, meteorological instrumentation, oceanography and submarine geology.

### Requirements

Candidates for the degree B.S.(Meteor. & Ocean.)—Bachelor of Science (Meteorology and Oceanography)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Groups II and III | 4 |
| Chem. 265 or 346 | 4 |
| Eng. Mech. 208 or 218 | 3 |
| Eng. Mech. 324 or 345 | 3 |
| Eng. Mech. 343 or 326 | 3 or 4 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Civ. Eng. 420, Hydrology | 2 |
| M.&O. 304, Introduction to Atmospheric and Oceanic Sciences I | 3 |
| M.&O. 305, Introduction to Atmospheric and Oceanic Sciences II | 3 |
| M.&O. 306, Laboratory in Geophysical Data I | 2 |
| M.&O. 307, Laboratory in Geophysical Data II | 1 |

| | Hours |
|---|---|
| M.&O. 432, Atmospheric Thermodynamics and Radiation | 3 |
| M.&O. 440, Principles of Weather Analysis | 3 |
| M.&O. 445, Dynamic Meteorology | 3 |
| Electives in mathematics, engineering science, physical science, biological science* | 11 or 10 |
| Electives in the humanities and social sciences | 13 |
| Options 1, 2, or 3 | 30 |
| Total hours in Group B | 95 |

One of the following options should be selected by the student before the first term of his junior year:

**1. Aeronomy**

| | |
|---|---|
| M.&O. 464, Aeronomy I | 3 |
| M.&O. 465, Aeronomy II | 3 |
| Math. 450, Advanced Mathematics for Engineers | 4 |
| Math. 473, Introduction to Digital Computers | 3 |
| Aero. Eng. 425, Principles of Aerodynamics | 3 |
| Physics 402, Light | 3 |
| Physics 405, Intermediate Electricity and Magnetism | 3 |
| Physics 406, Heat and Thermodynamics | 3 |
| Physics 425, Introduction to Infrared Spectra | 2 |
| Physics 453, Atomic and Molecular Structure | 3 |
| | 30 |

**2. Meteorology**

| | |
|---|---|
| M.&O. 412, Physical Climatology | 3 |
| M.&O. 441, Laboratory in Weather Analysis I | 3 |
| M.&O. 452, Physical Meteorology | 3 |
| M.&O. 462, Meteorological Instrumentation | 3 |
| M.&O. 470, Applied Meteorology | 2 |
| M.&O. 472, Hydrometeorological Design | 2 |
| M.&O. 475, Meteorological Analysis and Design Criteria | 2 |
| Math 450, Advanced Mathematics for Engineers | 4 |
| Sci. Eng. 330 and 340 or Phys. 406, 409, and 509 | 8 |
| | 30 |

**3. Oceanography**

| | |
|---|---|
| M.&O. 443, Limnology and Oceanography | 3 |
| M.&O. 444, Investigations in Limnology and Oceanography | 3 |
| Geol. 111, Introductory Geology | 4 |
| Geol. 112, Introductory Geology | 4 |
| Geol. 381, Introductory Chemistry of the Earth | 2 |
| Geol. 382, Introductory Physics of the Earth | 2 |
| Zool. 101 or 105 | 4 |
| M.&O. 453, Dynamic Oceanography | 4 |
| M.&O. 449, Marine Geology | 4 |
| | 30 |

With the assistance of his adviser, each student is expected to draw up his own program of studies, which may include not only the required courses in meteor-

* A maximum of four hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

ology but also one or more sequences of related courses in the humanities and social sciences and in such areas as instrumentation, electronics, statistics, high-speed computation, geophysics, operations analysis, upper atmosphere analysis, water resources, air sanitation, or some other appropriate area.

## Representative Schedule

For studies of the first year, see page 20

| *Third Term* | *Hours* |
|---|---|
| Math. 215 | 4 |
| Physics 146 | 5 |
| M.&O. 304 | 3 |
| M.&O. 306 | 2 |
| English, Group II | 2 |
| Elective | 2 |
| | 18 |

| *Fourth Term* | *Hours* |
|---|---|
| Math. 315 | 2 |
| Math. 316 | 2 |
| Eng. Mech. 208 | 3 |
| M.&O. 305 | 3 |
| M.&O. 307 | 1 |
| M.&O. 445 | 3 |
| Electives | 4 |
| | 18 |

| *Fifth Term* | *Option 1* | *2* | *3* |
|---|---|---|---|
| Eng. Mech. 324 | 3 | 3 | 3 |
| Elec. Eng. 316 | 4 | 4 | — |
| Chem. 265 | 4 | 4 | 4 |
| M.&O. 432 | 3 | 3 | 3 |
| M.&O. 412 | — | 3 | — |
| M.&O. 440 | — | — | 3 |
| Civ. Eng. 420 | — | — | 2 |
| Geology 111 | — | — | 4 |
| Physics 402 | 3 | — | — |
| Electives | 2 | 2 | — |
| | 19 | 19 | 19 |

| *Sixth Term* | *Option 1* | *2* | *3* |
|---|---|---|---|
| Math. 450 | 4 | 4 | — |
| Geology 112 | — | — | 4 |
| Eng. Mech. 343 | 3 | 3 | 3 |
| Physics 406 | 3 | — | — |
| M.&O. 452 | — | 3 | — |
| Zoology 101 | — | — | 4 |
| Electives | 8 | 8 | 7 |
| | 18 | 18 | 18 |

| *Seventh Term* | *Option 1* | *2* | *3* |
|---|---|---|---|
| Geology 381 | — | — | 2 |
| M.&O. 453 | — | — | 4 |
| M.&O. 443 | — | — | 3 |
| M.&O. 444 | — | — | 3 |
| M.&O. 464 | 3 | — | — |
| Aero Eng. 425 | 3 | — | — |
| Civ. Eng. 420 | 2 | 2 | — |
| Physics 425 | 2 | — | — |
| M.&O. 449 | — | — | 4 |
| M.&O. 440 | 3 | 3 | — |
| M.&O. 441 | — | 3 | — |
| M.&O. 462 | — | 3 | — |
| M.&O. 472 | — | 2 | — |
| Sci. Eng. 330 | — | 4 | — |
| Electives | 5 | — | 2 |
| | 18 | 17 | 18 |

| *Eighth Term* | *Option 1* | *2* | *3* |
|---|---|---|---|
| M.&O. 465 | 3 | — | — |
| Physics 453 | 3 | — | — |
| Math. 473 | 3 | — | — |
| Phys. 405 | 3 | — | — |
| Geol. 382 | — | — | 2 |
| Elec. Eng. 316 | — | — | 4 |
| English, Group III | 2 | 2 | 2 |
| M.&O. 470 | — | 2 | — |
| M.&O. 475 | — | 2 | — |
| Sci. Eng. 340 | — | 4 | — |
| Electives | 3 | 8 | 9 |
| | 17 | 18 | 17 |

## Naval Architecture and Marine Engineering

*Program Advisers:* Option 1: Associate Professor Yagle, 448E West Engineering; Option 2: Professor West, 448A West Engineering; Option 3: Associate Professor Yagle, 448E West Engineering

The program of study in naval architecture and marine engineering covers all aspects of ship hull design and ship power plants. For example, such topics as the form, strength, stability, cost, and resistance and propulsion characteristics of ship hulls are included. Various types of propelling machinery, such as steam and gas turbines and oil engines as well as conventional boilers and nuclear reactors, are considered. Other items of concern include propellers, economic aspects of ship design, model testing and ship hydrodynamics, vibration, heat transfer, and piping system design and analysis.

The design of a modern ship encompasses many engineering fields; also, graduates of this department are called upon to handle diverse professional responsibilities. It is essential that the program include training in the fundamentals of the physical sciences, mathematics, human relations, and other nonengineering subjects. 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, each of which leads to the degree B.S.E.(Nav.Arch.&Mar.E.)—Bachelor of Science in Engineering (Naval Architecture and Marine Engineering); he thus acquires competence in one division of the field while obtaining a good introduction to the rest. These options are:

**Option 1. Naval Architecture** relates to the design of ship hulls and includes such topics as form, strength, stability, arrangements, resistance, powering, and methods of preliminary design.

**Option 2. Marine Engineering** places emphasis on the design of various types of propelling and auxiliary machinery and on their relation to the ship as a whole.

**Option 3. Maritime Engineering Science** stresses preparation for research and provides a stronger grounding in basic engineering science with less emphasis on design than that found in the other options. It will be normal for students in this option to spend an extra term and receive an additional B.S.E. degree in mathematics or engineering mechanics or to do graduate work toward an M.S.E. degree from this or other departments.

Students wishing to obtain an additional B.S.E. degree in aeronautical engineering may do so under a combined program which allows for substantial substitution of courses in one curriculum for those required in the other. (See item 4, page 35.)

The department is in constant touch with the country's ship design offices, shipyards, and ship operators, and it is able to aid its graduates in obtaining positions in the various lines mentioned.

### Facilities

A large ship-model towing tank complete with shops and instrumentation is operated by the department for teaching and student and faculty research. A new wave tank and propeller cavitation tunnel is under construction at North Campus.

### Requirements

Candidates for the degree B.S.E.(Nav.Arch.&Mar.E.)—Bachelor of Science in Engineering (Naval Architecture and Marine Engineering)—are required to complete the following:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Eng. Graphics 104, Geometry of Engineering Drawing | 2 |
| English, Groups II and III | 4 |
| Math. 273, Elementary Computer Techniques | 1 |
| Mathematics (additional work beyond Math. 316) | 3 |
| Econ. 401 | 3 |
| Eng. Mech. 208, Statics | 3 |
| Eng. Mech. 210, Mechanics of Material | 4 |
| Eng. Mech. 212, Laboratory in Mechanics of Material | 1 |
| Eng. Mech. 324, Fluid Mechanics | 3 |
| Eng. Mech. 343, Dynamics | 3 |
| Mech. Eng. 335, Thermodynamics I | 3 |
| Elec. Eng. 316, Circuit Analysis and Electronics | 4 |
| Nav. Arch. 200, Introduction to Practice | 3 |
| Nav. Arch. 201, Form Calculations and Static Stability I | 3 |
| Nav. Arch. 310, Structural Design I | 3 |
| Nav. Arch. 331, Marine Auxiliary Machinery | 3 |
| Nav. Arch. 420, Resistance, Propulsion, and Propellers | 5 |
| Electives in humanities and social sciences | 9 |
| Options 1, 2, or 3 | 32 |
| Total hours in Group B | 95 |

One of the following options should be selected by the student before the second term of his sophomore year:

**1. Naval Architecture.** *Adviser:* Associate Professor Yagle

| | |
|---|---|
| Mech. Eng. 337, Mechanical Engineering Laboratory | 2 |
| Eng. Mech. 411, Structural Mechanics | 3 |
| Nav. Arch. 300, Form Calculations and Static Stability II | 2 |
| Nav. Arch. 330, Marine Propulsion Machinery | 3 |
| Nav. Arch. 400, Shipbuilding Contracts and Cost Estimating | 2 |
| Nav. Arch. 410, Stress Analysis of Ship Structures | 2 |
| Nav. Arch. 440, Ship Dynamics | 2 |
| Nav. Arch. 446, Theory of Ship Vibrations I | 3 |
| Nav. Arch. 470, Ship Design I | 3 |
| Nav. Arch. 471, Ship Design II | 2 |
| Nav. Arch. 472, Structural Design II | 2 |
| Technical elective | 3 |
| Free elective | 3 |
| | 32 |

**2. Marine Engineering.** *Adviser:* Professor West

| | *Hours* |
|---|---|
| Mech. Eng. 336, Thermodynamics II | 4 |
| Mech. Eng. 471, Heat Transfer I | 4 |
| Eng. Mech. 411, Structural Mechanics | 3 |
| Elec. Eng. 442, Motor Control and Electronics | 4 |
| Nuc. Eng. 400, Elements of Nuclear Engineering | 3 |
| Nav. Arch. 430, Design of Marine Power Plants I | 2 |
| Nav. Arch. 446, Theory of Ship Vibrations I | 3 |
| Nav. Arch. 473, Design of Marine Power Plants II | 3 |
| Technical elective | 3 |
| Free elective | 3 |
| | 32 |

**3. Maritime Engineering Science.** *Adviser:* Associate Professor Yagle

| | |
|---|---|
| Nav. Arch. 330, Marine Propulsion Machinery | 3 |
| Eng. Mech. 403, Experimental Mechanics | 2 |
| Free elective | 3 |
| | 8 |

Either of the following two sequences:

| | |
|---|---|
| Eng. Mech. 412, Intermediate Mechanics of Material | 3 |
| Eng. Mech. 442, Intermediate Dynamics | 3 |
| *or* | |
| Eng. Mech. 411, Structural Mechanics | 3 |
| Nav. Arch. 446, Theory of Ship Vibrations I | 3 |
| | 6 |

Eighteen hours of technical electives, at least 12 of which are chosen from the following list. Of the 12 hours chosen from the list, a minimum of 4 hours must be in mathematics and naval architecture, respectively.

| | |
|---|---|
| Ind. Eng. 472, Operations Research | 3 |
| Instr. Eng. 510, Applications of the Electronic Differential Analyzer I | 3 |
| Instr. Eng. 570, Principles of Automatic Control | 3 |
| Instr. Eng. 571, Automatic Control Laboratory | 1 |
| Eng. Mech. 422, Intermediate Mechanics of Fluids | 3 |
| Math. 513, Introduction to Matrices | 3 |
| Math. 440, Vector Analysis | 2 |
| Math. 447, Modern Operational Mathematics | 2 |
| Math. 473, Introduction to Digital Computers | 3 |
| Math. 552, Fourier Series and Application | 3 |
| Physics 305, Modern Physics | 2 |
| Aero. Eng. 425, Principles of Aerodynamics | 3 |
| Mech. Eng. 471, Heat Transfer I | 4 |
| Nav. Arch. 410, Stress Analysis of Ship Structures | 2 |
| Nav. Arch. 430, Design of Marine Power Plants I | 2 |
| Nav. Arch. 440, Ship Dynamics | 2 |
| Nav. Arch. 470, Ship Design I | 3 |
| Nav. Arch. 630, Nuclear Ship Propulsion | 3 |
| Nuc. Eng. 400, Elements of Nuclear Engineering | 3 |

### Representative Schedule

For studies of the first year, see page 20

| *Third Term* | *Hours* |
|---|---|
| Math. 215 | 4 |
| Physics 146 | 5 |
| Eng. Mech. 208 | 3 |
| Nav. Arch. 200 | 3 |
| Eng. Graphics 104 | 2 |
| | 17 |

| *Fourth Term* | *Hours* |
|---|---|
| Math. 315 | 2 |
| Math. 316 | 2 |
| Eng. Mech. 210 | 4 |
| Eng. Mech. 212 | 1 |
| Nav. Arch. 201 | 3 |
| Chem.-Met. Eng. 250 | 3 |
| Math. 273 | 1 |
| | 16 |

| *Half Term* | |
|---|---|
| Mech. Eng. 335 | 3 |
| Math. | 3 |
| English, Group II | 2 |
| | 8 |

| *Fifth Term* | *Option* 1 | 2 | 3 |
|---|---|---|---|
| Elec. Eng. 316 | 4 | 4 | 4 |
| Eng. Mech. 324 | 3 | 3 | 3 |
| Eng. Mech. 343 | 3 | 3 | 3 |
| Mech. Eng. 336 | — | 4 | — |
| Mech. Eng. 337 | 2 | — | — |
| Nav. Arch. 300 | 2 | — | — |
| Nav. Arch. 310 | — | 3 | — |
| Nav. Arch. 330 | 3 | — | 3 |
| Technical electives | — | — | 4 |
| | 17 | 17 | 17 |

| *Sixth Term* | *Option* 1 | 2 | 3 |
|---|---|---|---|
| Eng. Mech. 403 | — | — | 2 |
| Eng. Mech. 411 | 3 | 3 | — |
| Mech. Eng. 471 | — | 4 | — |
| Nav. Arch. 310 | 3 | — | 3 |
| Nav. Arch. 331 | 3 | 3 | 3 |
| Nav. Arch. 420 | 5 | — | 5 |
| Humanities | — | 3 | — |
| Free electives | 3 | 3 | 3 |
| | 17 | 16 | 16 |

| *Seventh Term* | *Option* 1 | 2 | 3 |
|---|---|---|---|
| Econ. 401 | — | — | 3 |
| Elec. Eng. 442 | — | 4 | — |
| Nav. Arch. 400 | 2 | — | — |
| Nav. Arch. 410 | 2 | — | — |
| Nav. Arch. 420 | — | 5 | — |
| Nav. Arch. 430 | — | 2 | — |
| Nav. Arch. 440 | 2 | — | — |
| Nav. Arch. 446 | 3 | 3 | — |
| Nav. Arch. 470 | 3 | — | — |
| Humanities | 5 | 3 | 4 |
| Technical electives | — | — | 10 |
| | 17 | 17 | 17 |

| *Eighth Term* | *Option* 1 | 2 | 3 |
|---|---|---|---|
| Econ. 401 | 3 | 3 | — |
| English, Group III | 2 | 2 | 2 |
| Nav. Arch. 471 | 2 | — | — |
| Nav. Arch. 472 | 2 | — | — |
| Nav. Arch. 473 | — | 3 | — |
| Nuc. Eng. 400 | — | 3 | — |
| Humanities | 4 | 3 | 5 |
| Technical electives | 3 | 3 | 10 |
| | 16 | 17 | 17 |

## Physics

*Program Co-Advisers:* Professor Wiedenbeck, 1072 Randall; Professor Enns, 312B West Engineering

The rapid advance in physics and its applications in industry have developed increasing demands for applied physicists. This program is intended to meet the demand and usually leads to activities in research, development, or teaching.

Students who are candidates for degrees in engineering programs often elect additional courses in this program and qualify for graduation with a degree in physics as well. See Requirements for Graduation.

**Requirements**

Candidates for the degree B.S.E.(Phys.)—Bachelor of Science in Engineering (Physics)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | *Hours* |
|---|---|
| English, Groups II and III | 4 |
| Modern language | 8 |
| Chem.-Met. Eng. 250, Principles of Engineering Materials | 3 |
| Chem. 265, Principles of Physical Chemistry | 4 |
| Math. 273, Elementary Computer Techniques | 1 |
| Math. 450, Advanced Mathematics for Engineers | 4 |
| Eng. Mech. 208, Statics | 3 |
| Eng. Mech. 210, Mechanics of Material | 4 |
| Eng. Mech. 343, Dynamics, or Physics 401, Intermediate Mechanics | 3 |
| Eng. Mech. 324, Fluid Mechanics, or Physics 411, Mechanics of Fluids | 3 |
| Elec. Eng. 210, Circuits I | 4 |
| Elec. Eng. 310, Circuits II | 4 |
| Mech. Eng. 252, Engineering Materials and Manufacturing Processes | 2 |
| Physics 405, Intermediate Electricity and Magnetism | 3 |
| Physics 406, Heat and Thermodynamics, or course in engineering thermodynamics | 3 |
| Physics 453, Atomic and Molecular Structure | 3 |
| Physics 455, Electron Tubes | 4 |
| Group options and electives | 35 |
| Total hours in Group B | 95 |

Group options and electives are to be selected with the advice and consent of the program adviser in accordance with the distribution of hours as listed below. For the group of engineering electives, each student is expected to complete a planned sequence including analysis, design, and systems in some particular field of engineering.

| | |
|---|---|
| Physics | 7 |
| Mathematics | 3 |
| Engineering electives | 12 |
| From economics, geography, history, philosophy, political science, psychology, or sociology | 6 |
| Electives* | 7 |
| | 35 |

* A maximum of four hours of advanced courses in air, army, or naval science (300 and 400 series) may be used as electives in this group.

## Science Engineering

*Program Adviser:* Professor Bigelow, 4213 East Engineering

Science engineering is an interdepartmental degree program which combines a strong background in mathematics and the physical and engineering sciences with a high degree of flexibility in the choice of the area of engineering specialization. A primary objective of this program is to supplement and reinforce the academic offerings of the several established departments of the College of Engineering. The unique features of this program are its outstanding sequence of basic engineering science courses; the large amount of elective freedom which it allows in the selection of courses in the humanities and social sciences, and in advanced mathematics, chemistry, physics, and engineering subjects; and a basic structure which usually does not require selection of the area of specialization until the fifth or sixth term when students are well acquainted with the possibilities for specialization and with their own interests and aptitudes.

Students electing the Science Engineering Program can acquire a depth of training and experience in engineering principles and practice comparable to that provided by other programs of the College; however, they are not required to take all of the specialized courses normally included in many other programs and are therefore able to devote more time to courses of fundamental scientific nature. As a consequence of its greater elective freedom, the Science Engineering Program offers a greater variety of areas of specialization than any other program in the College. Science engineering students may choose their electives so as to obtain the substantial equivalent of an undergraduate degree in a number of traditional fields of engineering and to prepare for graduate work in these fields. Alternately, they may prepare for future work in law, management, sales, administration, writing and editing, or medicine, or they may specialize in one of the newly developing subject areas which overlap established fields of science and engineering and which may not be available to students in traditional departments. Examples of such subject areas are: nuclear science, instrumentation, communications, radio astronomy, bioengineering, computer science, solid state devices, high temperature gas dynamics, plasma physics, energy conversion, and systems engineering. The Science Engineering Program is particularly well suited for students who transfer to the College of Engineering after one or two years of work at another institution. It is also well suited for students who wish to obtain two degrees in the College of Engineering and for those who wish to participate in the Combined Degree Program leading to bachelor's degrees in both the College of Engineering and the College of Literature, Science, and the Arts.

The Science Engineering Program is administered by an interdepartmental committee whose members work closely with individual Science Engineering students and with counselors in the several departments of the College to select courses which best fulfill each student's academic objectives. Each student, however, is expected to assume the basic initiative and responsibility in developing his own program and in keeping account of his own academic progress. In this connection, it is intended that the elective freedom of the program should be accepted as a challenge to intellectual achievement, and each student is expected to design his program to develop his abilities to the highest possible level.

**Requirements**

Candidates for the degree B.S.E. (Sci.E.)—Bachelor of Science in Engineering (Science Engineering)—are required to complete the following program:

*A. Subjects to be elected or equivalent proficiencies to be demonstrated (see page 35)*

*B. Professional and advanced subjects and electives*

| | | *Hours* |
|---|---|---|
| Engineering science, including engineering materials, statics, strength of materials, dynamics, fluid mechanics, thermodynamics, electromagnetics and energy conversion, network analysis, electronics and systems, rate processes | | 36 |
| Electives in engineering, including at least one elective in design or analysis and at least one elective involving engineering laboratory | | 17 |
| Electives in mathematics, physics, chemistry, or thermodynamics, including Chemistry 195 or 265 and at least 3 hours of advanced mathematics | | 16 |
| Electives in English, fine arts, history of art, music, or philosophy, and at least 4 hours of literature | 6-10 | 20 |
| Electives in anthropology, economics, geography, history, journalism, political science, psychology, or sociology | 6-14 | |
| Electives in foreign language | 0-8 | |
| Electives* | | 6 |
| Total hours in Group B | | 95 |

Among the Group A subjects, the unified science sequence of accelerated and integrated preparatory courses consisting of Mathematics 185, 186, and 285, Physics 153 and 154, and Chemistry 194 and 195, are strongly recommended for those students who are qualified. The representative schedule on pages 75–76 is expressed in terms of this sequence. It is to be emphasized, however, that the many alternative sequences of preparatory courses with the same terminal level of accomplishment are equally acceptable, but add hours to the preparatory portion of the illustrated schedule. The mathematics sequence beginning with Mathematics 115 adds 4 hours; the physics sequence beginning with Physics 145 adds 2 hours; the chemistry sequence beginning with Chemistry 107 adds 1 hour; and the chemistry sequence beginning with Chemistry 103 adds 4 hours.

For the engineering science courses of the Group B subjects, the special sequences of courses consisting of Engineering Mechanics 218, 219, 326, 345, Electrical Engineering 215, 320, 337, and Science Engineering 330 and 340 are normally recommended. These have been developed by the respective departments, especially for the Science Engineering Program, and are among the most effective, efficient, and challenging courses available in their respective subject areas. Certain equivalent courses, however, may be substituted for these, with the approval of the program adviser, when it is advantageous in developing a program to meet the special interests of individual students.

The electives in humanities and social sciences are considered especially important because of the increasing contributions of scientists and engineers to the political, cultural, and philosophical aspects of modern civilization. These

* Advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

electives should therefore be carefully chosen to obtain a significant and meaningful experience in nontechnical subjects. Courses selected from among the offerings of the English Department of the College of Engineering and from among those listed as acceptable for fulfilling distribution requirements in the *Announcement* of the College of Literature, Science, and the Arts are recommended for this purpose. Foreign languages are particularly appropriate for students planning to undertake graduate work for a doctorate degree.

The electives in advanced mathematics, science, and engineering subjects should be chosen with a definite professional objective in mind, and should be such as to provide significant depth of training in engineering principles. The possibilities here are too numerous to list completely; however, several typical groups of electives are given below to illustrate the versatility of the program and to show the depth of professional training expected. Members of the Science Engineering Program Committee will be pleased to assist students in developing elective sequences for specialization in appropriate subject areas other than those shown below.

## Typical Elective Sequences

**Aeronautics and Astronautics:** Math, 404, (3) and 450 (4), Aero. Eng. 320 (4) (for fluid mechanics requirement), Aero. Eng. 314 (4), 330 (3), 420 (4), 441 (4), one or more of Aero. Eng. 414 (4), 430 (4), 471 (4), 520 (3), 540 (3), or alternate courses recommended by the aeronautical engineering adviser.

**Bioengineering:** Math. 450 (4), Chem. 225 (3), 226 (3), 227 (2), 346 (4), Biochem. 515 (3), Zool. 105 (5), Chem.-Met. Eng. 341 (3), and 342 (4) (for rate processes requirement) or 448 (3), 484 (3), 485 (3), 580 (3), Civ. Eng. 587 (3), or alternate courses recommended by bioengineering adviser.

**Communications Science:** Math. 404 (3) or 450 (4), 425 (3), 473 (3), Com. Sci. 400 (3), 410 (3), Elec. Eng. 330 (4), Philos. 101 (4) or 233 (3), 414 (3), and additional courses selected on recommendation of communications science adviser to meet the interests of individual student.

**Chemical Engineering:** Chem. 225 (3), 226 (3), 227 (2), 265 (4), 266 (4), Chem.-Met. Eng. 200 (3), 230 (5) (for thermodynamics requirement), 341 (3) (for rate processes requirement), 342 (4), 343 (4), 460 (3), 480 (3) or 481 (3) or alternate courses recommended by chemical engineering adviser.

**Electrical Engineering:** Math. 273 (1), 404 (3), 450 (4), Elec. Eng. 310 (4) (not required if an A or high B is obtained in EE 215), 343 (3), 360 (3), 380 (4) (not required if Chem.-Met. Eng. 350 and Phys. 307, 453, or Nuc. Eng. 470 are taken), 410 (3), 420 (3), 444 (4), 470 (4). A number of other sequences for specialization in various areas of electrical engineering can be suggested by the electrical engineering adviser.

**Engineering Mechanics:** Math. 404 (3), 447 (2), 450 (4), Eng. Mech. 403 (2), 412 (3), 422 (3), 441 (3), and additional courses selected upon recommendation of engineering mechanics adviser.

**Heat Transfer and Thermodynamics:** Math. 404 (3), 450 (4), 273 (1), Mech. Eng. 531 (3), 471 (4), 571 (3), 672 (3), 673 (3), Chem.-Met. Eng. 430 (3), 480 (3), and additional or alternate courses selected on recommendation of program adviser.

**Instrumentation:** Math. 404 (3), 448 (4), 450 (4), Elec. Eng. 310 (4) (not required with A or B+ in EE 215), Instr. Eng. 510 (3), 530 (2), 570 (3), 571 (1), and additional courses recommended by instrumentation engineering adviser.

**Materials Engineering:** Chem. 225 (3), 226 (3), 227 (2), Chem.-Met. Eng. 450 (4), 451 (4), 470 (4), 471 (3), 472 (3), and 480 (3) or 481 (3) or 489 (4) or Mech.

Eng. 343 (3) or 362 (3), or alternate courses recommended by materials engineering adviser.

**Materials Processing:** Chem.-Met. Eng. 250 (3) (for materials requirement), Mech. Eng. 251 (3), 381 (4), 343 (3), and additional courses selected from the following: Chem.-Met. Eng. 370 (3), 477 (3), 479 (3), 535 (3), 576 (3), Mech. Eng. 417 (3), 486 (3), 487 (3), 488 (3), 517 (3), Phys. 307 (3) or 453 (3), or Nuc. Eng. 470 (3), as recommended by materials processing adviser.

**Mechanical Engineering:** Chem.-Met. Eng. 250 (3) (for materials requirement), Mech. Eng. 251 (3), 324 (4), 336 (4), or 531 (3), 340 (4), 362 (3), 381 (3), 460 (4) or 462 (4), 471 (4) and additional or alternate courses recommended by mechanical engineering adviser.

**Metallurgical Engineering:** Chem. 225 (3), 266 (4), 346 (4), Math. 273 (1), Chem.-Met. Eng. 370 (3), 390 (3), 470 (4), 471 (3), 472 (3), 477 (3), 489 (4) or alternate courses recommended by metallurgical engineering adviser.

**Meteorology and Oceanography:** Math. 404 (4), M. & O. 412 (3), 432 (3), 440 (3), 441 (3), 445 (3), 472 (2) or 475 (2), or alternate courses recommended by meteorology adviser.

**Nuclear Engineering:** Math. 404 (3), 450 (4), Nuc. Eng. 470 (3), Mech. Eng. 471 (3), Elec. Eng. 420 (3), and additional or alternate courses selected from Nuc. Eng. 400 (3), 550 (3), 560 (3), 570 (3), Chem.-Met. Eng. 480 (3), Phys. 401 (3), Eng. Mech. 422 (3), Math. 448 (4), upon recommendation of nuclear engineering adviser.

**Physics:** Math. 404 (3), 450 (4), and 15 credit hours of intermediate physics courses selected from Phys. 401 (3) or 507 (3), 402 (3), 405 (3), or 455 (4) or 456 (3), 406 (3) or 509 (3), 451 (3), 452 (3), 453 (3), 457 (3), upon recommendation of program adviser.

**Radio Astronomy:** Math. 404 (3), 450 (4), Astron. 421 (3), 422 (3), Elec. Eng. 410 (3), 420 (3), 535 (3), 536 (3), with additional or alternate courses selected from Astron. 546 (3), Elec. Eng. 475 (3), 530 (4), as recommended by radio astronomy adviser.

**Solid State Devices:** Math. 404 (3), 450 (4), Phys. 453 (3), 463 (3), Chem.-Met. Eng. 551 (3), Elec. Eng. 380 (4), 419 (2), 420 (3), 526 (3) with additional or alternate courses selected from Chem.-Met. Eng. 550 (3), Elec. Eng. 580 (4), 588 (3), 626 (3), upon recommendation of program adviser.

**Structure of Solids:** Math. 450 (3), 473 (3), 552 (3), Phys. 453 (3), Mineral. 455 (3), 456 (3), Chem.-Met. Eng. 450 (3), 470 (4), 471 (3), 472 (3), 560 (3). 572 (3) with additional or alternate courses from Chem.-Met. Eng. 535 (3), 550 (3), Mineral. 451 (3), 501 (3), Chem. 767 (3), 769 (3), Phys. 402 (3), as recommended by program adviser.

## Representative Schedule

(In terms of accelerated sequences)

| *First Term* | *Hours* | *Second Term* | *Hours* |
|---|---|---|---|
| Math. 185 | 4 | Math. 186 | 4 |
| Physics 153 | 4 | Chem. 194 | 4 |
| Eng. Graphics 101 | 3 | English 112 | 2 |
| English 111 | 3 | Electives (humanities, soc. sci., language) | 6 |
| English 121 | 1 | | |
| | 15 | | 16 |

| *Third Term* | *Hours* |
|---|---|
| Math. 285 | 4 |
| Chem. 195 | 4 |
| Eng. Mech. 218 | 3 |
| Electives (humanities, soc. sci.) | 7 |
| | 18 |

| *Fourth Term* | *Hours* |
|---|---|
| Elective (math.) | 4 |
| Physics 154 | 4 |
| Eng. Mech. 345 | 3 |
| Elec. Eng. 215 | 3 |
| Electives (humanities, soc. sci.) | 4 |
| | 18 |

| *Fifth Term* | |
|---|---|
| Sci. Eng. 330 | 4 |
| Elec. Eng. 320 | 4 |
| Eng. Mech. 219 | 4 |
| Elective (math., chem., physics) | 3 |
| Elective (humanities, soc. sci.) | 3 |
| | 18 |

| *Sixth Term* | |
|---|---|
| Sci. Eng. 340 | 4 |
| Elec. Eng. 337 | 4 |
| Eng. Mech. 326 | 4 |
| Elective (math., chem., physics) | 2 |
| Elective (engineering) | 4 |
| | 18 |

| *Seventh Term* | |
|---|---|
| Electives (engineering) | 6 |
| Elective (math., chem., physics) | 3 |
| Chem.-Met. Eng. 350 | 3 |
| Electives | 6 |
| | 18 |

| *Eighth Term* | |
|---|---|
| Electives (engineering) | 7 |
| | 7 |

# Special Fields

New developments in science and in the art of engineering are reflected in new courses offered by an alert faculty. Such courses may be elected under the system of group options and electives in the undergraduate program or in a program of advanced work in the Graduate School. Many of these special fields have been specifically mentioned under the various degree programs. Information regarding these fields and others in which the student may be interested will be made available upon request. Program advisers will assist any student in preparing a program to fit his particular desires.

## Bioengineering

Opportunity to study in the new educational field of bioengineering is being offered to qualified students enrolled in the College of Engineering. The purpose is to provide an educational opportunity for engineering students to study the biological sciences along with the physical sciences, mathematics, and engineering sciences in order that they may apply the physical and engineering sciences with understanding to biological systems. It is intended to prepare an engineering student for a new professional area in which the engineer will find additional outlets for his analytical ability.

The new field of bioengineering is very broad. There are many areas of collaborative activity in investigation of biological systems, both basic and applied, involving the engineer and the biologist, where a knowledge of systems theory is required. Chemical reactions and transport, electrical behavior and response, fluid flow in biological systems, and biomechanics require quantitative analyses of component behavior. The complex coupling of components, involving advanced adaptive servo and signal theory, is further necessary to the understanding of biological system function and response. As biological systems are better understood, their complexities require a more sophisticated formulation that is a part of the most recent advances in engineering science. The advances in operations research provide a further approach to the problems associated with biological systems studies. There are no boundaries to the opportunities for the qualified engineer.

Plans are being developed for bioengineering to be available to students in the several professional departments of the College. Such students will be associated with educational programs in the College of Engineering, the College of Literature, Science, and the Arts, the Medical School, and the School of Public Health.

Students interested in exploring this opportunity for study should review their plans with their program advisers.

## Instrumentation Engineering

Instrumentation engineering is a program covering the dynamical aspects of systems engineering. This involves the principles and application of areas including measurement, information theory, data transmission, computers, feedback control, and random processes as they relate and are basic to systems in all fields of technology and science.

The best preparation can be achieved by completing the requirements for one of the undergraduate B.S.E. degree programs, the science engineering program being the most appropriate, followed by special work in instrumentation at the graduate level. See under M.S.E. degree programs and course listings.

Undergraduate students may start these special studies by electing one or more of the following courses: Instr. Eng. 570, Principles of Automatic Control I *(3)*; Instr. Eng. 571, Automatic Control Laboratory I *(1)*; Instr. Eng. 530, Probability in Instrumentation *(2)*; Elec. Eng. 438, Electronics and Radio Communication *(4)*; Math. 448, Operational Methods for Systems Analysis *(4)*.

## Nuclear Engineering

Nuclear engineering is concerned with the release, control, and utilization of energy from nuclear sources. In common with other rapidly developing fields of technology, nuclear engineering is characterized by a short time lag between basic scientific discovery and industrial application. In order to develop economic uses of nuclear energy, one needs a basic scientific background as well as specialized engineering training. The degree programs in nuclear engineering are offered only at the graduate level. Undergraduates interested in electing courses in the department should consult Professor Kikuchi or Professor Hammitt, 300 Automotive Engineering Laboratory.

Students who wish to acquire a background for the use of radiation in science and industry may elect Nuc. Eng. 470, 550, and 560. Students desiring a one-term course in nuclear engineering should elect Nuc. Eng. 400.

Students planning to enter the nuclear engineering program should take, as undergraduates, courses in atomic and nuclear physics (Nuc. Eng. 470 or equivalent), advanced calculus (Math. 450 or 451 or equivalent), and electronics (Elec. Eng. 337 or Physics 455 or equivalent). Those entering without these prerequisites will be required to make up the deficiencies in addition to the thirty hours required for the master's degree. Courses in heat transfer (Mech. Eng. 471), electromagnetic field theory (Elec. Eng. 420), and use of digital computers (Math. 473) are also recommended as desirable preparation.

**Facilities**

Facilities available to students in nuclear engineering include a 2-megawatt, swimming-pool type, research reactor; a light-water-moderated, natural-uranium-fueled subcritical reactor; both a single crystal and a high resolution triple axis crystal neutron spectrometer; a mechanical monochromator with four phased rotating shutters for low energy neutron time of flight studies; two hot caves, each of which can handle up to 10,000 curies of Cobalt-60 and each of which is equipped with master-slave manipulators; an analog computer facility; an IBM-7090 digital computer; a 10,000 curie Cobalt-60 gamma source; portable neutron and gamma sources; extensive radiation measuring equipment; hot metallurgical laboratory equipment; hot chemistry laboratories; a radiation solid state laboratory; an electron spin resonance laboratory; several multichannel analyzers; a thermonuclear and plasma laboratory facility; and extensive fluid flow and heat transfer equipment.

## Reserve Officer Training Corps

**Objective.** Officer training is available to all University men through the Senior Reserve Officer Training Corps. The purpose of this Corps is to provide a permanent system of training and instruction in essential military subjects and to provide a source from which qualified officers may be obtained for the Armed Services of the United States.

**Programs Offered.** Each of the services offers a scholarship and two nonscholarship programs:

*a)* The scholarship program provides for those eligible and selected to receive scholarship assistance for a period up to four years to include all tuition, fees, books, and laboratory expenses. The cadet/midshipman will also be provided with uniforms required for participation and will receive retainer pay at the rate of $50 per month.

*b)* The four-year nonscholarship program provides for those qualified and enrolled to receive uniforms required for participation as a cadet/midshipman, books for military science subjects, and during the Advanced training phase (the third and fourth years) retainer pay at the rate of $40 per month, not to exceed twenty months.

*c)* The two-year nonscholarship program permits direct entry into the Advanced Course by attending Summer training as substitution for the Basic Course. The cadet/midshipman will receive uniforms, books for military science subjects, and retainer pay at the rate of $40 per month, not to exceed twenty months.

**Conditions of Enrollment.** A student who enrolls in the scholarship program or in the Advanced Course of the nonscholarship programs must enlist in a reserve component of an armed force under the jurisdiction of the Secretary of the Military Department concerned and for the period prescribed by the Secretary. In addition, the student will contract (with the consent of his parents or guardian if he is a minor) with the Secretary of the Military Department concerned, or his designated representative, to serve for the period prescribed by the Secretary.

Those students in the scholarship program and Advanced Course students in the nonscholarship programs who for reasons beyond their control or who, without intent to defraud the government, or who do not willfully violate the terms of their contract will, if disenrolled from the program, also be discharged from their enlisted reserve status at the same time. Students who willfully evade the terms of their contract, or complete the program and decline to accept a commission when tendered, may be called to active duty in their enlisted grade for a period not to exceed four years if in the scholarship program or two years if in the nonscholarship program.

Since there are minor variations among the three services, interested engineering students should study the pertinent information in this *Announcement,* and if any questions arise consult the Professor of Military Science for further information about the Army; the Professor of Naval Science about the Navy; and the Professor of Air Science about the Air Force.

On permission to drop, refer to Election of Studies.

## Air Science

Department Office: 158 North Hall

**General Information.** The Department of Air Science offers a program of studies designed to prepare selected male officer candidates for a professional career in the United States Air Force. This program, entitled the Air Force Reserve Officer Training Corps Program, is a new one, based on the recently enacted Reserve Officer's Training Corps Vitalization Act of 1964. The sequence of courses provides understanding of national and international defense requirements, of the global mission and organization of the United States Air Force, of current and projected aerospace weapons systems, and of officer leadership and management responsibilities and skills. Classroom activities throughout the program emphasize the development of imaginative and communicative skills by the participation of all members in group discussions, panel presentations, debates, individual reports, and other dialogue processes.

New legislation provides for two alternative plans of study: a four-year plan, and a two-year plan, The four-year plan is designed primarily for scholarship students. Four-year scholarships will be provided by the Air

Force to a limited number of incoming freshmen, based on a nationwide competition. The two-year program is designed primarily to enable non-scholarship and transfer students to prepare themselves for Air Force careers with a lesser expenditure of course time.

**Flying Activities.** Qualified senior-year cadets desiring active service pilot training receive in a Flight Instruction Program approximately 36 hours of dual/solo light-plane instruction under a licensed civilian instructor, with the opportunity also to earn a private pilot's license. They receive 35 hours of "ground school" work. (See A.S. 401 listing below.) When possible, local area orientation flights and overnight flights to Active Air Force bases are made to familiarize all cadets with Air Force life.

**Requirements for Enrollment.** Incoming male students, who are physically qualified citizens of the United States (or will become citizens during the fourth term) who can complete eight terms of aerospace studies prior to receiving their degrees, and who will meet all requirements for commissioning prior to their 28th birthday, may compete for scholarships or enroll in the four-year program on a nonscholarship basis. Male students enrolled in the University, or male transfer students interested in the two-year program, should contact the professor of Air Science as early as possible before March 1 prior to fall enrollment to schedule attendance at a Field Training Course conducted during a 6-week period at an Air Force base prior to attendance for the fall term. Students with prior military service may enroll above the entry level, based upon evaluation of such military service by the Professor of Air Science.

**Transfer Students.** Students who have completed one or more years of ROTC studies (Air Force, Army, or Navy) at any college-level institution or who have sufficient prior military service may enter the Program as late as the first term of the junior year. Transfer students already in the AF-ROTC Program will be accepted at their level of training through prior concurrence with Department of Air Science. They should contact the Professor of Air Science prior to registration week, if possible, in order that a tentative determination of eligibility may be made, and to allow time for the Department of Air Science to procure records from the ROTC department with which previously enrolled.

**Monetary Allowances.** The scholarship program provides for tuition, books, and fees plus $50 per month retainer fee. Advanced cadets (third and fourth Air Science years) who are not on Air Force scholarships receive a retainer of $40 per month. Additional pay and travel allowances are provided for attendance at the Field Training Course.

**Uniforms and Books** are furnished to all cadets. Each advanced program cadet is measured for a fitted uniform which becomes a gift from the University on the date of his commissioning. A uniform deposit of $20 is required and is refunded when aerospace studies are terminated.

**Selective Service Deferment.** Cadets are entitled to deferment after the first term of enrollment in the Air Force ROTC Program. Deferment of a cadet may be continued as late as one year beyond the completion of the fourth year of aerospace studies provided the cadet is still working to earn his degree and commission.

**Commissions in the Air Force.** Cadets completing the Program and receiving a baccalaureate degree from the University are commissioned as second lieutenants in the United States Air Force. These new officers are then called into active duty with the Air Force for a period of at least four years. This active duty can be served in any of approximately thirty Officer Utilization Fields, ranging from jet pilot through a wide range of technical fields, such as missile operations, weather, research and development, communications-electronics, avionics, aircraft maintenance, civil-engineering, transportation, logistics, and intelligence, and including a broad selection of managerial and training areas, such as administrative services, accounting and finance, personnel, statistics, manpower management, education and training, investigations, air police, and information services. Advanced education or technical training for these career areas may be obtained on active duty at Air Force expense. Cadets with a distinguished undergraduate record may apply for commission as a regular officer upon graduation. Those who do not receive a regular commission upon graduation may compete for such a commission while in their initial years of active duty.

**Extracurricular Activities.** The Department of Air Science sponsors a rifle team and cadet work in Civil Air Patrol training; it also co-sponsors a tri-service ROTC band. Selected cadets may become members of the local chapter of the national Arnold Air Society. Qualified cadets may participate in tri-service honorary organizations.

**Implementation of the New Legislation.** At the time of writing, several details regarding implementation of the Vitalization Act of 1964 were not available. The act requires that a student who enrolls in the scholarship program or in the Advanced Course of the nonscholarship programs also must enlist in the Air Force Reserve (Ineligible Reserve Section) for a period of six years and execute a contract with the Air Force to serve on active duty for a period of at least four years. In a statement of policy the Air Force states that those students in the scholarship program or advanced course in the nonscholarship programs who for reasons beyond their control or who, without intent to defraud the government, or who do not willfully violate the terms of their contract, will if disenrolled from the program also be discharged from their enlisted reserve status at the same time. The Air Force further states that those students who willfully evade the terms of their contract, or complete the program and decline to accept a commission when tendered, may be called to active duty in their enlisted grade for a period not to exceed two years for nonscholarship students or four years for scholarship students. Additional details will be published in a special brochure as early as possible. It is also expected that announcements will be made in high schools regarding application for the four-year scholarship program. The courses listed below are those which the department expects to offer during academic year 1965-66; however, there may be certain modifications which may be announced prior to the start of the fall term. It should be noted that, in several cases, the Air Science course is reduced in classroom time and is accompanied by an approved University course to add up to the total number of hours required for the ROTC Program. This combination of Air Force courses and University courses is designed to enable cadets to receive the most effective instruction in each subject area.

*Courses Offered in Air Science*

**101. Foundations of Leadership.** I. *(1)*.
Laboratory or lecture, 1 hour a week; to be accompanied by approved University course.
Customs and courtesies of military organizations; fundamentals of military procedures; elements of national power; evolution and development of U.S. military forces; the place of the United States in the world today.

**102. World Military Systems.** II. *(2)*.
Seminar, 2 hours a week, laboratory 1 hour a week.
Analysis of factors, causes and types of present world conflicts and political philosophies; the U.S. power position in World affairs; the armed forces as an instrument of national policy; missions and functions of the Air Force, and the student's relation to United States world commitments.

**201. World Military Systems.** I. *(2)*.
Seminar, 2 hours a week, laboratory 1 hour a week.
A comparative study of world military forces to include Free World land and naval forces, Free World air forces, Communist military systems, and trends in the development of military power and to international alliances and conflicts.

**202. Foundations of Leadership.** II. *(1)*.
Laboratory 1 hour a week; to be accompanied by approved University course.
Development of the cadet's leadership ability as a noncommissioned officer in the Cadet Corps.

**301. Growth and Development of Aerospace Power.** I. *(3)*.
Seminar 3 hours a week, laboratory 1 hour a week.
The nature of military conflict; development of aerospace power; development of doctrine governing the employment of aerospace forces; the mission and organization of the USAF; employment of forces in general war, limited war, and actions short of war.

**302. Growth and Development of Aerospace Power.** II. *(3)*.
Seminar 3 hours a week, laboratory 1 hour a week.
Evolution of the space program; the effects of solar geography on the space program; principles and problems affecting the use of orbits and trajectories; operating principles, characteristics, and problems associated with components of space vehicles; current and planned capabilities for space operations.

**401. The Professional Officer.** I. *(2)*.
Seminar, 2 hours a week; laboratory 1 hour a week; accompanied by Geography 435.
Principles of weather and navigation for pilot and navigation trainees. (Seniors not candidates for flying training may take this course or may arrange with the Education Officer of the Department of Air Science for permission to take an alternate University course which will enhance their officer qualifications. Such cadets should concurrently enroll for A.S. 403.)

**402. The Professional Officer.** II. *(2)*.
Seminar, 2 hours a week; laboratory 1 hour a week; accompanied by a University course approved by the Professor of Air Science.
Principles of leadership and management; the junior staff officer; Air Force personnel policies and procedures.

**403. Advanced Leadership Laboratory.** I. *(1)*.
Laboratory 1 hour a week; accompanied by approved University course. For senior cadets excused from A.S. 401.

## Military Science

Professor McNair, Assistant Professors Andrew, Dahl, Roberts, and Wood. Department office, 131 North Hall.

**General Information.** The objective of the Army ROTC program is to produce junior officers who, by their education, training, and inherent qualities, are suitable for continued development as officers in the United States Army. ROTC graduates, after attaining a baccalaureate degree, are commissioned as second lieutenants in the Army Reserve. Outstanding ROTC cadets who are designated as Distinguished Military students may apply for a direct commission in the regular Army (the same commission as given United States Military Academy graduates).

Regularly enrolled University of Michigan male students who meet the established physical, age, and moral standards prescribed may enroll in the Army ROTC program. Enrollment in the ROTC is elective and ROTC cadets are excused from the University requirement of two terms of physical education. A cadet enrolled in the College of Engineering may drop the basic nonscholarship course, if he so desires, during the first eight weeks of the first term. A cadet who remains in the basic ROTC program after this dropout period is expected to complete four terms of ROTC. This requirement can be waived only in exceptional circumstances; for example, physical, financial, or academic reasons.

Entrance into the advanced program (junior and senior years) is on an invitational basis, the cadet having the option to accept or decline. Among the factors considered for entry into the advanced course are demonstrated leadership potential and academic record. In order for a cadet to enter the advanced program (junior and senior years) he must have completed the basic program (freshman and sophomore years) or six weeks basic training camp in the term between the sophomore and junior years at an Army Basic Training Camp. Those cadets who desire to enter the advanced course by attendance at the 6-week basic summer camp should contact the Professor of Military Science, room 131, North Hall, as soon as possible after the beginning of the winter term. A cadet having accepted the advanced program is required to enlist in the reserve and to sign a contract to (1) continue the ROTC program for the remaining four terms, (2) accept a commission if tendered, (3) serve his military obligation of active and reserve duty as required by law. Time spent in the enlisted reserve will reduce the cadet's total military obligation accordingly; he will be required to serve active duty after commissioning as required by the program, however. Although the advanced course cadet is required to enlist in the reserve, he is not required to attend weekly meetings or participate in reserve summer training. The purpose of this reserve enlistment is to prevent any student from defrauding the government by refusing to accept his commission when tendered, or by willfully evading his contract. It will have no effect on the cadet who enters and continues the program in good faith. Upon commissioning, or withdrawal for valid reasons, such as academic, physical or financial problems, the cadet will be discharged from his enlisted reserve status.

Although the current military obligation is two years active duty and four years in the reserve for the nonscholarship programs and four years active duty and two years in the reserve for the scholarship program, Army regulations also provide for six months active duty for training and seven and one-half years in the reserve. This provision is not being offered at this time; however, when the needs of the service permit, it is expected that the six months active duty for training option will again be offered.

Each cadet is required to attend a six-week ROTC Summer Camp, normally at the end of his junior year. Emphasis of training at summer camp is on leadership and field application of studies at the University.

ROTC graduates who desire to defer their tour of active duty in order to do graduate work at any accredited university may apply for an academic delay. Academic delays are given for one year and may be renewed for a maximum total of four years. To date, no University of Michigan ROTC graduate has been denied his request for delay or extension of delay.

**Scholarship Program.** Recent ROTC legislation has provided for scholarship assistance to selected students in the four-year program. Details of the scholarship program are not available at this time. Interested cadets should see the Professor of Military Science, 131 North Hall, for further information.

**Flight Program.** Qualified senior cadets may apply for the Army Flight Instruction program. The program consists of approximately 36½ hours of light plane flying instruction, and 35 hours of ground school instruction. All instruction is taught by licensed civilian instructors at no cost to the cadet. Upon successful completion, the cadet is awarded a private pilot's license.

**Branch Assignments.** In their senior year, cadets will be classified for branch assignments upon commissioning to one of fourteen branches in accordance with their preference, aptitude, curriculum, interest, physical condition, and the nationwide needs of the Army. In the past, 80 per cent of University of Michigan students have been granted their first preference; 90 per cent their first or second preference, 100 per cent have received their first, second, or third preference. Branches in which a cadet may be commissioned are as follows: Armor, Artillery, Adjutant General's Corps, Army Intelligence and Security, Chemical Corps, Corps of Engineers, Finance Corps, Infantry, Medical Service Corps, Military Police Corps, Ordnance Corps, Quartermaster Corps, Signal Corps, and Transportation Corps.

**Advanced Standing.** Students with prior military service or prior ROTC training (high school or college) may receive advanced standing in the ROTC program. Transfer students from colleges without ROTC units may qualify for advanced standing by completion of summer training after their sophomore year. The many variables preclude a blanket statement of eligibility; thus, students should contact the Professor of Military Science, 131 North Hall, personally for advanced standing determination. Students who desire to qualify for advanced standing by attendance at summer training should contact the Professor of Military Science as soon as possible after the beginning of the winter term.

**Pay and Allowances.** Pay and allowances begin with enrollment in the third year of military science in the nonscholarship programs and amount to approximately $400 for each of the last two years. In addition, the cadet receives approximately $180 plus travel expenses to and from the six-week summer camp, and a $300 uniform allowance after he is commissioned.

**Uniforms, Texts, and Equipment.** All ROTC cadets are furnished a uniform and all texts and equipment without charge; however, a security deposit of $20 is required. The uniform furnished at the beginning of the third year is custom tailored and may be retained by the individual for active duty wear as an officer.

**Extracurricular Activities.** Cadets are free to elect as few or as many of the following activities as desired:

Army Rifle and Pistol Team–range, rifle or pistol, and ammunition available without charge

ROTC Marching Band—winter term only, instruments furnished, attendance not required at Leadership Laboratory

Pershing Rifles—a national honorary to promote leadership and comradeship through impeccable close order drill and fancy drill

Scabbard and Blade–a national honorary

**Course of Instruction.** The complete course of instruction is divided into four major blocks of instruction: (1) American Military History; (2) Operations, Tactics, and Techniques; (3) Logistics and Materiel; (4) School of the Soldier and Exercise of Command (Leadership Laboratory). The instructional objective of the Department of Military Science is to integrate the instruction under the four areas of military knowledge and skill into the progressive development of self-confidence, initiative, sense of responsibility, high moral standards, and leadership.

The Department of the Army has revised the course of instruction to include "academic substitution." The effect of the substitution program is that it is far less demanding on the cadet's time and amounts to a reduction of 24 per cent of the classroom hours over the four-year period. For each hour that the cadet is excused from ROTC classes, he is required to attend one hour of class in one of the following broad fields: general psychology, science comprehension, effective communication, and political development and political institutions. The substitute course may be a specific degree requirement during both terms of the freshman year but should not be during the junior and senior years. The substitution during the junior and senior years should fall in the elective category.

*Courses Offered In Military Science*

**101. Organization of the Army.** *Prerequisite: none. (1).*
Five hours of instruction on organization of the Army and ROTC; ten hours of instruction on the M-14 rifle and marksmanship; eight two-hour periods of leadership laboratory. Academic substitution of fifteen hours (one credit hour) required. Leadership laboratory is designed to teach the fundamentals of drill, drill being the vehicle used by the ROTC for progressive leadership development and evaluation.

**102. United States Army and National Security.** *Prerequisite: none. (1).*
Fifteen hours on U. S. Army and national security; seven two-hour periods of leadership laboratory. Academic substitution of fifteen hours (one credit hour) required. Leadership laboratory is designed to perfect individual performance and prepare cadets to serve as noncommissioned cadet officers during the sophomore year.

**201. Operations and Tactics.** *Prerequisite: M.S. 102 or permission of P.M.S. (2).*
Fifteen hours of map and aerial photograph reading; fifteen hours of introduction to operations and basic tactics; eight two-hour periods of leadership laboratory. Leadership laboratory designed to give sophomores continued opportunity to develop their leadership potential as cadet noncommissioned officers with view toward selection by army staff into advanced course.

**202. American Military History.** *Prerequisite: M.S. 102 or permission of P.M.S. (2).*
Twenty-nine hours of instruction on American military history; one hour of counterinsurgency operations, seven two-hour periods of leadership laboratory. Leadership laboratory designed for sophomores, acting as cadet noncommissioned officers, to develop their leadership potential teaching the freshmen.

**301. Military Teaching Principles.** *Prerequisite: M.S. 202 and selection. (1).*
Eighteen hours of instruction on military teaching principles; 45 hours (three credit hours) of academic substitution; eight two-hour periods of leadership laboratory. Leadership laboratory designed to prepare each cadet for summer camp by rotating positions of leadership (company commander, platoon lieutenant, and NCO positions) weekly within the junior class.

**302. Tactics and Communications.** *Prerequisite: M.S. 202. (3).*
Sixteen hours on leadership; nine hours on all branches of the Army; twenty-seven hours on small unit tactics and communications; three hours on precamp orientation; five hours of counterinsurgency operations; seven two-hour periods of leadership laboratory. Leadership laboratory continuation of M.S. 301.

**401. Operations, Administration, and Logistics.** *Prerequisite: M.S. 302. (3).*
Fifteen hours of instruction in operations; fifteen hours of logistics; fifteen hours of Army administration; fifteen hours of military law; two hours of map reading review; eight two-hour periods of leadership laboratory. Leadership laboratory designed for seniors to act as cadet officers by organizing, running, and evaluating the leadership laboratory for all undergraduates.

**402. Role of the United States in World Affairs.** *Prerequisite: M.S. 302. (1).*
Eight hours of instruction in the role of the United States in world affairs; five hours of service orientation; 45 hours (3 credit hours) of academic substitution; seven two-hour periods of leadership laboratory. Leadership laboratory designed as the final chance in the ROTC program for continued leadership development prior to functioning as commissioned officers on active duty in the Army.

## Naval Science

Professor Laforest; Assistant Professors Allnutt, Boufford, Danielson, Dankel, Hurd, and Maynard; Instructors Hepler, Keel, Mays, Morley, and Wilfong. Department Office, North Hall.

**Mission.** The mission of the Naval Reserve Officers Training Corps is to provide a permanent system of training and instruction in essential naval subjects at civilian educational institutions, and to provide a source from which qualified officers may be obtained for the Navy and Marine Corps and the Naval Reserve and Marine Corps Reserve.

**Objectives.** The objectives of the Department of Naval Science in carrying out the above mission at the University are:

1. To provide the student with a well-rounded course in basic naval subjects, which, in conjunction with a baccalaureate degree, will qualify him for a commission in the United States Naval Service.
2. To develop an interest in the naval service and a knowledge of naval practice.
3. By precept, example, and instruction, to develop the psychology and technique of leadership in order that the young officer may be able to inspire others to their best efforts.
4. To supplement the academic work of the school year by summer cruises, aviation training, and/or Marine Corps encampments.
5. To provide certain selected groups of students with such specific training, differentiated in the last part of the course, as will qualify them for commissions in the United States Marine Corps or the United States Navy (Supply Corps).

**Officer Candidates.** NROTC offers a scholarship and two nonscholarship programs:

The scholarship program provides for those eligible and selected to receive scholarship assistance for a period up to four years to include all tuition, fees, books, and laboratory expenses. The midshipman will also be provided with uniforms required for participation and will receive retainer pay at the rate of $50 per month.

The four year scholarship program provides for those qualified and enrolled to receive: uniforms required for participation as a midshipman, books for naval science subjects, and during the Advanced training phase (the third and fourth years) retainer pay at the rate of $40 per month, not to exceed twenty months.

The two year nonscholarship program permits direct entry into the Advanced Course by attending summer training as substitution for the Basic Course. The midshipman will receive uniforms, books for naval science subjects, and retainer pay at the rate of $40 per month, not to exceed twenty months.

A student who enrolls in the scholarship program or in the Advanced Course of the nonscholarship programs must enlist in a reserve component of an armed force under the jurisdiction of the Secretary of the Military Department concerned for the period prescribed by the Secretary. In addition, the student will contract, with the consent of his parents or guardian if he is a minor, with the Secretary of the Military Department concerned, or his designated representative, to serve for the period prescribed by the Secretary. Those students in the scholarship program and Advanced Course students in the nonscholarship programs who for reasons beyond their control or who, without intent to defraud the government, or who do not willfully violate the terms of their contract, will if disenrolled from the program also be discharged from their enlisted reserve status at the same time. Students who willfully evade the terms of their contract, or complete the program and decline to accept a commission when tendered, may be called to active duty in their enlisted grade for a period not to exceed four years if in the scholarship program or two years if in the nonscholarship program.

Upon satisfactory completion of the requirements for a baccalaureate degree and the naval science requirements a midshipman, if tendered, must accept a commission in the regular or reserve component of the Navy or Marine Corps and to serve on active duty for such period as prescribed by the Secretary of the Navy.

Candidates must be between seventeen and twenty-one years of age. In special cases students sixteen years of age may be enrolled. All must pass the Navy physical examination. Height must be between 64 and 78 inches and general physical development good. Vision must be not less than 20/40 and uncorrected by glasses and in all cases must be correctible to 20/20.

All students are required to complete eight terms of naval science subjects. Candidates for Marine Corps commissions complete four terms of general naval science subjects and four terms of Marine Corp specialty courses. Candidates for Navy Supply Corps commissions complete four terms of general naval science subjects and four terms of Navy Supply Corps subjects.

A psychology course taught by the civilian faculty of the University is required during one term of the sophomore year.

Midshipmen in the scholarship program participate in three summer cruises of six to eight weeks' duration; midshipmen in the nonscholarship program participate in one six-week summer cruise. Marine candidates spend the third cruise period at the Marine Corps Schools, Quantico, Virginia.

Midshipmen in the scholarship program must satisfactorily complete one year of college mathematics and one year of college physics by the end of their sophomore year. Midshipmen in the nonscholarship program must have satisfactorily completed a sequence of mathematics through trigonometry in high school or one term of mathematics in college.

Each of the following subjects requires attendance at three one-hour recitations and a two-hour laboratory period each week.

*Courses Offered In Naval Science*

**101. Naval Orientation and Sea Power.** I. *(3)*.
Introduction to basic Navy background, procedures, regulations, and organization, with emphasis on the junior officer duties and responsibilities. The last third of the term introduces Navy history and sea power.

**102. Sea Power and Naval History.** *Prerequisite: N.S. 101.* II. *(3).*
Continuation of Naval Science 101, developing historically the importance of sea power from 1775 to present. Emphasis on present day application of past developments in techniques, strategy, tactics, organization, and leadership.

**200. Naval Weapons.** *Prerequisite: N.S. 102.* II. *(3).*
A basic familiarity in modern naval weapons and the purpose of each, stressing the following specifics: ballistics and ordnance, automatic control equipment, fire control problem, and fleet air defense. Instruction in the general nature of naval weapons systems stressing guided missiles, nuclear weapons, anti-submarine warfare, and space technology. A course in psychology, as selected by the Professor of Naval Science, is required during the term the student is not enrolled in N.S. 200.

**301. Navigation.** *Prerequisite: N.S. 200.* I. *(3).*
Thoroughly acquaints the student with the theory of dead reckoning, piloting, and celestial methods of navigation. Practical problem solution is stressed during summer cruises.

**302. Naval Operations.** *Prerequisite: N.S. 301.* II. *(3).*
Provides a broad understanding of basic naval tactics, tactical communications, relative motion, and the rules of the nautical road.

**303. Navy Supply Management I.** *Prerequisite: N.S. 200.* I. *(3).*
For Navy Supply Corps candidates only. Naval finance, organization, and administration afloat.

**304. Navy Supply Management II.** *Prerequisite: N.S. 303.* II. *(3).*
For Navy Supply Corps candidates only. Supply organization and administration afloat.

**305. Study of Evolution of Art of War.** *Prerequisite: N.S. 200.* I. *(3).*
For Marine Corps candidates only. Analysis of decisive battles of history according to principles of war and evolution of weapons.

**306. Modern Strategy and Tactics.** *Prerequisite: N.S. 305.* II. *(3).*
For Marine Corps candidates only. Study of European and United States military policies and strategies and fundamental infantry tactics.

**401. Naval Engineering.** *Prerequisite: N.S. 302.* I. *(3).*
Provides a broad general concept of the fundamentals of naval engineering installations, including steam, diesel, nuclear power, gas turbines, and auxiliary plants, and ship stability.

**402. Principles and Problems of Leadership.** *Prerequisite: N.S. 401 or 403.* II. *(3).*
Introduces the basic principles of human relations, leadership, and management with emphasis on naval shipboard administration and an introduction to the Uniform Code of Military Justice. (Required for Navy Supply Corps students.)

**403. Navy Afloat Retail Sales.** *Prerequisite: N.S. 304.* I. *(3).*
For Navy Supply Corps candidates only. Study of management techniques involved in the operation of afloat ships store.

**405. Amphibious Warfare.** *Prerequisite: N.S. 306.* I. *(3).*
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare.

**406. Amphibious Warfare.** *Prerequisite: N.S. 405.* II. *(3).*
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare (15 sessions only; remaining 30 sessions deal with study of naval justice and Marine Corps leadership).

# Graduate Studies

The undergraduate program in engineering offers only a limited opportunity 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.

Opportunities to continue advanced-level study in selected engineering subjects are available in the University's graduate residence centers in the state of Michigan, provided through the Extension Service.

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

Undergraduate students contemplating graduate work should consult with the program adviser or the advisory committee for the desired program.

## 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 of Bachelor of Science in Engineering at the University in his field of specialization, or essentially the equivalent of these requirements, with sufficient evidence that he can meet the scholastic requirements of study at an advanced level.

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

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

**Degree Requirement.** The requirements for a master's degree include the completion of at least thirty credit hours of graduate work approved by the program adviser or advisory committee for the program elected with an average grade of at least B covering all courses elected as a graduate student. Courses numbered 400 and above are generally acceptable for graduate credit.

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 Aeronautical and Astronautical Engineering and M.S. in Aeronautics and Astronautics**

*Advisory Committee:* Professors Greenwood and Liu; Associate Professor Messiter.

A candidate for the M.S.E. degree will normally include in his program three to five advanced courses in areonautical and astronautical engineering, two or three courses in mathematics beyond advanced calculus, and one or two selected courses in other cognate fields. Up to four credit hours of nontechnical studies and up to five credit hours of directed study may be elected. The courses in aeronautical and astronautical engineering may be selected to emphasize one or more of the following technical areas: gasdynamics (aerodynamics and propulsion), flight mechanics and control, and structural mechanics.

A candidate for the M.S. degree in aeronautics and astronautics must present substantially the equivalent of the four-year program in engineering, physics, or mathematics at the University and must complete a program of thirty credit hours to be determined in consultation with the departmental graduate committee. Normally, this program will include Physics 451 and 452, selected courses in mathematics, and several courses in aeronautical and astronautical engineering. Up to four credit hours of nontechnical studies and up to five credit hours of directed study may be elected. The courses in aeronautical and astronautical engineering may be selected to emphasize one or more of the following technical areas: gasdynamics, flight mechanics and control, and structural mechanics.

**M.S.E. in Chemical Engineering**

*Program Adviser:* Professor York, 3215 East Engineering Building

The requirements for the M.S.E. degree comprise a minimum of thirty hours of graduate work with a grade of B or better in each course, including Chem-Met. Eng. 541, 542, a graduate-level course in thermodynamics, and such other courses as are approved by the adviser. Each student is required to engage in either teaching or research activities during part of each academic year. Each student is encouraged to develop a program to fit his professional objectives and should consult with the adviser in this matter.

A full range of courses is available for those interested in many special fields, particularly: biochemical engineering, catalysis, materials, petroleum refining and production, polymers, process dynamics, process and equipment design.

**M.S.E. in Civil Engineering**

*Program Adviser:* Professor Maugh

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 thirty credit hours of graduate work approved by the adviser, of which fifteen 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, geodetic, highway, hydraulic, hydrological, municipal, railway, sanitary, structural, soil, and transportation engineering.

**M.S.E. and M.S. in Communication Sciences**

*Advisory Committee:* Professors Burks, Fitts, Garner, Hok, Peterson, Rapoport, and Thrall; Associate Professors Galler, J. H. Holland, and Swain. Candidates may be admitted to advanced study in communication sciences after a bachelor's degree in an appropriate area of concentration. See Special Fields.

Students may be admitted to the M.S.E. degree program from any of the undergraduate engineering curriculums if accepted by the advisory committee. The requirements have been established in co-operation with the Department of Electrical Engineering. At least thirty hours of graduate work, as approved by the advisory committee, must be completed, including Com. Sci. 400, 410, 473, 510, 522, 530, 541, 550, and 580.

**M.S.E. in Construction Engineering**

*Program Adviser:* Associate Professor Harris
This program is available to students interested in construction who meet the requirements for admission to master's degree work in civil engineering. The requirements for this degree are the completion of at least thirty credit hours of graduate work including Civ. Eng. 501, 531, 532, and 545; and other courses in engineering, economics, business administration, and other fields approved by the program adviser.

**M.S.E. in Electrical Engineering and M.S. in Energy Systems**

*Program Advisers:* Professors L. N. Holland, Kazda, Macnee, Scott and Sharpe.
A candidate for the M.S.E. degree must have satisfactorily completed the undergraduate electrical engineering program of the University or its equivalent. A minimum of thirty credit hours of graduate work is required for this degree and must include Elec. Eng. 620 and two courses in advanced mathematics. At least fifteen credit hours must be in electrical engineering. By suitable selection of his courses, the candidate may specialize in any of the following fields: communications engineering, computer engineering, engineering systems and design, electrical measurements and instrumentation, electric power engineering, electromagnetic field theory, control systems, energy conversion machinery, microwave engineering, physical electronics, solid-state engineering.

A candidate for the M.S. degree in energy systems must present substantially the equivalent of a four-year program in engineering, including courses in engineering materials, fluid flow, thermodynamics, electrical circuits, electromechanical energy conversion, and physical electronics (required for Direct Conversion Area.) Once a student has satisfactorily demonstrated his knowledge in these areas he will be admitted into the Graduate Program. The satisfactory completion of the requirements for the degree M.S. (energy systems) requires that the student complete the following courses: Math. 450 plus 2 graduate hours of mathematics. Mech. Eng. 471 and 535 or Chem.-Met. Eng. 430, Elec. Eng. 420 and 444 and Nuc.

Eng. 400. The hours remaining after the above courses have been completed are to be selected in an area of specialization designated and approved by the program adviser. It is expected that the majority of these credits will be obtained in courses of the 500 (or higher) series level. *However, a student will not receive graduate credit for any course required in the undergraduate program at The University of Michigan corresponding to the program in which he receives his B.S. degree.*

Typical areas of specialization which are available to the candidate are listed below.

*Control Systems:* Elec. Eng. 545 or Instr. Eng. 570, and one or more of the following: Elec. Eng. 547, 548, 673.

*Power Generation:* (1) Nuclear: Nuc. Eng. 630, and one or more of the following, Nuc. Eng. 640, 680, 730; Chem.-Met. Eng. 573, 574, 579, 586. (2) Chemical Combustion: Mech. Eng. 432, 531; Chem.-Met. Eng. 449, and one or more of the following, Mech. Eng. 437, 496, 535 or Chem.-Met. Eng. 530, Mech. Eng. 571, 672, 673; Chem.-Met. Eng. 573, 574. (3) Hydraulic: Civ. Eng. 522, 523; and one or more of the following, Mech. Eng. 422, Civ. Eng. 524, 526. (4) Direct Conversion: Elec. Eng. 480, and one or more of the following, Chem.-Met. Eng. 510, Elec. Eng. 526, 588, Mech. Eng. 673.

*Power Transmission and Utilization:* Elec. Eng. 553, 554, and one or more of the following: Elec. Eng. 541, 542, 555, 557, 558.

*Energy Systems Economics:* Elec. Eng. 552 or Ind. Eng. 451, and one or more of the following: Ind. Eng. 472, Civ. Eng. 501, 603.

There will be special seminars in topics as required.

**M.S.E. in Engineering Materials**

*Graduate Adviser:* Professor Van Vlack, 4215 East Engineering Building.

A candidate for the M.S.E. degree is required to have a minimum of thirty hours of graduate credit in addition to a basic science background essentially equivalent to that represented by the program leading to the degree Bachelor of Science in Engineering (Materials Engineering) at the University, which includes chemistry, through organic and physical, structure of materials, mechanics of materials, and thermodynamics. The graduate courses are to be selected with the approval of the adviser of the program and must include at least one of the following three courses: Chem-Met. Eng. 570, 636, or 535. Each student is required to engage in either research or teaching activities during part of each academic year.

**M.S.E. in Engineering Mechanics**

*Advisory Committee:* Professors Clark, Enns, Haythornthwaite, Ormondroyd, Smith, and Yih.

Candidates may be admitted to this degree program from any of the undergraduate engineering curriculums. A student whose undergraduate training is inadequate will be permitted to make up the deficiency in a manner prescribed by the advisory committee. The transition is simplified for those who have had some advanced mathematics.

A total of thirty credit hours of graduate study is required for the master's degree, seventeen from the graduate courses offered in the Department of Engineering Mechanics and thirteen from cognate fields. The program must include Eng. Mech. 412, 422, and 442, and Math. 552 and 555 or their equivalents. Students who have had any of the required courses, or their equivalents, may substitute cognate subjects as part of the seventeen required hours if permitted to do so by the adviser. For those who expect to pursue the doctorate. Math. 557 is recommended. A master's thesis, subject to departmental approval, may be substituted for part of the course work. The student's program of study is to be approved by the departmental graduate adviser.

**M.S.E. in Geodetic Engineering**

*Program Adviser:* Professor Berry.

This program is available to students who have satisfactorily completed an undergraduate engineering program of the University, or its equivalent, including mathematics through differential equations and at least nine semester hours in geodetic engineering. A minimum of thirty credit hours of graduate work, approved by the Department of Civil Engineering, is required for this degree, including Civ. Eng. 560 and 561; and other courses in engineering, mathematics, astronomy, city planning, or other closely allied fields related to the professional practice of geodetic engineering in government or private practice.

**M.S.E. in Industrial Engineering and M.S. in Industrial Administration**

*Program Adviser:* Associate Professor R.C. Wilson

A candidate for the M.S.E. degree must present substantially the equivalent of a bachelor's degree in industrial engineering at the University. He must complete in residence a minimum of thirty hours of graduate work approved by the adviser, approximately fifteen hours of this will be in the industrial engineering area.

A candidate for the M.S. degree in industrial administration must present the equivalent of a bachelor's degree in recognized programs in any of the engineering fields, physics, or mathematics. He must complete in residence a minimum of thirty hours of graduate work approved by the adviser; approximately fifteen hours of this will be in the industrial engineering area.

**M.S.E. and M.S. in Instrumentation**

*Program Adviser:* Professor Howe

Candidates may be admitted to the M.S.E. degree program from any of the undergraduate engineering curriculums. A minimum of thirty credit hours of graduate work is required for the degree and must include Math. 448, Elec. Eng. 438; Instr. Eng. 530, 570, 571, and Instr. Eng. 630; and other courses approved by the committee on instrumentation. The systems-engineering concept is emphasized throughout the program. See Special Fields and course listings.

For students lacking the essential equivalent of the degree Bachelor of Science in Engineering but having an acceptable science background at the bachelor's degree level, the degree Master of Science in instrumentation is offered.

**M.S.E. in Mechanical Engineering**

*Program Adviser:* Professor Clark

The requirement for this degree is thirty credit hours of approved graduate work. At least fifteen 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. 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 which they have been required to take for the bachelor's degree or for courses required in the undergraduate curriculum of this department.

**M.S.E. in Metallurgical Engineering**

*Program Adviser:* Professor Hucke, 2211 East Engineering Building.

The requirements for the M.S.E. degree comprise a minimum of thirty hours of graduate work with a grade of B or better in each course, including Chem.-Met. Eng. 535, 570, and 690 (4 hours).

Other courses are to be selected from the areas of physical, mechanical, and process metallurgy as approved by the adviser. Each student is encouraged to design his program to satisfy his special interest. Each student is required to engage in either teaching or research activities during part of each academic year.

**M.S. in Meteorology and/or Oceanography**

*Program Advisers:* Professors Wiin-Nielsen and Ayers.

Candidates for the M.S. in meteorology and/or oceanography 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 146. Each candidate will follow a special program arranged in conference with the adviser, and the candidate may be required to make up deficiencies. A total of thirty hours is required, including fifteen hours of meteorology and/or oceanography, and six hours of mathematics, or three hours of mathematics and three hours of physical science. Interdisciplinary programs may be arranged. Six hours of course work in meteorology and/or oceanography may, after agreement with the graduate adviser, be replaced by a master's thesis.

**M.S.E. in Naval Architecture and Marine Engineering**

*Program Adviser:* Associate Professor Michelsen

A candidate for this degree must have completed the equivalent engineering courses for the degree Bachelor of Science in Engineering (Naval Architecture and Marine Engineering) or, if he has had practical experience in the subject matter covered by these courses, pass an examination in them. The requirements include advanced mathematics for engineers, Nav. Arch. 590 or 591, Eng. Mech. 422, and electives in mathematics, engineering mechanics, and naval architecture. A total of thirty hours of graduate credit courses must be completed.

It is also possible to obtain a combined degree of Master of Science in Engineering in marine and other engineering disciplines upon mutual agreement with the respective departments. The Graduate School requirements for such a degree are a minimum of forty hours of graduate level courses and the approval of the candidate's program by the Dean of the Graduate School.

**M.S.E. in Nuclear Engineering and M.S. in Nuclear Science**

*Program Adviser:* Professor Hammitt

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 and who wish to work on nuclear energy development. The undergraduate preparation required for these programs is listed under Special Fields.

The credit requirements for the master's degree are thirty hours of completed course work including twenty hours from nuclear engineering. The following core courses must be included in the twenty hours: Nuc. Eng. 560, 570, 630, 660, and 680. A B average must be maintained in the core courses. All students are required to complete a one-term research or design problem under Nuc. Eng. 690 for at least two credit hours. When desired, facilities for the supervision of work leading to a master's thesis will be made available. 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 core courses, substitution of other courses will be arranged by the program adviser.

**M.S.E. in Public Works Administration**

*Program Adviser:* Associate Professor Glysson

The program in municipal engineering and public administration is conducted in co-operation with the Institute of Public Administration. It is available to students in the administrative problems of municipal engineering and city management who meet the requirements for admission to master's work in civil engineering.

The degree requires satisfactory completion of at least thirty hours of course work balanced between the fields of civil engineering and public administration subject to approval of the program adviser.

**M.S.E. in Sanitary Engineering**

*Program Adviser:* Professor Borchardt

The program leading to this degree is generally open to graduates in civil, chemical, and mechanical engineering. A student is expected to elect at least fifteen hours of the required thirty hours for the M.S.E. degree in the field of civil and sanitary engineering. A minimum of two cognate courses is required in related fields of interest. The remainder of the program will be selected in conference with the student's adviser along lines designed to best complement the student's ultimate objective.

**M.S.E. in Water Resources Engineering and M.S. in Water Resources**

*Program Adviser:* Assistant Professor Weber

A co-ordinated program of advanced study in engineering as it relates to water resources is centered in the Department of Civil Engineering and guided by an interdepartmental advisory committee of the College of Engineering. The program leading to a Master of Science in Engineering (Water Resources) degree is open to candidates with a Bachelor of Science in Engineering degree. Special programs leading to a Master of Science in Water Resources degree are also available to individuals with a baccalaureate degree other than in engineering, who may otherwise be qualified to pursue advanced study in one of many specialized areas dealing with a particular phase of water resource analysis, development, or use.

The candidate must complete a minimum of thirty hours of course work constituting an integrated program in water resources. The program of study, however, is somewhat flexible to meet the individual student needs within an objective of providing both increased depth in traditional physical, chemical, or biological science disciplines applicable to the engineering solution of problems in water resources and an opportunity to gain new insights with study in cognate areas.

Water serves many economic uses and social needs, and programs of study in water resources will necessarily vary somewhat to provide flexible opportunities for study with water as the common bond of relationship.

## Professional Degrees

Programs are offered which lead to the following professional degrees:

**Aeronautical and Astronautical Engineer**—Ae. & Astrn.E.
**Applied Mechanics Engineer**—App.M.E.
**Chemical Engineer**—Ch.E.
**Civil Engineer**—C.E.
**Electrical Engineer**—E.E.
**Industrial Engineer**—Ind.E.
**Instrumentation Engineer**—Instm.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 thirty 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 twenty-four 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 results of his investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when he has been admitted to the Horace H. Rackham School of Graduate Studies and has been accepted in a field of specialization. No assurance is given that he may become a candidate for the doctorate until he has given evidence of superior scholarship and ability as an original investigator.

There is no general course or credit requirement for the doctorate. In most areas a student must pass a comprehensive examination in his major field of specialization, which tests his knowledge in that field and in the supporting fields, before he will 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.

A reading knowledge of two of the following three languages is required: German, French, or Russian. A student must meet the language requirements for the doctorate before he can be accepted as a candidate for the degree. He should consult the Examiner in Foreign Languages, 3028 Rackham Building, at his earliest convenience after becoming an applicant. A student who completes French 112, German 112, Spanish 112, or Russian 112 with a grade of B or better will be recorded as having met the language requirement in the respective language. Substitution for one of the required languages may be made under certain conditions which are defined in the *Announcement* of the Graduate School.

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, with certain closely associated departments of other units of the University, are listed with a brief description for each.

See page 26 for definitions relating to the University's term. Time schedules are issued giving hours and room assignments for classes.

As a general rule, courses numbered from 100 to 199 are introductory or beginning courses, 200 to 299 are intermediate, and 300 and above are advanced level courses. Those numbered 400 and above are generally acceptable for graduate credit. A Roman numeral in boldface type indicates the position of the course in a sequence of courses on the same subject. Prerequisites appear in italics immediately after course titles.

When they appear, Roman numerals in light-face type indicate the time in which the department concerned plans to offer the course: I, fall; II, winter; III, spring-summer — III*a*, spring half; III*b*, **summer half** (summer session). The italic number enclosed in parentheses indicates the hours of credit for the course, e.g., *(3)* denotes three credit hours, or *(To be arranged)* denotes credit to be arranged.

## Aeronautical and Astronautical Engineering

*Department Office:* 1079 East Engineering

**200. General Aeronautics and Astronautics.** *Prerequisite: Physics 145, or equivalent.* I and II. *(2).*
Introduction to aeronautical and astronautical engineering. Elementary problems designed to orient the student in the program of aeronautical engineering, together with a discussion of the current state of aeronautical developments and the role of the engineer. Recitations and demonstrations.

**314(Eng. Mech. 314). Structural Mechanics I.** *Prerequisite: Eng. Mech. 210 or 219.* I and II. *(4).*
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. Aerodynamics I.** *Prerequisite: preceded or accompanied by Eng. Mech. 343 and Math. 450.* I and II. *(4).*
Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Calculation of the forces and moments acting on wings and bodies in incompressible inviscid flow and comparison with experiment.

**330. Propulsion I.** *Prerequisite: Mech. Eng. 335, Aero. Eng. 320, or Mech. Eng. 336.* I and II. *(3).*
Introduction to aerothermodynamics and applications to problems in flight propulsion. Discussion of the momentum theorem, one-dimensional flow systems, with heat addition, shock waves, diffusers, compressors, and turbines.

**414(Eng. Mech. 414). Structural Mechanics II.** *Prerequisite: Aero. Eng. 314.* I and II. *(4).*
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. Lectures and laboratory.

**415. Principles of Structural Mechanics.** *Prerequisite: Eng. Mech. 210 or 219.* I. *(3).*
An accelerated coverage of the material in Aero. Eng. 314 and 414 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 314 or 414.

**420. Aerodynamics II.** *Prerequisite: Aero. Eng. 320, and preceded or accompanied by Aero Eng. 330.* I and II. *(4).*
Continuation of Aerodynamics I. Viscous and compressible fluid theory applied to the calculation of the forces and moments on wings and bodies and comparison with experiment. Loads on an airplane. Lectures and laboratory.

**422. Theory of Propellers and Fans.** *Prerequisite: Aero. Eng. 320, and Mech. Eng. 335. (2).*
Critical study of the fundamental areodynamic and strength theories of the propeller; viscosity and compressibility effects; theory and performance of axial and centrifugal blowers, with application to superchargers and jet propulsion systems.

**425. Principles of Aerodynamics.** *Prerequisite: Eng. Mech. 324. (3).*
An accelerated coverage of the material in Aero. Eng. 320 and 420 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 320 or 420.

**430. Propulsion II.** *Prerequisite: Aero. Eng. 330 or equivalent.* I and II. *(4).*
Performance and analysis of flight-propulsion systems including the reciprocating engine-propeller, turboprop, ramjet, pulsejet, and rocket. Lectures and laboratory.

**435. Principles of Propulsion.** *Prerequisite: Mech. Eng. 335 or equivalent. (3).*
An accelerated coverage of the material in Aero. Eng. 330 and 430 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 330 or 430.

**439. Aircraft Propulsion Laboratory.** *Prerequisite: preceded by Aero. Eng. 330. (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.

**441. Mechanics of Flight.** *Prerequisite: Aero. Eng. 320.* I and II. *(4).*
Mechanics of a particle applied to the analysis of vehicle flight paths. Orbits, ballistic trajectories, and trajectories of vehicles in the atmosphere. Rigid body mechanics applied to translational and rotational vehicle motion. Analysis of vehicle motion and static and dynamic stability using perturbation theory. Control characteristics.

**442. Performance of High-Speed Vehicles.** *Prerequisite: Aero. Eng. 435 and 445 or equivalent. (3).*
Properties of the atmosphere, regimes of flow, analysis and optimization of thrust programming, performance of high-speed vehicles, including coasting and glide trajectories, optimum flight paths, orbital vehicles, and re-entry problems.

**445. Priniciples of Mechanics of Flight.** *Prerequisite: Math. 316. (3).*
An accelerated coverage of the material in Aero. Eng. 441 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 441.

**447. Flight Testing.** *Prerequisite: Aero. Eng. 441 or equivalent. (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.

**449. Principles of Vertical Take-off and Landing Aircraft.** *Prerequisite: Aero. Eng. 420. (3).*
Lifting rotor and propeller analysis in vertical and forward flight; ducted fan analysis; helicopter performance analysis; transitional flight problems of VTOL aircraft; stability and control problems of helicopters and VTOL aircraft.

**460. Wind Tunnel Instrumentation.** *Prerequisite: permission of instructor. (2).*
Study of the role of schlieren, shadow, and interferometric techniques in areodynamic research and a comparison of their relative accuracy and effect in data reduction; pressure and temperature measurements. Lectures and laboratory.

**464(Meteor.-Ocean. 464). Aeronomy I.** *Prerequisite: senior or graduate standing. (3).*
An introduction to physical processes in the upper atmosphere. The structure of the upper atmosphere: density, temperature, composition and winds; acoustical propagation and visible phenomena; the ionosphere. The physical basis of the techniques of satellite meteorology: solar, terrestrial, and atmospheric radiation processes including transfer and heat balance.

**465(Meteor.-Ocean. 465). Aeronomy II.** *Prerequisite: Aero. Eng. 464. (3).*
High altitude observations of aeronomical and meteorological phenomena. The physical basis and need for aerodynamic, mass spectrometric, and radiative experiments. Sensor characteristics. Current balloon, aircraft, rocket, and satellite techniques.

**471. Automatic Control Systems.** *Prerequisite: Aero. Eng. 441. (4).*
Transient and steady-state analysis of linear control systems; transfer functions, stability analysis, and synthesis methods; airplane transfer functions and synthesis of autopilot and powerplant control systems; use of analog computer in the laboratory for simulation. Lectures and laboratory.

**481. Airplane Design I.** *Prerequisite: Aero. Eng. 310 and 441.* I and II. *(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. Airplane Design II.** *Prerequisite: Aero. Eng. 480. (2).*
Design procedure, including layouts and preliminary structural design; stress analysis and detail design. Lectures and drawing.

**500. Directed Study.** *(To be arranged).*
Individual study of specialized aspects of aeronautical engineering.

**510. Structural Mechanics III.** *Prerequisite: Aero. Eng. 414.* I. *(3).*
Energy principles of structural analysis. Applications to elements of light weight structures. Introduction to matrix force and matrix displacement methods of analysis.

**515. Structures at Elevated Temperatures.** *Prerequisite: Aero. Eng. 414 or 415. (3).*
Aerodynamic heating of high-speed aircraft and space vehicles. Thermal radiation. Heat transmission within the structure. Thermal stress; thermal deflection and buckling. Brief discussion of material properties at elevated temperature, creep, thermal stress effects on structural stiffness.

**520. Intermediate Aerodynamics.** *Prerequisite: Aero. Eng. 420 or 425 or a course in advanced calculus. (3).*
Aerodynamics of viscous and compressible fluids. Equations of motion and energy, high subsonic, transonic, and supersonic flow, shock waves, characteristics, boundary layers, turbulence, unsteady flow. Physical aspects of subject are stressed.

**521. Experimental Aerodynamics.** *Prerequisite: Aero. Eng. 520. (2).*
Covers the work presented in the experiments in Aero. Eng. 420 but with more attention to detail and more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

**525. Aerodynamics of High-Speed Flight.** *Prerequisite: Aero. Eng. 420 or 425 or permission of instructor. (3).*
Treatment of problems in the aerodynamics of flight at supersonic and hypersonic velocities; linearized theory of wings with arbitrary planform and bodies of revolution; wing-body interference; hypersonic aerodynamics, aerodynamic heating, real gas effects.

**530. Propulsion III.** *Prerequisite: Aero. Eng. 430 or equivalent. (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 or permission of instructor. (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 effects, high temperature effects, multicomponent flows, etc.

**535. Rocket Propulsion.** *Prerequisite: Aero. Eng. 430 or 435 or equivalent. (3).*
Analysis and performance of liquid and solid propellant rocket powerplants; propellant thermochemistry, heat transfer, system considerations, advanced rocket propulsion techniques.

**540. Flight Mechanics of Space Vehicles I.** *Prerequisite: Math. 316.*
Kinematics of motion, particle dynamics, orbital motion and calculation of orbital parameters, 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 system parameters.

**544. Aeroelasticity I.** *Prerequisite: Aero. Eng. 414. (3).*
Deformation characteristics of aircraft and missile structures. Deformation under dynamic loads; differential equation, integral equation, and energy methods of

analysis. Nonsteady aerodynamics. Static aeroelastic effects, lifting surface flutter, and panel flutter.

**610. Structural Mechanics IV.** *Prerequisite: Aero. Eng. 510. (3).*
Matrix force, matrix displacement, transfer matrix, and finite difference methods of structural analysis. Applications to structural dynamics. Nonlinear problems in structural mechanics.

**620. Dynamics of Viscous Fluids.** *Prerequisite: Aero. Eng. 520 or permission of instructor. (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.

**622. Hypersonic Aerodynamics.** *Prerequisite: Aero. Eng. 520. (3).*
Inviscid flow past thin bodies at high Mach number; blunt-body methods; blast-wave theory; viscous interaction; nonequilibrium flows.

**624. Linearized Aerodynamic Theory.** *Prerequisite: Aero. Eng. 520. (3).*
Application of conformal mapping in the study of thin airfoils; three-dimensional subsonic and supersonic wing theory; forces acting on oscillating wings; slender-body theory; higher approximations.

**627. Continuum Theory of Fluids.** *Prerequisite: Aero. Eng. 520 or equivalent. (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 and energy in a moving fluid, and some solutions of the complete equations.

**628. Statistical Theory of Fluids.** *Prerequisite: Aero. Eng. 532 or permission of instructor. (3).*
A study of the physics of flow from the viewpoint of discrete particles using methods of statistical physics; transport phenomena, rarefied gas dynamics, plasma interactions and radiation gas dynamics.

**640. Flight Mechanics of Space Vehicles II.** *Prerequisite: preceded or accompanied by Aero. Eng. 540. (3).*
Dynamic performance of hypervelocity vehicles within the atmosphere. Problems associated with departure from and re-entry into the atmosphere.

**641. Flight Mechanics of Space Vehicles III.** *Prerequisite: Math. 450, Aero. Eng. 540, or equivalent. (3).*
Motion of a point mass in a gravitation field. Restricted three-body problems; perturbations from reference trajectories. Analysis of orbital transfers; capture and hyperbolic encounters, including error analysis. Trajectories of powered space vehicles.

**644. Aeroelasticity II.** *Prerequisite: Aero. Eng. 544. (3).*
Static and dynamic aeroelastic problems relative to swept wings and wings of low aspect ratio. Transient aeroelastic response problems. Aeroelastic effects on aircraft flying qualities.

**670. Control and Guidance of Missiles.** *Prerequisite: Instr. Eng. 670 or Elec. Eng. 646, Math. 448. (2).*
Analysis and synthesis of missile autopilot systems. Navigational homing systems; inertial and celestial navigation systems. Trajectories of ballistic missiles.

**671. Missile Guidance and Control Laboratory.** *Prerequisite: preceded or accompanied by Aero. Eng. 670. (1).*
Simulation of missile control and guidance systems on the electronic differential analyzer.

**674. Control of Space Vehicles.** *Prerequisite: Instr. Eng. 570 or equivalent and Aero. Eng. 540 or equivalent. (3).*
Analysis and synthesis of nonlinear control systems. Design of autopilots using thrust-vector control; transfer functions of elastic structures as part of closed-loop systems. Mechanization of space vehicle guidance. Attitude control of satellites and space vehicles using jet reaction and inertia wheel control systems.

**721. Turbulence.** *Prerequisite: Aero. Eng. 620 or permission of instructor. (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 magneto hydrodynamic equations.

**730. Energy Transfer in High Temperature Gas Flows.** *Prerequisite: Aero. Eng. 532 and 620 or permission of instructor. (3).*
Energy transfer processes as related to high temperature gas flows: unsteady heat conduction, convection in non-reactive and reactive flows, transport properties, ablation and gaseous radiation.

**732. Combustion and Flame Propagation.** *Prerequisite: Aero. Eng. 532, 620 or permission of instructor. (3).*
Thermodynamics of gas mixtures, chemical kinetics, conservation equations for reacting gas mixtures. Derivation of the fluid dynamic and thermodynamic relationships governing the propagation of combustion waves and their applications to deflagrations and detonations.

**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 Mechanics of Flight.** *(To be arranged).*

**870. Seminar in Instrumentation.** *(To be arranged).*

**880. Seminar in Space Technology.** *Prerequisite: permission of instructor. (To be arranged).*

**882. Seminar in Guided Missiles.** *Prerequisite: permission of instructor. (To be arranged).*
Primarily for military officers.

**895. Seminar in Space Research.** *Prerequisite: permission of instructor. (2).*
Detailed analysis of objectives, procedures, and results of research being carried out at The University of Michigan. Topics will include the following: structure of the upper atmosphere; measurement of temperature, pressure, density, composition, and winds. The ionosphere; measurement of ion and electron density and temperature. Investigation of radio waves incident on the earth at frequencies absorbed by the ionosphere by means of instrumented satellites. Interpretation of infrared data from meteorological satellites. Research in attitude control of multistage sounding rockets.

**900. Research.** *(To be arranged).*
Specialized individual or group problems of research or design nature supervised by a member of the staff.

## Business Administration*

*Office:* 150 Business Administration

Professors Dixon, Dykstra, Gies, Leabo, Moore, Pilcher, Rewoldt, Schmidt, and Taggart; Associate Professor Southwick; Assistant Professor Munson.

The courses listed below are of special interest to engineering students. 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 (sixty credit hours). This does not apply to Accounting 271 and 272 which are listed as sophomore-level courses in the economics department of the College of Literature, Science, and the Arts.
2. Juniors may elect courses numbered 300 to 399 inclusive, and seniors may elect any course numbered 300 to 499 inclusive, provided they have satisfied particular course prerequisites.
3. Courses numbered above 500 may be elected only by properly qualified graduate students and are not open to juniors and seniors.

For a description of courses in business administration, see the *Announcement* of the School of Business Administration. A supplement will be issued indicating the course offerings for each term. The following are courses of particular interest to engineering students:

*Business Administration—General*

305. Business Law. *(3).*
306. Business Law. *(3).*
454. Industrial Cost Accounting. *(3).*

*Accounting*

271. Principles of Accounting. *(3).*
272. Principles of Accounting. *(4).*

*Finance*

300. Money and Banking. *(3).*
301. Financial Principles. *(3).*

*Industrial Relations*

300. Management of Personnel. *(3).*

*School of Business Administration.

*Management*
311. Production Management. *(3)*.

*Marketing*
300. Marketing Principles and Policies. *(3)*.

*Statistics*
300. Introduction to Statistics. *(3)*.

## Chemical and Metallurgical Engineering

*Department Office:* 2028 East Engineering

**200. Introduction to Engineering Calculations.** *Prerequisite: a university course in chemistry or physics.* I and II. *(3)*.
Material and energy balances, the equilibrium concept. Properties of fluids and solids. Engineering systems.

**230. Thermodynamics I.** *Prerequisite: Chem.-Met. Eng. 200, Math. 215, and Physics 146.* I and II. *(5)*.
Development of fundamental thermodynamic property relation 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.

**250. Principles of Engineering Materials.** *Prerequisite: Chem. 105 or equivalent; preceded or accompanied by Physics 146. (Physics 153 and Chem. 194 are equivalent to this prerequisite.)* I and II. *(3)*.
An introductory course in the science of engineering materials. Engineering properties are correlated with (1) internal structures (atomic, crystal, micro-, and macro-); and (2) service environments (mechanical, thermal, chemical, electrical, magnetic, and radiation). Two lectures and two recitations.

**270. Metals and Alloys.** *Prerequisite: Chem.-Met. Eng. 250 and Mech. Eng. 251. (3)*.
May not be elected by chemical or metallurgical engineers.
Structures and properties as affected by composition and mechanical and thermal treatment, with special emphasis on the utilization of common metals and alloys and their behavior in service. Lecture, recitation, and laboratory.

**341. Rate Processes I.** *Prerequisite: Chem.-Met. Eng. 200.* I and II. *(3)*.
A study of momentum and heat transfer and diffusion. Emphasis on measurement, interpretation, and correlation of rate data and use of rate data in design.

**342. Rate Processes II.** *Prerequisite: Chem.-Met. Eng. 230 and 341.* I and II. *(4)*.
Mass transfer and chemical kinetics. Emphasis on measurement, interpretation, and correlation of rate data and use of rate data in design. Lectures, recitations, and laboratory.

**343. Separations Processes I.** *Prerequisite: Chem.-Met. Eng. 342.* I and II. *(4)*.
Introduction and survey of separations based on mechanical properties, separations based on interphase activities, and capacity and performance of separations equipment. Lectures, recitations, and laboratory.

**350. Structure of Solids.** *Prerequisite: Chem. 266.* I and II. *(3).*
Atomic structure, crystallography, equilibria, rate processes, solid types, bonding, structure, imperfections. Mechanical, thermal, electrical, magnetic, optical, and surface properties of solids. Electron and zone theories of solids.

**370. Fundamentals of Casting.** *Prerequisite: preceded or accompanied by Math. 214.* II. *(3).*
Physical and chemical principles applied to casting. Experiments include mechanism and rate of solidification, flow of liquid metal, fluidity, development of residual stresses during cooling, gases in liquid metals, slag-metal reactions, operation and selection of melting furnaces.

**390. Research and Special Problems.** I, II, and III*a* and III*b*. *(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.

**400. Chemical Engineering Calculations.** *Prerequisite: Math. 316 or 404 and Chem.-Met. Eng. 342. (3).*
Applications of topics in mathematics to engineering problems. Solutions to ordinary and partial differential equations, orthogonality properties, matrix notations, numerical analysis.

**430. Thermodynamics II.** *Prerequisite: Chem.-Met. Eng. 230 or Sci. Eng. 330.* II. *(3).*
Basic relations among thermodynamic properties; entropy balance and concept of availability. Physical and chemical equilibrium, solutions, and equilibrium stage calculations.

**439(Mech. Eng. 439). Combustion and Air Pollution Control.** *Prerequisite: permission of instructor.* II. *(3).*
Fundamentals of combustion as related to furnaces, internal combustion engines, and process plants, emphasizing formation and control of gaseous and particulate air contaminants.

**445. Applied Chemical Kinetics.** *Prerequisite: Chem. 265 and 266. (3).*
Description of kinetic systems, systematic approach to chemical reactions, mathematical and experimental characterization of kinetic systems, homogeneous and heterogeneous reactions, photochemical and chain reactions, explosions.

**446. Introduction to Control and Dynamics of Chemical Systems.** *Prerequisite: Chem.-Met Eng. 342, 400, or equivalent. (3).*
The transient response of simple one- and two-time constant systems are considered. The relationships between electrical, thermal, mechanical, and hydraulic examples are established and defined on the basis of their frequency response characteristics. The mathematical models for more complex chemical processing equipment and systems are derived and applied to the problems of automatic control encountered in the chemical industry.

**448. Unit Operations.** *Prerequisite: calculus, senior or graduate standing.* I. *(3).*
Equipment and theory of unit operations, including separations, heat and mass transfer with particular reference to basic operations in sanitary engineering, pharmaceutical manufacturing, and the chemical industry. Not open to chemical engineers.

**449. Fuels and Chemical Equilibrium in Combustion.** *Prerequisite: Mech. Eng. 335 or Chem.-Met. Eng. 200. (3).*
Chemical properties of jet fuels, rocket fuels, and oxidizers; computation of propulsive performance under equilibrium conditions; kinetics of reactions.

**450. Physical Ceramics.** *Prerequisite: preceded or accompanied by Chem. 266 and Chem.-Met. Eng. 350.* II. *(4).*
The nature, properties, processing, and application of ceramic materials. Lectures, recitation, and laboratory.

**451. Introduction to High Polymers.** *Prerequisite: organic chemistry, physical chemistry, or permission of instructor.* I. *(4).*
Preparation, properties, and utilization of polymeric materials. Lectures, recitation, and laboratory.

**460. Engineering Operations Laboratory.** *Prerequisite: Chem.-Met. Eng. 342.* I and II. *(3).*
Laboratory determination of operating data of equipment for chemical and metallurgical operations. Laboratory, conferences, and reports.

**470. Physical Metallurgy I.** *Prerequisite: Chem.-Met. Eng. 350.* I and II. *(4).*
Structure and properties of nonferrous metals as related to their composition, thermal and mechanical treatments. Metallurgical laboratory techniques. Lectures, recitation, and laboratory.

**471. Physical Metallurgy II.** *Prerequisite: Chem.-Met. Eng. 470.* I and II. *(3).*
Surface hardening, hardenability, hardening, tempering, isothermal transformation, related properties of iron and steel. Lectures, recitation, and laboratory.

**472. X-ray Studies of Engineering Materials.** *Prerequisite: Chem.-Met. Eng. 350 and 470.* I. *(3).*
Radiography, investigation of welds and castings; diffraction studies of metals and alloys. Lectures, recitation, and laboratory.

**477. Metallurgical Operations.** *Prerequisite: Chem.-Met. Eng. 470 or 479 or 576.* II. *(3).*
The study of deformation and joining processes and their influence on the mechanical, physical, and chemical properties of metals. Special emphasis on the roles of phase transformations, state changes, surface and stress conditions.

**479. Metals and Alloys.** *Prerequisite: Chem.-Met. Eng. 350.* I and II. *(3).*
Structures of metals as affected by composition and thermal and mechanical treatment; their resultant physical properties and behavior in service. Lectures, recitation, and laboratory.

**480. Design of Process Equipment.** *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 342.* I and II. *(3).*
Applications of fluid-flow, heat transfer, mass transfer, stress analysis, and behavior of materials to the design of chemical and petrochemical process equipment for vacuum, low-pressure, high-pressure, and high-temperature services.

**481. Chemical Process Design I.** *Prerequisite: Chem.-Met. Eng. 342.* I and II. *(3).*
Applications of fluid-flow, heat transfer, mass transfer, stress analysis, and behavior of materials to the design of chemical and petrochemical process equipment for vacuum, low-pressure, and high-temperature services.

**482. Chemical Process Design II.** *Prerequisite: Chem.-Met. Eng. 480 or 481 or 489.* I and II. *(1).*
Assigned problem in chemical engineering process design as specified by the instructor, or the annual AIChE Student Contest Problem.

**484. Biochemical Technology.** *Prerequisite: Civ. Eng. 580 and organic chemistry. (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.

**485. Biochemical Engineering Process Design.** *Prerequisite: Chem. 227 and Chem.-Met. Eng. 342 or 448.* II. *(3).*
Selection and design of processes and equipment for the industrial manufacture of biochemicals including foods, pharmaceuticals, and potable water, and for industrial waste treatment. Recitation and calculation periods.

**489. Metallurgical Process Design.** *Prerequisite: Chem.-Met. Eng. 341.* II. *(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.

**500. Advanced Chemical Engineering Calculations.** *Prerequisite: Chem.-Met. Eng. 400 and courses in differential equations and operational mathematics with concurrent registration in latter permitted.* I and II. *(3).*
Calculations on steady- and unsteady-state heat and mass transfer, stagewise operations, fluid mechanics, thermodynamics, chemical reactions, and automatic control systems. Emphasizes formulation and solution of mathematical models that are often similar for different processes.

**501. Numerical Methods in the Solution of Chemical Engineering Problems.** *Prerequisite: a course in computer programming, a course in differential equations, and a course in rate processes.* I. *(3).*
Application of numerical and computer-oriented methods to the correlation of experimental data, and the solution of problems in the fields of flow through porous media and equipment, staged operations, reaction kinetics, and heat transfer.

**510. Electrochemical Operations.** *Prerequisite: Chem.-Met. Eng. 230 and course in physical chemistry.* I or II. *(4).*
Theory and applications of electrochemistry with first half of time devoted to basic principles and last half to research problems and industrial processes. One laboratory per week included.

**521. Petroleum Engineering.** *Prerequisite: Chem.-Met. Eng. 343.* I. *(3).*
Properties of petroleum gases and liquids under pressure, process design in the production and refining of natural gas, crude oil, and other important fossil fuels.

**522. Mechanics of Multiphase Flow.** *Prerequisite: Chem.-Met. Eng. 341 or permission of instructor. (3).*
The fluid mechanics of multiphase flow systems, such as suspensions, fluidized solids, and gas-liquid systems, with emphasis on engineering principles and relation with equipment and surroundings.

**530. Thermodynamics III.** *Prerequisite: Chem.-Met. Eng. 430.* I and II. *(3).*
Statistical and irreversible thermodynamics. Equations of state; modern viewpoints. Applications to chemical engineering processes.

**535. Metallurgical Thermodynamics.** *Prerequisite: a course in physical chemistry, an undergraduate course in thermodynamics, such as Chem.-Met. Eng. 230.* I. *(3).*
Laws of thermodynamics applied to metallurgical systems. Introduction to statistical mechanics.

**536. Metal Reactions in Melting and Refining.** *Prerequisite: Chem. 266, Chem.-Met. Eng. 489.* I. *(4).*
Applied thermodynamics and kinetics of high-temperature melting and refining reactions employed in extractive metallurgical processes. Experiments concerning these reactions. Lecture and laboratory.

**541. Rate Operations I.** *Prerequisite: Chem.-Met. Eng. 342.* I. *(3).*
The first part of a unified study at graduate level of engineering operations described by rate models, including interpretation of rate data and theories and their use in process design. This part of the study stresses heat and momentum transfer.

**542. Rate Operations II.** *Prerequisite: Chem.-Met. Eng. 541.* II. *(3).*
A continuation of Chem.-Met. Eng. 541, with stress on mass transfer and chemical kinetics.

**543. Separations Operations.** *Prerequisite: Chem.-Met. Eng. 541.* II. *(3).*
Design of multicomponent separation systems including adsorption, distillation, extraction, and ion exchange. Emphasis on the concepts of the equilibrium stage and the differential contactor.

**550. Solid-State Kinetics.** *Prerequisite: physical chemistry or a course in solid state.* II. *(3).*
Kinetics and mechanics of reactions involving solids. Solid-state defects and thermodynamics and kinetics of solid-state transformations. Nonstoichiometric compounds, spinels, ceramics. Oxidation, carburization, nitridization of metals and compounds. Lectures and recitations.

**551. Solid-State Chemical Principles of Semiconductors.** *Prerequisite: Chem.-Met. Eng. 400 concurrently and a course in solid-state, or equivalent, or permission of instructor.* II. *(3).*
Structures and properties of semiconductor materials. Quantum concepts, band theory of solids. Mass action, ionization, and kinetics in semiconductors. Diffusion and field equations; p-n junction theory, Zone refining, p-n junction fabrication processes. Surface properties: adsorption and heterogeneous catalysis. Theory and materials for thermoelectric converters.

**560. Electron Microscopy.** *Prerequisite: senior or graduate standing in engineering or science.* I. *(3).*
Theory, techniques, and applications of electron microscopy. Laboratory instruction in the preparation of specimens, operation of the microscope, and interpretation of micrographs. An opportunity will be provided for laboratory work on problems of interest to individual students.

**561. Engineering Experiments and Their Design.** *Prerequisite: senior or graduate standing in engineering or science.* II. *(3).*
The use of statistical methods in analyzing and interpreting experimental data and in planning complex experimental programs. Subjects covered include: probability, distribution functions, theory of sampling techniques and process control, use of the "Chi-Square" and "t" tests in analyzing and comparing data from simple experiments. An introduction to the analysis of variance and the design of complex experiments. Lecture, recitation, and computation.

**563. Chemical Process Control and Dynamics.** *Prerequisite: a course in Laplace transforms, or permission of instructor.* I. *(3).*
The concepts of automatic control and process dynamics are presented and applied to typical processes encountered in chemical engineering practice, such

as the control of temperature, fluid-flow, mass transfer processes, and chemical reaction system.

**570. Theoretical Metallurgy.** *Prerequisite: a course in physical metallurgy.* II. *(3).*
Electron and zone theories of metals. Theories of alloying, nucleation, and growth; theories of imperfections; topology of metallurgical structures; diffusion.

**571. Physical Metallurgy III.** *Prerequisite: Chem.-Met. Eng. 471.* II. *(3).*
Ternary systems, phase transformations, plastic deformation, and fracture. Lecture, recitation, and laboratory.

**572. X-ray Studies of Engineering Materials.** *Prerequisite: Chem.-Met. Eng. 472.* II. *(3).*
Application of X-ray methods to the study of age hardening, cold working, and phase changes.

**573. Corrosion and High Temperature Resistance of Metals.** *Prerequisite: Chem.-Met. Eng. 270 or 479.* I. *(3).*
Fundamentals involved in choosing a metal for use in a corroding medium or at elevated temperatures.

**574. Metals at High Temperatures.** *Prerequisite: Chem.-Met. Eng. 270, 470, or 479.* II. *(3).*
Fundamental principles determining the behavior of metals at high temperatures and the selection and performance of alloys in such applications as jet-propulsion engines, gas turbines, chemical industries, and steam power plants.

**575. Steels.** *Prerequisite: Chem.-Met. Eng. 471 or equivalent.* II. *(3).*
Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steels.

**576. Metals for Process Design.** *Prerequisite: a course in physical chemistry.* II. *(3).*
The structures and properties of solids. Influence of composition, mechanical and thermal treatments on the properties of metals, and their subsequent behavior in service in industry.

**577. Metallurgical Operations.** *Prerequisite: Chem.-Met. Eng. 489.* II. *(3).*
The plastic deformation of metals and alloys. Rolling, forging, extrusion, piercing, and deep drawing.

**579. Nuclear Metallurgy.** *Prerequisite: a course in physical metallurgy.* II. *(3).*
Process, mechanical, and physical metallurgy of metals used in nuclear reactors; uranium, plutonium, and thorium. Radiation damage to solids. Container materials, fuel element design and fabrication, moderator and control elements, liquid metals.

**580(Civ. Eng. 580). Microbiology I.** *Prerequisite: Math. 316, Chem. 225, and senior standing, or permission of instructor.* I. *(3).*
Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

**581. Engineering Process Design.** *Prerequisite: Chem.-Met. Eng. 481.* I and II. *(4).*
Selection and design of processes, equipment, and control systems. Utilization and extension of minimum available information to produce workable systems. Economic studies and comparisons in optimization of systems. This course is recommended as preparation for the preliminary examination.

**582. Process Equipment Design for Advanced Chemical Engineering Students.** *Prerequisite: Chem.-Met. Eng. 343 or equivalent.* I. *(3).*
The design of chemical and petrochemical process equipment involving heat transfer and mass transfer. Process computations, stress considerations, corrosion problems and material selections, fabrication methods, assembly and maintenance problems. Equipment evaluation and estimates. Lectures, designs, and reports.

**583. Process Engineering of Polymer Plants.** *Prerequisite: Chem.-Met. Eng. 343 and 479, or permission of instructor.* II. *(3).*
Processing methods for production of polymers from raw materials. Design of plants for the manufacture of materials such as polyhydrocarbons, cellulose plastics, nylon, and rubbers.

**584(Civ. Eng. 587). Industrial Bacteriology.** *Prerequisite: Chem.-Met. Eng. 580. (3).*
Lectures and demonstrations to illustrate the application of microbiological principles and techniques to industrial processes.

**585. Petrochemical and Refining Studies.** II. *(4).*
Designs and economic studies of selected petrochemical and refining processes.

**586. Nuclear Fuels and Fuel Processing.** II. *(3).*
The processing of ores containing fissionable and fertile materials; the reprocessing of spent fuel systems; aqueous techniques including solvent extraction and ion exchange; pyrometallurgical methods for component separations. Problems arising when handling fissionable and radioactive materials will be treated in connection with student design problems.

**587. Cast Iron and Steel.** *Prerequisite: Chem.-Met. Eng. 270, 470, or 479.* II. *(3).*
Solidification, structures, and properties of cast ferrous metals, influence of composition, section size and other variables on the rate of malleabilization, influence of variables on the properties and structures of gray irons, selection of cast metals for specific purposes.

**589. Cast Metals in Engineering Design.** *Prerequisite: Chem.-Met. Eng. 470, 479, or permission of instructor.* II. *(3).*
An understanding of the properties of the important cast metals is obtained by melting, casting, and testing. In addition to measurement of mechanical properties, resistance to heat, wear, and corrosion is discussed. One lecture and one three-hour laboratory.

**636. Metallic-Ceramic Reactions.** *Prerequisite: physical chemistry and graduate standing.* I. *(3).*
Ceramic solids; metallic and nonmetallic liquid structures; polycomponent equilibria; polycomponent microstructures; high-temperature kinetics. Metallurgical and ceramic applications; melting and refining slags, high-temperature oxidation-reduction reactions, refractories, nonmetallic inclusions, cermets.

**640. Special Topics in Chemical Engineering.** *Prerequisite: Chem.-Met. Eng. 542.* II. *(3).*
Special subjects in chemical engineering fundamentals and applications. Intensive summaries of recent research.

**645. Process Analysis.** *Prerequisite: Chem.-Met. Eng. 400 or equivalent.* II. *(3).*
Problems in the analysis, design, stability and sensitivity, optimization, and transient response of staged, continuous, and batch operations are considered with emphasis on their common mathematical and physical foundations.

**650. High Polymer Processes and Materials.** *Prerequisite: a course in physical and organic chemistry or permission of instructor.* I. *(3).*
Nature and types of polymers and copolymers. Condensation, free radical and ionic polymerization. Stereospecific polymerization. Amorphous and crystalline polymers. Structure and properties of polymeric materials, plastics, fibers, elastomers. Lectures and recitations.

**661. Design of Complex Experiments.** *Prerequisite: Chem.-Met. Eng. 561 or equivalent.* I. *(3).*
Consideration of statistical methods which are useful in designing and analyzing experiments involving several variables.

**690. Research and Special Problems.** I, II, III*a* and III*b*. *(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 staff. Any problem in the field of chemical and metallurgical engineering may be selected; current elections include problems in the following fields: fluid flow, heat transfer, distillation, filtration, catalysis, petroleum, plastics, ferrous metallurgy, metals at high temperature, nonferrous metallurgy, foundry and cast metals, X-ray applications, electrodeposition, and nuclear energy. The student writes a final report on his project.

**691. Engineering Problems.** *Prerequisite: permission of instructor.* I and II. *(To be arranged.)*
A study of contemporary engineering problems and of new areas of engineering exploitation of recent mathematical or scientific advances or breakthroughs.

**692. Practice of Teaching or Research.** I, II, III*a* and III*b*.

**780. Advanced Separations.** *Prerequisite: Chem.-Met. Eng. 543.* I. *(3).*
Advanced study and design of multicomponent and nonideal separations with emphasis on distillation, absorption, and extraction. Equilibrium, rate, and stage.

**801. Seminar in Chemical Engineering Analysis.** *Prerequisite: Chem.-Met. Eng. 500.* I. *(3).*
Modern developments in the analysis and solution of chemical engineering problems.

**830. Seminar in Engineering Thermodynamics.** *Prerequisite: Chem.-Met. Eng. 530.* I. *(3).*
Special topics in thermodynamics of chemical engineering processes. Review of latest developments and current research in thermodynamics. Students select individual problems for intensive study.

**835. Seminar in Metallurgical Thermodynamics.** *Prerequisite: a graduate course in thermodynamics.* II. *(3).*
Selected subjects in thermodynamics. Irreversible thermodynamics, and statistical mechanics applied to metallurgical systems.

**840. Heat Transfer Seminar.** *Prerequisite: Chem.-Met. Eng. 541.* I. *(2).*
Theoretical aspects of heat transfer. Classical and current developments presented by students, staff, and guest lecturers. Term paper on original work.

**841. Mass Transfer Seminar.** *Prerequisite: Chem.-Met. Eng. 542.* I. *(2).*

**845. Seminar in Applied Chemical Kinetics.** *Prerequisite: a course in chemical kinetics.* *(2).*

**870. Physical Metallurgy Seminar.** *Prerequisite: open to persons engaged in doctoral level research.* I. *(2).*
Selected topics in the more advanced fields of physical metallurgy.

**885. Petroleum Seminar.** *Prerequisite: Chem.-Met. Eng. 521 or 585. (2).*
Individual study of advanced topics in production, commercial natural gas, refining and petrochemical processes. Seminar and reports.

**981. Professional Engineering Project.** I and II. *(1).*
The engineering design and economic analysis of a process or research proposal. The project is to represent original, individual work; excellence of reporting is emphasized. If the project is started during a University recess, the course is to be elected in the term in which the report is submitted. Required of all applicants for the doctorate.

**999. Doctoral Dissertation.** I, II, III*a* and III*b*. *(To be arranged).*

## Chemistry*

*Department Office:* 2028 Chemistry Building

Professor Anderson; Professors Brockway, Case, Dunn, Elderfield, Elving, Halford, Nordman, Oncley, Parry, Rulfs, Smith, Stiles, Tamres, Taylor, Vaughan, and Westrum; Associate Professors Gordus and Ireland; Assistant Professors Blinder, Catherino, Cooke, Current, Gendell, Griffin, Lawton, Liu, Longone, Mark, Martin, Mellon, Rasmussen, and Verdieck.

**Laboratory fees** in the range from $8 to $30 must be paid in advance for each course involving laboratory work.

**103. General and Inorganic Chemistry.** I and II. *(4).*
Elementary course for students who have not studied chemistry in high school. Three lectures, two recitations, and one three-hour laboratory.

**104. General and Inorganic Chemistry.** *Prerequisite: one year of high school chemistry.* I and II. *(4).*
Elementary course for students who have studied chemistry in high school. Three lectures, one recitation, and four hours of laboratory.

**105. General Chemistry.** *Prerequisite: Chem. 103 or 104.* II. *(4).*
Continuation of Chem. 103 or 104 for students who are not planning to take further courses in chemistry. Includes all engineering students except those planning to enter the curriculum in chemical, metallurgical, or materials engineering, who should elect Chem. 106. *Chem. 105 with a grade below B will not be accepted as a prerequisite for more advanced courses in chemistry.* Three lectures, one recitation, and three hours of laboratory.

**106. General and Inorganic Chemistry.** *Prerequisite: Chem. 103 or 104.* I and II. *(4).*
Continuation of Chem. 103 or 104 for students planning to take additional work in chemistry. Students in engineering not planning to enter the curriculum in chemical, civil, metallurgical, materials, or science engineering should elect Chem. 105 rather than Chem. 106. In Chem. 103 or 104 and 106 the fundamental principles of chemistry are studied, accompanied by the descriptive chemistry of most nonmetallic elements (Chem. 103 or 104) and of the important metallic elements (Chem. 106). Three lectures, two recitations, and three hours of laboratory.

*College of Literature, Science, and the Arts.

**107. General and Inorganic Chemistry.** *Prerequisite: one year of high school chemistry validated by a satisfactory grade on the placement test given during the orientation period. All other students should elect Chem. 103 or 104 followed by Chem. 105 or 106.* I. *(5).*
Fundamental principles of chemistry and a study of the more important elements and compounds, omitting the common nonmetallic elements. Three lectures, two recitations, and four hours of laboratory.

**191. Inorganic Chemistry and Qualitative Analysis.** *Prerequisite: Chem. 104 with a grade of A or high B.* II. *(5).*
Ionic equilibrium, descriptive chemistry of the metallic elements, qualitative analysis of the metallic ions, and an introduction to thermodynamics. Three lecture-recitation periods and eight hours of laboratory.

**194. Unified Chemistry.** *Prerequisite: Physics 153.* II. *(4).*
The properties of matter discussed from the viewpoint of dynamics; discussions of thermodynamic functions, kinetic theory, and chemical kinetics. Lectures, recitations, and laboratory.

**195. Unified Chemistry.** *Prerequisite: Chem. 194.* I. *(4).*
Properties of matter from the viewpoint of atomic structure, including periodic relationships; organic and inorganic chemistry. Lectures, recitations, and laboratory.

**220. Organic Chemistry.** *Prerequisite: Chem. 106, 107, 191, or 195.* II. *(3).*
A survey of the field of organic chemistry. Will not meet premedical or predental requirements and is not accepted as a prerequisite for any other course in the Chemistry Department except Chem. 227 or 419. Students wishing more organic chemistry will be required to take Chem. 225.

**225. Organic Chemistry.** *Prerequisite: Chem. 106, 107, 191, or 195.* I and II. *(3).*
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 in consecutive semesters.

**226. Organic Chemistry.** *Prerequisite: Chem. 225.* I and II. *(3).*
Aromatic compounds, proteins, and other topics.

**227. Organic Chemistry.** *Prerequisite: Chem. 220 or 225.* I and II. *(2).*
Designed 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.

**265. Principles of Physical Chemistry.** *Prerequisite: Chem. 106 or 107 and preceded or accompanied by Math. 116 or 186 and Physics 145 or 153.* I and II. *(4).*
An introduction to topics such as: kinetic theory of gases and liquids, the first and second laws of thermodynamics, free energy and spontaneity of chemical reactions, and phase equilibrium. Lecture and recitation.

**266. Principles of Physical Chemistry.** *Prerequisite: Chem. 265 and preceded or accompanied by Math. 215 or 285 and Physics 146 or 154.* II. *(4).*
A continuation of Chem. 265 covering topics such as: chemical kinetics, electrochemistry, elementary quantum theory, and atomic and molecular structure Lecture, recitation, and laboratory.

**346. Quantitative Analysis.** *Prerequisite: Chem. 191, 195 or 266.* I and II. *(4).*
A survey of the theory and practice of volumetric, gravimetric, electrometric, and colorimetric analysis. Systematic analysis of complex materials. Two lectures, one recitation, and two four-hour laboratory periods.

**403. Inorganic Chemistry.** *Prerequisite: Chem. 346.* I and II. *(2).*
A systematic survey of the chemistry of the elements from the standpoint of atomic structure, periodic and group relationships.

**425. Qualitative Organic Analysis.** *Prerequisite: Chem. 228 or 295.* I and II. *(3).*
Fundamental organic reactions are studied as a basis for systematic analysis and identification of organic compounds.

**447. Physicochemical Methods in Analytical Chemistry.** *Prerequisite: Chem. 346 and 468.* II. *(4).*
Theory, operation, and applicability of the principal physical and physicochemical approaches used in chemical analysis, including electrical, optical, and radiochemical methods. Lecture, recitation, and laboratory.

**468. Physical Chemistry.** *Prerequisite: Chem. 346, Physics 146, and Math. 214 or 215.* I and II. *(3).*
Nature of the gaseous and liquid states, solution theory, homogeneous and heterogeneous equilibria, thermochemistry and thermodynamics.

**469. Physical Chemistry.** *Prerequisite: Chem. 468.* I and II. *(3).*
Electrochemistry, atomic concepts of matter and energy, molecular and crystal structures, chemical kinetics.

**481. Physicochemical Measurements.** *Prerequisite: Chem. 346 and 468.* I and II. *(2).*
Laboratory work, including determinations of molecular weights, measurements of properties of pure liquids and solutions, and thermochemical measurements. One discussion period dealing with treatment of errors and related topics to be arranged.

**482. Physicochemical Measurements.** *Prerequisite: Chem. 481.* I and II. *(2).*
A continuation of Chem. 481. Homogeneous and heterogeneous equilibria, kinetics, atomic and molecular properties, and electrochemistry. One discussion period to be arranged.

**538. Organic Chemistry of Synthetic Polymers.** *Prerequisite: Chem. 227 or 295.* II. *(2).*
Chemistry of synthetic polymers, including the preparation of the intermediates for resins and rubber substitutes of commerical importance. Two lectures and reading.

**555. Radioisotope Techniques.** *Prerequisite: permission of instructor.* I. *(3).*
Elementary theory of nuclear transitions and of interactions of radiations with matter. Laboratory work (fee) deals with methods of production, manipulation, and detection of radioactive materials.

## Civil Engineering

*Department Office:* 304 West Engineering

**262. Geodetic Engineering I.** *Prerequisite: Math. 116.* I. *(3).*
Basic principles of geodetic measurements as required on important engineering projects; use of theodolite, tilting level, and precise taping procedures; reduc-

tion of observations for calibration and observational procedures; simple positional computations and adjustments; topographic mapping; horizontal and vertical curves, and elementary earthwork computations. One lecture, two laboratory sessions per week.

**263. Geodetic Engineering II.** *Prerequisite: Math. 273, Civ. Eng. 262.* I and II. *(4).*
Principles of geodetic engineering computations; co-ordinates as a computational system; applications of electronic computers; concepts, requirements, and specifications for engineering positional control; least-squares adjustment; elementary photogrammetry; engineering astronomy; electronic distance-measurement; property surveys. Two lectures, two laboratory sessions per week.

**312. Theory of Structures.** *Prerequisite: Eng. Mech. 210.* I, II, and III*a*. *(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; columns; tension members; girders; introduction to design.

**313. Elementary Design of Structures.** *Prerequisite: Civ. Eng. 312.* I and II. *(2).*
Application of fundamental structural theory to design problems in which the properties of the material are important factors. Composition of members, connections, and arrangement of elements into structures are studied on a practical basis.

**350. Concrete Mixtures.** I and II. *(1).*
Theory and design of concrete mixtures; analysis of aggregate grading; bulking due to moisture; strength, permeability, durability, yield, and economy. Discussions, problems, and laboratory.

**363. Basic Surveying.** *Prerequisite: Math. 115 or equivalent.* I and II. *(2).*
For noncivil engineering students or those having permission of program adviser. Care, adjustment, and use of basic surveying instruments; leveling, taping, horizontal angle measurement, traverse surveys; computation, use of calculating machines.

**364. Surveying.** *Prerequisite: Math. 115 or equivalent.* II. *(3).*
Similar to Civ. Eng. 262. Designed for forestry students.

**400. Contracts, Specifications, Professional Conduct, and Engineering-Legal Relationships.** I and II. *(2).*
Legal principles of contracts, torts, and agency; ethics, professional registration and professional conduct; technical specifications; engineering-legal relationships and problems. Lectures, reading, problems, and discussion.

**415. Reinforced Concrete.** *Prerequisite. Civ. Eng. 312.* I, II, and III*a*. *(3).*
Properties of materials; stress analysis and design of reinforced concrete structures; introduction to prestressed concrete and ultimate strength analysis. Lectures, problems, and laboratory.

**420. Hydrology I.** *Prerequisite: preceded or accompanied by Eng. Mech. 324 or permission of instructor.* I and II. *(2).*
The hydrologic cycle and the runoff process; precipitation, its causes, variability, distribution, and frequency; snow melting processes; evaporation, transpiration and other water losses; infiltration; ground water occurrence and movement; normal and low flows; magnitude and frequency of floods; flood routing; selection of storage requirements for water supplies; method of measuring river discharge.

**421. Hydraulics.** *Prerequisite: Eng. Mech. 324, Math. 273.* I and II. *(2).*
Hydrostatic stability; orifices and weirs; Venturi meters; cavitation; pump characteristics; flow in pipes and fittings, unsteady-uniform flow; steady-non-uniform flow. Lecture, laboratory, and computation.

**445. Engineering Properties of Soil.** *Prerequisite: Eng. Mech. 210, preceded or accompanied by Eng. Mech. 324 and Chem.-Met. Eng. 250.* I and II. *(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: Civ. Eng. 263, preceded or accompanied by Civ. Eng. 445.* I and II. *(3).*
Planning, location, and design of inland transportation facilities. Introduction to engineering economy studies.

**480. Water Supply and Treatment.** *Prerequisite: Eng. Mech. 324.* I and II. *(3).*
Sources of water supply, quality and quantity requirements, design fundamentals of works for development, collection, purification, and distribution of water.

**481. Sewerage and Sewage Treatment.** *Prerequisite: Civ. Eng. 480.* I and II. *(2).*
Requirements of residential and municipal sewerage systems, procedures for the design and construction of sewerage and sewage-treatment works.

**483. Water Resources Engineering.** *Prerequisite: Eng. Mech. 324 or permission of instructor.* III*a*. *(3).*
Development of water resources for purposes of supply; hydrologic factors, consideration of multiuse, water-quality parameters, distribution, and treatment.

**484. Wastes Engineering.** *Prerequisite: Eng. Mech. 324 or permission of instructor.* III*b*. *(3).*
Collection, treatment, and disposal of the liquid and solid wastes from urban populations.

**500. Fundamentals of Experimental Research.** I. *(2).*
The scientific method, its elements and procedures. Design of experiments, analysis of data, inferences, and conclusions; preparation for publication. Discussion, problems, and laboratory.

**501. Legal Aspects of Engineering.** I and II. *(3).*
Duty of care, nuisances, injunctions and damages, mines and minerals, carriers and shipping documents, N.L.R.A., F.L.S.A., social security, unemployment compensation, industrial injuries, and garnishment. Cases, lectures, and discussion.

**505. Boundary Surveys.** *Prerequisite: Civ. Eng. 262 or equivalent.* I. *(3).*
Problems relating to the establishment of land boundaries, including study of special legal phases which confront the land surveyor; basic principles of the U.S. Public Land System.

**511. Timber Construction.** *Prerequisite: Civ. Eng. 313.* I. *(1).*
Physical characteristics of structural woods; grading rules; design of timber structures.

**512. Advanced Theory of Structures.** *Prerequisite: Civ. Eng. 312.* I and II. *(3).*
Stresses in subdivided panel trusses; principle of virtual displacements and virtual work; energy theorems; graphical methods; analysis of statically indeterminate trusses and frames.

**513. Design of Structures.** *Prerequisite: Civ. Eng. 313 and 415.* I and II. *(3).*
Design problems and reports pertaining to structural frames, members, and details. Steel, reinforced concrete, and composite construction. Introduction to plastic design. Modern trends in bridge and building construction, specifications, and in the use of constructional materials.

**514. Rigid Frame Structures.** *Prerequisite: preceded or accompanied by Civ. Eng. 415.* I and II. *(3).*
Analysis of rigid frames by methods of successive approximations and slope deflections; special problems in the design of continuous frames.

**515. Prestressed Reinforced Concrete.** *Prerequisite: Civ. Eng. 313 and 415.* I, II, and III*a*. *(2).*
Fundamental principles of prestressing; prestress losses due to shrinkage, elastic action, plastic flow, creep, etc.; stress analysis and design of prestressed concrete structures.

**516. Advanced Design of Structures.** *Prerequisite: Civ. Eng. 513.* I. *(3).*
Functional design of buildings; selection and analysis of structural elements; reinforced concrete flat slab design; digital computer applications. Lectures and computation laboratory.

**517. Bridge Engineering and Design.** *Prerequisite: Civ. Eng. 513 or 573.* II. *(3).*
History of bridges; selection and design of reinforced concrete and steel highway and railway bridge structures based upon the requirements of economics, underclearance, site, foundations, erection, maintenance, aesthetics, safety, and financing. Lectures and computation laboratory.

**520. Hydrology II.** *Prerequisite: Civ. Eng. 420 and 421 or equivalent.* II. *(2).*
Factors affecting runoff; methods of predicting runoff from rainfall; variation of infiltration capacity and surface runoff parameters with seasonal factors and characteristics of the drainage basin; urban runoff; characteristics of aquifers; ground water and well hydraulics.

**522. Hydraulic Transients.** *Prerequisite: Eng. Mech. 324, Math. 273.* II. *(2).*
Introduction to water-power development, including selection of type of turbine; storage and pondage; surge in pipe lines; water hammer analysis; digital programming of unsteady flow situations.

**523. Flow in Open Channels.** *Prerequisite: Civ. Eng. 421 or equivalent.* I and II. *(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. Lectures and demonstrations.

**524. Advanced Hydraulics.** *Prerequisite: Civ. Eng. 421.* I. *(3).*
Two-dimensional potential flow; the flow net; percolation and hydrostatic uplift; side-channel spillways; boundary-layer; hydraulic similitude; hydraulic models; stilling pools.

**526. Hydraulic Engineering Design.** *Prerequisite: Civ. Eng. 415 and 420; preceded or accompanied by Civ. Eng. 523.* 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.

**531. Cost Analysis and Estimating.** I. *(2).*
Open to seniors and graduates. Elements of cost in construction; determination of unit costs; analysis of cost records; estimates of cost; amortization and debt retirement; quantity surveys.

**532. Construction Methods and Equipment.** II. *(3).*
Open to seniors and graduates. Contractors' organizations; plant selection and layout; equipment studies; methods of construction. Seminar. A student may not elect both Civ. Eng. 532 and Civ. Eng. 535 for credit to satisfy a technical option group.

**533. Estimating Practice.** *Prerequisite: preceded or accompanied by Civ. Eng. 531.* I. *(1).*
Laboratory practice in the estimating and pricing of construction work. Quantity surveys, unit costs of labor and material, indirect costs.

**534. Construction Methods and Equipment.** *(2).*
Open to seniors and graduates. Contractors' organizations; plant selection and layout; equipment studies; methods of construction. (Similar to Civ. Eng. 532 but does not include seminar.)

**535. Analysis of Highway Construction Operations.** *Prerequisite: Civ. Eng. 470 and preceded or accompanied by Civ. Eng. 531 or permission of instructor.* I. *(3).*
Highway construction project planning. Analysis of construction methods and equipment productivity. Work organization and cost analysis. For use of students interested in highway construction. A student may not elect both Civ. Eng. 532 and Civ. Eng. 535 for credit to satisfy a technical option group. Lectures, recitation, and problems.

**536. Critical Path Methods in Construction.** II and III*a*. *(3).*
Open to senior and graduate students. Critical path planning and scheduling, CPM and PERT programs, manpower and equipment leveling, minimum cost expediting.

**543. Soils in Highway Engineering.** *Prerequisite: Civ. Eng. 445.* II. *(2).*
Evaluation of soil in highway design and construction; soil surveys and mapping, identification and classification; subgrade bearing capacity, drainage, frost action, soil stabilization and design of flexible and rigid pavements; fills and embankments, swamp construction. Airphoto analysis; typical land forms, drainage patterns, field mapping, and materials surveys.

**544. Airport Design and Construction.** *Prerequisite: Civ. Eng. 445.* I. *(3).*
Selected problems in airport design and construction with emphasis on soil engineering; soil investigation and use of soil surveys in site selection; runway layouts, grading plans, and earthwork estimates; design and surface and subsurface drainage; airport pavement design. Airphoto analysis; typical land forms, drainage patterns, and mapping.

**545. Foundations and Underground Construction.** *Prerequisite: Civ. Eng. 445.* I and II. *(3).*
Soil as an engineering material, measurement of soil resistance in the field and laboratory; bearing capacity for spread footings and mats; friction piles, group capacity, bearing piles and caissons in deep foundations, mass stability, storage capacity, excavations, and large caissons; earth pressure, retaining walls, and tunnels; subsidence and control of damage from subsurface excavation. Lectures, references, and design problems.

**546. Soil Mechanics Laboratory.** *Prerequisite: a course in soil mechanics.* I and II. *(1).*
Laboratory and field practice in soil sampling and testing, analysis and interpretation of test results; mechanical analysis. Atterberg limits, shrinkage and expansion; measurement of physical properties, direct shear, unconfined and triaxial compression and internal stability; compaction characteristics; soil surveys and soil mapping.

**548. Marine Structures and Foundations.** *Prerequisite: Civ. Eng. 445 or permission of instructor.* I and III*a*. *(3).*
Design of piers, wharves, jetties, seawalls, dry docks, and other marine structures. Energy absorbing systems, fenders, and dolphins. Waterfront construction methods including dredging, filling, cofferdams, and water control.

**549. Case Studies in Soil Mechanics Practice.** *Prerequisite: Civ. Eng. 445.* I and II. *(2).*
Review of selected projects in which soil mechanics played a major role; presentation in chronological sequence of soil investigation, design, construction control, contract administration, claims and litigation. Lectures and seminar.

**550. Highway Materials.** *Prerequisite: preceded or accompanied by Civ. Eng. 470.* I. *(3).*
Sources, production, and testing of highway materials; specifications; minor research problems.

**552. Bituminous Materials and Pavements.** *Prerequisite: Civ. Eng. 470.* II. *(2).*
Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods.

**560. Photogrammetry.** *Prerequisite: preparation in trigonometry and physics.* II. *(2).*
Basic theory of photogrammetry, geometry of photogrammetric systems, analytical solutions; application to mapping from aerial photographs.

**561. Geodesy.** *Prerequisite: Civ. Eng. 263.* I. *(3).*
Introduction to geodesy; history, theory, figure of the earth, geographic position, map projections, state plane co-ordinate systems, application to the several branches of surveying. Each student will prepare a term paper on a subject approved by the instructor. Lectures, reference work, and recitation.

**562. Geodetic Field Methods.** *Prerequisite: Civ. Eng. 561 or permission of instructor.* II. *(2).*
Reconnaissance for geodetic triangulation; special observing methods for first-order horizontal and vertical control; Laplace stations and deflection of the vertical; actual observations, reduction, and adjustment of results in an actual field situation. Term paper or project report required of each student.

**563. Adjustment of Geodetic Measurements.** *Prerequisite: Math. 316 and Civ. Eng. 263 or permission of instructor.* I and II. *(2).*
Theory of least squares, applications to the adjustment of geodetic observations; arrangement for solution of complex adjustments on electronic computers; actual solution of selected problems.

**564. Problems in Geodetic Engineering.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Advanced problems in geodetic engineering.

**565. Municipal Surveying.** *Prerequisite: Civ. Eng. 263.* I. *(2).*
Control surveys, methods, and adjustments for use in municipal mapping and administration, surveys for streets, utilities, property lines, tax maps, subdivision control and development.

**570. Highway Traffic.** *Prerequisite: restricted to senior and graduate students. (2).*
Characteristics of highway traffic and driver behavior, traffic control and regulation, highway safety, traffic organization and administration.

**571. Traffic Engineering.** *Prerequisite: Civ. Eng. 470 or permission of instructor.* II. *(3).*
Principles of highway traffic flow, traffic surveys and planning, analysis and presentation of data, traffic design.

**572. Highway Economics.** *Prerequisite: Civ. Eng. 470.* II. *(2).*
Principles of engineering economics applied to highway planning, location, and design; highway finance, taxation, and administration.

**573. Highway Design.** *Prerequisite: Civ. Eng. 470.* I and II. *(3).*
Studies of highway capacity, alignment, profiles, intersections, interchanges, and grade separations.

**574. Railroad Engineering.** *Prerequisite: Civ. Eng. 470.* II. *(3).*
Theory and practice of railroad engineering principles. Stresses in track, performance and durability of track materials, stabilization of ballast and roadway, maintenance of way-work equipment, organization and administration of maintenance operations.

**575. Planning and Geometric Design of Terminal Facilities.** *Prerequisite: Civ. Eng. 470.* II. *(3).*
Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities.

**576. Economics of Railroad Construction and Operation.** *Prerequisite: Civ. Eng. 470.* II. *(2).*
Statistical analysis of operating expenses. Curve, grade, and train resistances, ruling grades, rise and fall, and virtual profiles; line changes, grade reductions, and elimination of grade crossings.

**580(Chem.-Met. Eng. 580). Microbiology I.** *Prerequisite: Math. 316, Chem. 225, and senior standing, or permission of instructor.* I. *(3).*
Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

**581. Applied Chemistry of Water and Waste Water I.** *Prerequisite: Chem. 106 or equivalent.* I. *(3).*
Principles and application of the chemistry of aqueous systems; homogeneous and heterogenous equilibria of chemical systems of import in natural waters and waste waters, and in the treatment thereof; principles and techniques of analytical methods for evaluating the quality of waters and waste waters. Two lecture periods and one laboratory session per week.

**582. Sanitary Engineering Design.** *Prerequisite: Civ. Eng. 415, 480, and 481.* II. *(3).*
Computations and design of processes and typical structures related to water supply, water purification, sewerage, and sewage disposal. Drawing room and visits to plants and work under construction.

**583. Water Purification and Treatment.** *Prerequisite: Civ. Eng. 480 and 581 or permission of instructor.* II. *(3).*
Engineering methods and devices for obtaining and improving the sanitary quality and economic value of municipal water supplies; processes of sedimentation, use of coagulants, filtration, softening, iron removal, sterilization; devices and structures for accomplishing these objectives. Lectures, library reading, and visits to municipal water purification plants.

**584. Waste Water Treatment and Disposal.** *Prerequisite: Civ. Eng. 481 and 581 or permission of instructor.* I. *(3).*
Engineering, public health, legal, and economic problems involved in the design and construction of facilities for the treatment and disposal of sewage and other waste waters. Lectures, library reading, and visits to nearby disposal plants.

**585. Municipal and Industrial Sanitation.** *(3).*
Scientific foundations of public sanitation, in particular relation to closely built-up areas and to industrial environments.

**586. Industrial Waste Treatment.** *Prerequisite: Civ. Eng. 581 and 584 or permission of instructor.* II. *(2).*
Evaluation of the industrial waste problem, the character and quantity of wastes produced, and the application of engineering principles to the satisfactory disposal of these wastes.

**587(Chem.-Met. Eng. 584) Industrial Bacteriology.** *Prerequisite: Civ. Eng. 580 or equivalent.* II. *(3).*
Lectures and demonstrations to illustrate the application of microbiological principles and techniques to industrial processes.

**611. Structural Dynamics.** *(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. Structural Members.** I. *(4).*
Analysis and design of structural members under bending, torsion, and axial load. Beams on elastic foundations, box girders, and curved beams. Buckling of columns and beams. Emphasis on numerical methods.

**613. Structural Plate Analysis.** II. *(2).*
Stress analysis of flat plates loaded either in their plane or in bending. Numerical analysis. Applications to special problems in flat slab construction.

**614. Advanced Problems in Statically Indeterminate Structures.** *Prerequisite: Civ. Eng. 514.* II. *(3).*
Continuous truss bents; hinged and fixed arches; rings; frames with curved members; flexible members including suspension bridges; frames with semirigid connections.

**615. Analysis and Design of Folded Plates, Domes, and Shells.** *Prerequisite: Civ. Eng. 512 and 514 or equivalent.* I. *(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. Plastic Analysis and Design of Frames.** I. *(2).*
Yield, fracture, and fatigue failure of metals. Plate buckling design criteria. Rules of practice for the plastic design of structures. Plastic analysis and design of continuous beams and frames.

**617. Mechanical Methods of Stress Analysis.** *Prerequisite: preceded or accompanied by Civ. Eng. 514.* II. *(1).*
Mechanical analysis of stresses in statically indeterminate structures by means of models. Use of the Begg's appartus in analyzing complicated structures is given particular attention. Students are required to make the models and the necessary observations and calculations.

**618. Computer Analysis of Structures.** *Prerequisite: Civ. Eng. 512 and 514 and Math. 273, or equivalent.* II. *(3).*
The anlysis of beams, frames, trusses, and arches by high-speed digital computer. The general method of influence coefficients; matrix methods, Algorithm development, flow charts, programming. Students will solve a sequence of problems on the high-speed computer in the University Computing Center.

**623. Applied Hydromechanics.** *Prerequisite: Civ. Eng. 523 or equivalent.* I. *(2).*
Problems in laminar flow; viscometry; the mechanics of turbulent flow; sedimentation; waves; high-velocity flow in open channels; variable flow in open channels.

**645. Theoretical Soil Mechanics I.** *Prerequisite: permission of instructor.* I. *(3).*
Stress conditions for failure in soils; arching in soils; earth pressures, retaining walls; anchored bulkheads; bearing capacity; stability of slopes; theories of elastic subgrade reaction.

**646. Theoretical Soil Mechanics II.** *Prerequisite: permission of instructor.* II. *(3).*
Effects of seepage on equilibrium of ideal soils; consolidation; mechanics of drainage; theories of semi-infinite elastic solids; behavior of soils under dynamic loads; vibrations of foundations.

**647. Soil Dynamics Laboratory.** *Prerequisite: permission of instructor.* I and II. *(1).*
Measurements of behavior of soils under static and dynamic loads; triaxial testing; evaluation of wave velocity and damping; vibrations of foundations.

**648. Dynamics of Soils and Foundations.** *Prerequisite: preceded or accompanied by Civ. Eng. 647.* II and III*a*. *(3).*
Strength of soil and stability of slopes under dynamic loading; propagation of energy through soils; protective construction; excavation by explosions; compaction and settlement; vibration of foundations.

**652. Advanced Bituminous Materials and Flexible Pavement Design.** *Prerequisite: Civ. Eng. 552. (To be arranged).*
Conferences and special problems on new developments in bituminous materials, bituminous mixture design, and flexible pavement design for highways and airports. Conferences, assigned reading, laboratory investigations, and reports.

**670. Transportation Planning.** *Prerequisite: Civ. Eng. 570 and 672, or permission of instructor. (3).*
Analysis of supply and demand for transportation services, transport relationships to land use and other elements of regional and urban planning, and planning techniques applied to transportation problems.

**671. Highway Engineering.** *Prerequisite: Civ. Eng. 470.* I. *(2).*
Seminar course dealing with special phases of highway design and construction. Assigned reading and reports.

**672. Transportation.** *Prerequisite: principles of economics.* I. *(3).*
Transportation facilities, services, and policies, with emphasis on comparative performance of the various agencies of transport.

**673. Highway Transport.** II. *(2).*
Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers, management of transportation companies.

**674. Industrial Transport Management.** *Prerequisite: Civ. Eng. 672 or Econ. 433, or permission of instructor. (4).*
Analysis of industrial transportation requirements; classification, rates, and tariffs; management of private transport services; organization of traffic department; regulatory procedures and practices.

**675. Advanced Highway Design.** *Prerequisite: Civ. Eng. 573 or permission of instructor. (3).*
Comparative analysis of alternate locations and designs of urban and rural highways.

**680. Microbiology II.** *Prerequisite: Civ. Eng. 580 or equivalent.* II. *(2).*
Lectures and laboratory dealing with inter-relationships between organisms of sanitary significance such as fungi, algae, protozoa, and higher forms of invertebrates.

**681. Applied Chemistry of Water and Waste Water II.** *Prerequisite: Civ. Eng. 581.* II. *(3).*
Energetics and kinetics of physicochemical phenomena of significance in natural waters and of processes used for treatment of waters and waste waters; processes considered include: aeration, adsorption, coagulation, digestion, disinfection, ion exchange, stabilization. Three lecture periods per week.

**682. Advanced Sanitary Engineering Design.** *Prerequisite: Civ. Eng. 584 and preceded or accompanied by Civ. Eng. 583.* II. *(3).*
Functional design of sanitary engineering structures and typical plant layouts; drafting room and field studies; preparation of design reports.

**685. Special Problems in Sanitary Engineering I.** *(To be arranged).*
Special problems in sanitary engineering offered the first term only. Designed to broaden the graduate student's perspective in one or more special fields.

**686. Special Problems in Sanitary Engineering II.** *(To be arranged).*
Further special problems in sanitary engineering offered the second term only for additional special work in a limited field.

**780. Water Resource Engineering.** II. *(3).*
Conservation and protection of sources of water supply; laws governing appropriation and use of water resources as affecting both quantity and quality; standards of water quality, purposes and results of water purification; legal rights and responsibilities of public water utilities. Text and library reading, lectures, and seminar.

**810. Structural Engineering Seminar.** I and II. *(1).*
Preparation and presentation of reports covering assigned subjects.

**825. Seminar in Hydraulic Engineering.** *Prerequisite: Civ. Eng. 420 and 523. (To be arranged).*
Lectures, assigned reading, and student reports on problems selected from the field of hydraulic engineering.

**880. Sanitary Engineering Seminar.** I and II. *(1).*
Preparation and presentation of reports covering assigned topics.

**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).*
Assigned work on some special problem in the field of hydrology; an enormous amount of data is available for such studies.

**921. Hydraulic Engineering Research.** *Prerequisite: Civ. Eng. 523. (To be arranged).*
Assigned work in hydraulic research; a wide range of matter and method permissible.

**930. Construction Engineering Research.** I and II. *(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.

**960. Geodetic Engineering Research.** *Prerequisite: Civ. Eng. 561. (To be arranged).*
Assigned work in geodetic engineering, or other special field in surveying of interest to the student and approved by the professor of geodetic engineering.

**970. Highway Engineering Research.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Individually assigned work in the field of highway engineering.

**971. Transportation Engineering Research.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Individual research and reports on library, laboratory, or field studies in the areas of transportation and traffic engineering.

**980. Sanitary Engineering Research.** *(To be arranged).*
Assigned work upon some definite problem related to public sanitation; a wide range of both subject matter and method is available, covering field investigations, experiments in the laboratory, searches in the library and among public records, and drafting room designing.

**990. Civil Engineering Research.** I and II. *(To be arranged).*
Assigned work in the field of public utilities or engineering relations and ethics. To obtain credit, a thesis must be prepared which would be acceptable for publication.

**999. Doctoral Thesis.** I, II, III, III*a*, and III*b*. *(To be arranged).*
For doctoral candidates only, under supervision of the individual's doctoral committee.

## Communication Sciences*

*Department Office:* 180 Frieze

Professor Peterson; Professors Burks, Fitts, Garner, Hok, Rapoport, and Thrall; Associate Professors Galler, Holland, and Swain; Assistant Professor Shoup.

The following courses have been developed through the co-operation of the College of Engineering, the Medical School, and the College of Literature, Science, and the Arts.

**400. Foundations of the Communication Sciences.** *Prerequisite: Math. 404 and Physics 146, or permission of instructor.* I. *(3).*
Introduction to the concepts of communication and processing of information by natural and artificial systems.

**410. Communications Electronics.** *Prerequisite: Com. Sci. 400 (may be taken concurrently) and Math. 404, or permission of instructor.* I. *(3).*
Steady-state and transient analysis. Active and passive circuits. Introduction to signal analysis and to stability analysis.

**473. Introduction to Digital Computers.** *Prerequisite: Math. 214 or 216.* I and II. *(3).*
Characteristics and logic of general purpose high-speed digital computers; introduction to logical design. The concepts of algorithm, language, and symbol manipulation as applied to computer instruction. Computational methods for linear systems, differential equations, linear programming, etc.

**510. Signal Theory.** *Prerequisite: Com. Sci. 410 or Elec. Eng. 330, and Com. Sci. 530.* II. *(3).*
Further development of the mathematical tools of signal and system analysis with particular emphasis on random signals. Also the study of communication channels from the information theoretic viewpoint.

**522. Theory of Automata.** *Prerequisite: Com. Sci. 400, Philos. 414, or Math. 481, or permission of instructor.* II. *(3).*
Application of logic to finite computers, Turing machines, probabilistic automata, and self-reproducing systems.

**524. Theory of Adaptive Systems.** *Prerequisite: Com. Sci. 400 or 522 or Elec. Eng. 465, or permission of instructor.* II. *(3).*
The organization, design, and programming of automata which change their structure and behavior in order to adapt to environments containing them.

**530. Introduction to Stochastic Processes and Information Theory.** *Prerequisite: Com. Sci. 400 (may be taken concurrently).* I. *(3).*
Introduction to stochastic processes and information theory with applications to the communication sciences. Topics studied include random variables, sample spaces, measures and distributions, conditional probabilities, Baye's theorem, sampling theorems, coding theorems, and capacity theorems.

* College of Literature, Science, and the Arts.

**541. Theory of Natural Language Structure.** *Prerequisite: Com. Sci. 400 and 410, or permission of instructor.* II. *(3).*
Introduction to physiological and acoustic phonetics and to mathematical methods in the structural description of natural language.

**542. Mathematical Linguistics.** *Prerequisite: Com. Sci. 400, and Math. 425 or 465.* II. *(3).*
The statistical properties of linguistic units; lexicostatistics. Finite-state and nonfinite-state languages; algebraic models of natural languages.

**546. Experimental Studies in Phonology.** *Prerequisite: Engl. 414 or Com. Sci. 541, or permission of instructor.* I. *(3).*
The application of instrumental and experimental techniques to the study of the linguistic structure of speech; the relation between phonological units and experimental measurements. Lecture and laboratory.

**550. Informational Processes in Behavorial Systems.** *Prerequisite: Com. Sci. 410, or permission of the instructor.* I. *(3).*
A survey of behavioral concepts and principles, with special emphasis on those relevant to adaptive systems.

**560. Theory of Coding I.** *Prerequisite: Com. Sci. 400 or Elec. Eng. 465.* I. *(3).*
Finite coding theory for error checking and secrecy; linear codes, error correction capabilities of linear codes, burst error correction and codes for the checking of arithmetic, linear switching circuits, cyclic codes. Bose-Chaudhuri codes.

**573. Automatic Programming.** *Prerequisite: Math. 473.* II. *(3).*
Topics in automatic programming of digital computers, including the structure of compilers and assemblers, use of executive systems, list storage, threaded lists, and automatic programming language.

**580. Informational Aspects of Biochemistry and Physiology.** *Prerequisite: Com. Sci. 400.* II. *(3).*
A survey of the role of information and control processes in biochemical and physiological systems.

**582. Biological Sensory Systems.** *Prerequisite: Com. Sci. 580 (may be taken concurrently), or permission of instructor. (3).*
Information processing in biological sensory systems, especially the eye and the ear. Perception, encoding, and transmission by the end organs; analysis of sensory inputs by the central nervous systems.

**622. Algebraic Theory of Automata.** *Prerequisite: Com. Sci. 522, or Elec. Eng. 467, and Math. 517, or permission of instructor.* II. *(3).*
The emphasis is placed on the use of algebraic techniques in the study of the relation between structure and behavior. Material covered will include decomposition of sequential machines, probabilistic automata, and various special automata. The course will also treat certain topics such as the relation of automata theory to coding theory and to mathematical linguistics.

**624. Theory of Adaptive Systems.** *Prerequisite: Com. Sci. 524, or permission of instructor.* I. *(3)*
Presents a unified theory of the adaptive systems discussed in Communication Sciences 524.

**644. Theories of Grammar.** *Prerequisite: Com. Sci. 541.* I. *(3).*
A study of the major theories of grammar of natural language.

**646. Acoustical Theory of Speech Communication.** *Prerequisite: Com. Sci. 546. (3).*
An analysis of the research literature on the acoustical theory of speech. The study of instrumental and experimental techniques in speech analysis.

**648. Automation of Natural Languages.** *Prerequisite: Com. Sci. 541. (3).*
Automatic speech recognition, speech synthesis, and machine translation of languages. The basic theoretical problems involved, current research literature, and current instrumental techniques in the field are studied.

**660. Theory of Coding II.** *Prerequisite: Com. Sci. 560.* II. *(3).*
Continuation of Com. Sci. 560.

**802. Interdisciplinary Seminary in Communication Sciences I.** *Prerequisite: permission of instructor.* I. *(3).*
Integration of information essential to communication sciences, and the study of theoretical formulations and experimental research in the communication sciences.

**803. Interdisciplinary Seminar in Communication Sciences II.** *Prerequisite: Com. Sci. 802.* II. *(3).*
Continuation of Com. Sci. 802.

**804. Seminar in Automata Theory.** *Prerequisite: Com. Sci. 522 or permission of instructor.* I. *(3).*

**805. Seminar in Adaptive Systems Theory.** *Prerequisite: Com. Sci. 524.* I. *(3).*

**900. Advanced Studies in the Communication Sciences.** *Prerequisite: permission of instructor.* I and II. *(1-6).*
Individual study and research.

## Economics*

*Department Office:* 105 Economics Building

Professor Smith; Professors Ackley, Bornstein, Boulding, Brazer, Eckstein, Ford, Fusfeld, Haber, Katona, Koo, Lansing, Levinson, Morgan, Mueller, Palmer, Peterson, Smith, Stolper, and Suits; Associate Professors G. Anderson, W. Anderson, Porter, and Stern; Assistant Professors Babcock, Barlow, Chao, Hymans, Morss, Parker, Shapiro, Shepherd, Teigen, and Tilly.

Econ. 203 and 204 are introductory courses designed especially for students in the College of Engineering and are the usual prerequisite to the election by engineering students of the more advanced courses in the Department of Economics listed below. For further details with respect to these courses and for additional courses in the field of economics, consult the *Announcement* of the College of Literature, Science, and the Arts.
*Students who elect any course without first completing the necessary prerequisites will be denied credit in that course.*

**203, 204. General Economics.** *Prerequisite: Econ. 203 is prerequisite to Econ. 204.* 203, I and II; 204, I and II. *(3 each).*
For students in the Colleges of Engineering and of Architecture and Design and other professional schools and colleges. Not open to freshmen. General survey of economic principles and problems, with primary emphasis on the latter in Econ. 204.

* College of Literature, Science, and the Arts.

**271, 272. Accounting.** *Prerequisite: Econ. 271 is prerequisite to Econ. 272. Not open to freshmen.* 271, I and II, *(3)*; 272, I and II. *(4)*.
Concepts and procedure of accounting from the standpoint of investors and business management.

**401. Modern Economic Society.** I and II. *(3)*.
For juniors, seniors, and graduates who have had no course in economics and who desire one term of work in the subject. May be used as prerequisite for advanced courses with permission of course instructor. Economic principles and their application to questions of public policy.

**411, 412. Money and Banking.** *Prerequisite: Econ. 203 and 204. Econ. 411 is prerequisite to Econ. 412.* 411, I; 412, II. *(3 each)*.
Nature and function of money and banking and contemporary monetary problems.

**421, 422. Labor.** *Prerequisite: Econ. 203 and 204.* 421, I and II; 422, I and II. *(3 each)*.
Econ. 421 considers the labor force, its employment and unemployment, wages, hours, social security, and an introduction to trade unions. Econ. 422 deals with union history, union structure and organization, the development of collective bargaining, labor disputes, labor law, and the significant issues in labor relations.

**423. Social Security.** *Prerequisite: Econ. 421 or permission of instructor.* I. *(3)*.
Application of the principles of social insurance to the problems of economic insecurity; unemployment compensation, old-age and survivors insurance, and health insurance; federal and state legislation and current proposals.

**431. Corporations.** *Prerequisite: Econ. 203 and 204.* I. *(3)*.
Large enterprises and especially the corporate form of organization and corporation financing, with emphasis on the public interest therein and on government policies.

**433. Transportation.** *Prerequisite: Econ. 203 and 204.* II. *(3)*.
An economic analysis of the transportation industries and the application of this analysis to public policy problems.

**434. Public Utilities.** *Prerequisite: Econ. 203 and 204.* II. *(3)*.
Nature and problems of the public utility industries from the standpoint of government regulation.

**457. Comparative Economic Systems.** *Prerequisite: Econ. 203 and 204.* I. *(3)*.
Theories of capitalism and socialism and of market and planned economies, and their application in selected countries, including the United States, the Soviet Union, and others.

**473. Fundamentals of Accounting.** *Not open to students who have had Econ. 271.* I and II. *(3)*.
A survey course for those not planning further work in accounting.

**475. Economic Statistics.** *Prerequisite: Econ. 203 and 204.* I and II. *(3)*.
Introduction to the principal methods of statistical analysis as applied to economic problems.

**481. Public Finance.** *Prerequisite: Econ. 203 and 204.* I. *(3)*.
Principles and problems of government finance—federal, state, and local.

## Electrical Engineering

*Department Office:* 2500 East Engineering

**210. Circuits I.** *Prerequisite: Math. 116. (4).*
Direct-current and alternating-current circuits. Kirchoff's laws, loop and node equations, network theorems. Alternating-current wave forms, effective and aver age values, instantaneous and average power. Single-phase circuits, resonance, complex operator, polyphase circuits, ideal transformers. Two lectures, one three hour computing period, and one three-hour laboratory.

**215. Network Analysis.** *Prerequisite: preceded or accompanied by Math 316. (3).*
Analysis of resistive, inductive, and capacitive circuits, direct current, transient and sinusoidal steady-state solution. Phasor and complex number analysis techniques. Superposition and reciprocity; mesh and nodal analysis; Thevenin's and Norton's theorems; maximum power transfer. Coupled circuits and transformers; polyphase systems. Transmission lines.

**220. Electromagnetic Field Theory I.** *Prerequisite: Physics 146 and preceded or accompanied by Math. 316. (3).*
The physical and mathematical treatment of forces and energy in electrostatic fields, the capacitance and inductance of systems of conductors; the concept of polarization and magnetization; relative permittivity and permeability; Faraday's Law of Induction, Ampere's Law, and applications to simple conduction systems; Maxwell's Equations.

**301. Introduction to Systems Engineering.** *Prerequisite: preceded or accompanied by Elec. Eng. 330 or permission of instructor. (2).*
Topics in systems engineering with emphasis on generalized cost functions (dollar economics, energy availability, military values, signal perceptibility, etc.): selected applications in communication systems, electric power systems, radar systems, etc., utilizing where applicable linear analysis, probability, noise theory, computer techniques, and decision principles. Surveys of professional engineering practice with guest lecturers.

**310. Circuits II.** *Prerequisite: Elec. Eng. 210. (4).*
Writing circuit equations; node and loop methods; transient and steady-state response; Fourier series analysis; Fourier integral; transients by Laplace methods; complex frequency; poles and zeroes; admittance and impedance; network theorems; graphical analysis methods; energy and power effects; polyphase circuits; electromechanical systems.

**316. Circuit Analysis and Electronics.** *Prerequisite: Math. 316 and Physics 146. (4).*
A comprehensive treatment of linear and nonlinear (electronic) circuit theory expressly developed to satisfy the requirements of nonelectrical engineering students. Laboratory experiments demonstrate and corroborate the theory developed in the class. Lectures and laboratory. Not open to electrical engineering or science engineering students.

**320. Electromagnetics and Energy Conversion.** *Prerequisite: preceded by Elec. Eng. 215, Physics 154, and Math. 316. (4).*
Discussion of the physical quantities, electrical charge, and current. Analysis of phenomena dependent on these quantities in terms of the field concept. Electric and magnetic forces; introduction to electric and magnetic properties or materials, definition of circuit elements, transient and nonlinear phenomena; magnetic circuits and principles of energy conversion. Three lectures and one three-hour laboratory.

**330. Electronics and Communications I.** *Prerequisite: Elec. Eng. 310 and 380 or Physics 455. (4).*
Circuit models of electronic devices; linear and nonlinear analysis of basic electronic circuits; rectification, amplification, modulation, and oscillation; circuit and device noise analysis. Lectures and laboratory.

**337. Electronic Circuits and Systems.** *Prerequisite: Elec. Eng. 320. (4).*
Introduction to electronic systems, block diagrams with identification of components. Analysis and design of rectifiers, amplifiers, waveform generators, and pulse circuits. Design and application of modulation and detection systems. Study of closed-loop systems including transient and steady-state response. Discussion of electronic equipment and systems, computers, control systems, and special instruments and devices. Lectures and laboratory.

**343. Energy Conversion and Control I.** *Prerequisite: Elec. Eng. 220 and 310, and Math. 404 or 450. (3).*
A unified and integrated treatment of the basic principles governing the dynamic behavior of physical components and systems. Introduction to Lagrange's equations, Hamiltonian functions, and Legendre transformations. Applications to elementary electromechanical, hydraulic, photo-electric, thermalelectric elements.

**360. Electrical Measurements.** *Prerequisite: preceded or accompanied by Elec. Eng. 310. (3).*
Methods of measuring current, resistance, electromotive force, capacitance, inductance, and hysteresis of iron, and the calibration of the instruments employed. Two lectures and one three-hour laboratory.

**376. Electric Lighting and Distribution.** *Prerequisite: Math. 107. (2).*
For students of architecture particularly; students of electrical engineering cannot receive credit for this course.

**380. Physical Electronics.** *Prerequisite: Elec. Eng. 210 or 316, 220, preceded or accompanied by Mech. Eng. 331. (3).*
Electron ballistics; physical principles of vacuum tubes; quantum concepts; energy levels in atoms; electronic phenomena in metals; thermionic emission; gaseous conduction phenomena; gas tubes; physical properties of semiconductors; junction theory and applications; transistor properties and characteristics. Lectures.

**381. Physical Electronics Laboratory.** *Prerequisite: preceded or accompanied by Elec. Eng. 380. (1).*
Measurement of electron trajectories in electric and magnetic fields; electron beam focusing; thermionic and photoemission; vacuum tube characteristics; plasma characteristics; conductivity, mobility, lifetime and diffusion in semiconductors; junction characteristics; transistor characteristics. One lecture and one three-hour laboratory.

**410. Circuits III.** *Prerequisite: Elec. Eng. 310. (3).*
Analysis of distributed parameter systems; transmission of electromagnetic waves in lines and waveguides; reflections; measurements; equivalent circuits; image-wave filter analysis.

**415. Network Analysis and Synthesis.** *Prerequisite: Elec. Eng. 310. (2).*
Matrix analysis of multiterminal networks; network function properties; two-port networks; synthesis of driving-point and transfer functions; cascaded net works; image filter synthesis.

**419. Transistor Circuits.** *Prerequisite: Elec. Eng. 316 or equivalent. (2).*
Not open to electrical engineering students. Basic semiconductor principles and transistor characteristics; the properties of small signal transistor amplifiers; bias considerations and temperature effects; power amplifiers, oscillators, and other circuits employing transistors; noise in transistors.

**420. Electromagnetic Field Theory II.** *Prerequisite: Elec. Eng. 220 and Math. 404 or 450. (3).*
Review of electrostatics and magnetostatics using vector calculus, solution of Laplace's and Poisson's equations in several co-ordinate systems; Maxwell's Equations, wave propagation, retarded potentials, reflection and refraction of electromagnetic radiation; applications to elementary radiating systems. Antennas.

**430. Electronics and Communications II.** *Prerequisite: Math. 404 or 450 and Elec. Eng. 330. (3 or 4).*
Basic concepts of information theory; signal transmission through electric networks; amplitude, frequency, and pulse modulation with system concepts; noise in electronic devices and circuits; statistical methods in analyzing information transmission systems. Three credit hours without laboratory.

**433. Electroacoustics and Ultrasonics.** *Prerequisite: Math. 404 or 450 and Elec. Eng. 310, or permission of instructor. (3).*
Derivation of the equations for propagation of sound; electromechanical and electroacoustical systems in terms of equivalent electrical networks; loudspeakers and microphones; acoustic instrumentation and measurements. Lectures and laboratory.

**434. Architectural Acoustics.** *Prerequisite: Math. 116 or permission of instructor. (2).*
The application of acoustics to architectural problems. Acoustical terminology and the properties of sound waves. Sound absorptive materials, noise control in relation to architecture, and the acoustics of rooms and buildings.

**438. Electronics and Radio Communications.** *Prerequisite: Elec. Eng. 310 or 316 or permission of instructor. (4).*
Electron tubes and semiconductors as circuit elements; network theory including these elements; amplifiers, radio-frequency circuits. Amplitude, frequency and pulse modulation, frequency spectra. Radio receivers and transmitters, noise in communication circuits. Not open to electrical engineering students. Lectures and laboratory.

**442. Automatic Control, Electronics and Electromechanical Energy Conversion.** *Prerequisite: Elec. Eng. 316. (4).*
Principles of automatic control, stability, steady-state and transient response; analysis of electronic systems; electromechanical energy conversion, alternating-current and direct-current machine applications; control-system design; three lectures and one four-hour laboratory. Not open to electrical engineering students.

**444. Energy Conversion and Control II.** *Prerequisite: Elec. Eng. 343 or permission of instructor. (4).*
Utilization of Lagrange's equations, Legendre transformations, and energy conversion principles in a unified and integrated treatment of transformers, d-c and a-c machines, direct energy converters. Introduction to feedback control system concepts including stability, transfer functions, frequency response functions and state variables. Lectures and laboratory.

**465. Electronic Computers I.** *Prerequisite: Math. 404 or 450, preceded or accompanied by Math. 273. (4).*
Introduction to the design and engineering application of digital computers, differential analyzers, and digital-differential analyzers. Treats computer organization and languages; system modeling and simulation; elementary numerical analysis; application of computers to engineering problems. Lectures and laboratory.

**466. Digital-Computer Engineering Laboratory.** *Prerequisite: Elec. Eng. 465 or permission of instructor. (2).*
Study of logic circuits and electronic circuits of digital-computer systems. Laboratory projects are carried out on the MIC (Michigan Instructional Computer) to investigate circuits for arithmetic, control, and storage. Lecture and laboratory.

**467. Switching Circuits and Logical Design.** *Prerequisite: junior standing in engineering. (3).*
Introduction to methods of designing and minimizing networks of switching elements, such as relays, magnetic cores, transistors, or other computer elements. Use of switching algebra and graphical techniques for the logical design of combinational and sequential switching circuits.

**470. Fundamentals of Electrical Design.** *Prerequisite: Elec. Eng. 210 and 220. (4).*
Design problems from various types of apparatus involving the electric and magnetic circuits; field mapping, heat-transfer and temperature-rise work. Three lectures and one four-hour computing period.

**473. 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.

**475. Optics of Coherent and Noncoherent Electromagnetic Radiations.** *Prerequisite: preceded or accompanied by Math. 450 and Elec. Eng. 420 or permission of instructor. (3).*
Review of the properties of light and of basic geometrical and physical optics; operational Fourier-transform and matrix treatment of optical image-forming processes, diffraction, spectroscopy and communications; optical filtering and computing; relativistic, statistical, and coherence properties of light; coherent light generation, amplification and control with optical masers; wave-propagation, frequency multiplication, and shifts in nonlinear media. Similarities and relations with microwave and electronic systems techniques.

**480. Microwave and Quantum Electronic Devices.** *Prerequisite: Elec. Eng. 380, 420 or 410. (3).*
Transit time effects: induced currents; velocity modulation and electron bunching theory; space-charge waves on electron beams; slow-waves on propagating circuits; introduction to coupled modes; space-charge and circuit wave coupling; application to microwave amplifiers and oscillators; the maser principle; energy level population distribution and inversion; solid state and gaseous lasers. Lectures and demonstrations.

**499. Directed Research Problems.** *Prerequisite: Elec. Eng. 210. (To be arranged).*
Special problems are selected for laboratory or library investigation with the

intent of developing initiative and resourcefulness. The work differs from that offered in Elec. Eng. 699 in that the instructor is in close touch with the work of the student. Elec. Eng. 699 is for graduates.

**510. Transients.** *Prerequisite: Elec. Eng. 310. (2).*
Advanced theory of electrical circuits; Laplace transform method of solution for transients in circuits with lumped constants; introduction to the complex frequency domain.

**515. Network Synthesis I.** *Prerequisite: Elec. Eng. 415 or 510, or permission of instructor. (3).*
Energy relations in passive networks; complex variable theory; realizability and synthesis of driving-point impedance and transfer functions.

**523. Application of Acoustics to Engineering Problems.** *Prerequisite: Elec. Eng. 433 or senior standing with permission of instructor. (2).*
Fundamental and practical acoustics involved in product design, development, and quality-control. Acoustic fields source and boundary characteristics, applications to anechoic and reverberant chambers. Types of acoustic measurements possible, valid deductions about noise sources from practical measurements. Maintenance of acoustic calibrations and acoustic criteria. Lectures and demonstrations.

**526. Electric and Magnetic Properties of Solids I.** *Prerequisite: Elec. Eng. 420 or permission of instructor. (3).*
The role of solids in determining the electric and magnetic parameters both of circuit elements and of wave propagation; thermodynamics of electric and magnetic processes; thermoelectric transport equations; development of Schroedinger's Equation and its application to the hydrogen atom, the periodic table; binding and conduction processes in solids.

**530. Microwaves I.** *Prerequisite: Elec. Eng. 410 and 420. (4).*
Theory and practice of microwave techniques; microwave generation, detection, and measurement; electromagnetic waves; wave guides and cavity resonance phenomena; special circuits. Lectures and laboratory.

**531. Radiation, Propagation, and Antennas.** *Prerequisite: Elec. Eng. 330, 410, and 420. (3).*
Fundamental theory; linear antennas and arrays in free space and in proximity to the earth; effective aperture and gain; basic transmission loss; ground-wave propagation; the ionosphere and sky-wave propagation; tropospheric progagation; ionosphere and tropospheric scatter.

**533. Pulse Circuits.** *Prerequisite: Elec. Eng. 330. (3).*
Waveform generation multivibrators, sawtooth generators, ringing oscillators, regenerative circuits, pulse-forming lines; pulse amplifier design; overshoot, sag, and applied transient analysis of linear amplifiers; use of maximally flat, linear phase, equal ripple, and other amplifier functions. Lectures and demonstrations.

**534. Noise in Electronic Circuits and Devices.** *Prerequisite: Elec. Eng. 310, Math. 404 or 450, and preceded or accompanied by Math. 552, or permission of instructor. (3).*
Probability and random processes; extension of Fourier analysis; sampling in the time domain; entropy of a random process; properties of a noise process; response of linear and nonlinear circuits to noise; noise factor; sources of noise in electronic circuits and devices.

**535(Astron. 535). Astronomical Radiophysics.** *Prerequisite: Elec. Eng. 420 or permission of instructor.* II. *(3).*
Review of electromagnetic theory. Propagation of radio waves through ionized media. Radiation by elementary dipoles and accelerated charges; emission and absorption in ionized media including thermal, Cerenkov, and synchroton mechanisms. The emphasis is on astronomical rather than engineering applications.

**536(Astron. 536). Introduction to Radio Astronomy.** *Prerequisite: Elec. Eng. 535 or permission of instructor.* I. *(3).*
The fundamental definitions and basic concepts necessary for a study of space and ground-based radio astronomy. The basic observational techniques, radiometer system designs, antenna problems, and data analysis methods. The observational results and the theory of radio emission from celestial bodies will be treated.

**539. Electronic Circuit Design.** *Prerequisite: Math. 404 or 450, Elec. Eng. 330, or permission of the instructor.* II. *(3).*
Topics to be drawn from the areas of: low noise circuits, oscillator design, parametric amplifiers and converters, tunnel diode circuits, integrated circuits, feedback amplifiers, modulation circuits, active circuit synthesis. Two lectures and one laboratory period a week.

**541. Alternating-Current Apparatus.** *Prerequisite: Elec. Eng. 444. (3).*
Advanced treatment of coupled circuits as applied to transformers and the induction machine. Generalized four terminal network theory and generalized circle diagrams. Space m.m.f. harmonics, rotating m.m.f. components, and harmonic iron losses of polyphase and single-phase windings.

**542. Synchronous Machinery.** *Prerequisite: Elec. Eng. 444. (2).*
M.m.f. and flux distribution in the air gap and voltage wave shapes of non-salient and salient pole machines. Direct and quadrature reactances under steady-state and transient conditions.

**545. Linear Control-System Theory.** *Prerequisite: Math. 404 or 450 and Elec. Eng. 444 or permission of instructor. (2).*
A theoretical study of feedback control systems; transfer function analysis; stability considerations; system sensitivities; root locus and frequency response techniques; introduction to discrete-time systems.

**547. Synthesis Problems in Control Systems Engineering.** *Prerequisite: Elec. Eng. 545 or Instr. Eng. 570, or permission of instructor. (3).*
A detailed study of typical complex control systems, utilizing linear control theory; major component choices, performance criteria, system compensation; examples taken from aero space systems, machine tool control systems, process control systems. Inspection trips planned to neighboring industries to inspect systems studied in class.

**548. Control Systems Engineering Computing Laboratory.** *Prerequisite: Elec. Eng. 545 or permission of instructor. (1).*
Project laboratory experiments on typical elementary control systems; control system design studies utilizing the electronic differential analyzer as a control system design tool.

**549. Foundations of Control Systems Engineering.** *Prerequisite: Elec. Eng. 301, 545, or permission of instructor.* II. *(3).*
An introduction to the analysis of dynamic control systems utilizing the con-

cepts of sets, function spaces, and linear operators to analyze continuous, discrete, and distributive control systems. Emphasis is placed on state-space concepts including transition matrices, canonical system forms, and mode analysis.

**552. Electric Rates and Cost Analysis.** *Prerequisite: permission of instructor. (1).*
Capitalization; fair return on investments; analysis of costs and value of electrical energy; customer charge, demand charges, energy charges; investigations of practical systems used in charging for electrical energy.

**553. Power Transmission Lines and Load Flow.** *Prerequisite: Elec. Eng. 410. (3).*
Symmetrical components; representation of power systems; resistance, inductance, and capacitance of transmission lines. Current and voltage relations of transmission lines; network equations and solutions; load flow studies. Solution of problems on transmission line inductance and on load flow on the analog and the digital computer.

**554. Load Flow and Economic Operation of Power Systems.** *Prerequisite: Elec. Eng. 410. (3).*
Load flow studies; skin effect; generalized circuit constants; circle diagrams. Economic operation of power systems; driving point and transfer impedances. Solution of load flow, economic operation, and driving point and transfer impedance problems on the analog and digital computer.

**555. Integrated Power System.** *Prerequisite: Elec. Eng. 410. (3).*
Symmetrical and unsymmetrical faults; steady state and transient stability; economic control of integrated systems; solution of problems in each of the above topics on the digital computer.

**557. Power System Protection.** *Prerequisite: permission of instructor. (2).*
Theory of overcurrent, differential, distance, pilot wire and carrier current relaying systems and their application for the protection of power systems. System grounding and the ground fault neutralizer.

**558. Power System Transients.** *Prerequisite: permission of instructor. (2).*
Lightning and its effects on a power system. Insulation and design for integrated protection. Transients due to lightning and system switching. Attenuation and reflection of traveling waves. Ground wires, counterpoise, and application of lightning arresters.

**559. Power Systems Laboratory.** *Prerequisite: permission of instructor. (1-3).*
Facilities available for laboratory studies in power systems. Graduate students electing this course, while working under the general supervision of a member of the staff, are expected to plan and carry out the work themselves and to make reports in the form of theses.

**560(Com. Sci. 560). Theory of Coding I.** *Prerequisite: Elec. Eng. 465 or Com. Sci. 400.* II. *(3).*
Finite coding theory for error checking and secrecy; linear codes, error correction capabilities of linear codes, burst error correction and codes for the checking of arithmetic, linear-switching circuits; cyclic codes. Bose-Chaudhuri Codes.

**565. Electronic Computers II.** *Prerequisite: Elec. Eng. 465 or permission of instructor. (3).*
Logical structure of computers; methods of problem preparation and scope of problems; study of computer components such as integrating amplifiers, magnetic and electrostatic storage elements, input and output devices. Lectures, laboratory work on department computers, and demonstrations of University computing facilities.

**575. Seminar in Optics of Coherent and Noncoherent Electromagnetic Radiations.** *Prerequisite: Elec. Eng. 475 or permission of instructor.* II. *(3).*
Special topics of current research interest in the field of electro-optical sciences.

**577. Interior Illumination, Study of Design.** *Prerequisite: Elec. Eng. 475 or equivalent. (2).*
Unusual as well as typical designs of lighting, particularly those which have been actually built and are available for testing as a check upon the calculations, are analyzed quantitatively and qualitatively.

**580. Physical Processes in Plasmas.** *Prerequisite: Elec. Eng. 480 or permission of instructor. (3)* without a laboratory by permission of instructor; *(4)* with a laboratory. *(3 or 4).*
Collision theory; Liouville theorem; development of Boltzmann equation; diffusion and mobility in a plasma; conductivity tensor of an ionized plasma; Langmuir probes; hydromagnetic equations; introduction to wave phenomena in solid state and gaseous plasmas; microwave determination of plasma density and temperature. Lectures and laboratory.

**588. Theory of Solid-State Electronic Devices.** *Prerequisite: Elec. Eng. 380 and Math. 404 or 450. (3).*
Structure of solids, metals, ionic crystals, and valence crystals. Band theory of solids. Electron energy distribution; Fermi level, mean-free time, life and mobility of holes and electrons. Junctions; rectifiers, thermistors, transistors, and photoconductive cells. Ferromagnetism, ferroelectricity, and piezoelectricity. Domain structure; reversible and irreversible movements of domain walls. Metals, alloys, ferrospinels, barium titanate.

**592. Vacuum and Material Techniques.** *Prerequisite: Elec. Eng. 380. (2).*
Vacuum systems including mechanical pumps, diffusion pumps and ion pumping systems; theory of vacuums, gauges and metering systems; physical and electrical properties of materials used in electron and solid-state devices; thin film preparation and measurements; evaporation and electron beam bombardment techniques; heliarc welding; crystal growing; glass properties and working. Lectures and demonstrations.

**595(Meteor.-Ocean. 595). Topics in Space Research.** *Prerequisite: permission of instructor. (3).*
Significant processes in the ionosphere and upper atmosphere (e.g. ionization, dissociation, diffusion, etc.). Solar electromagnetic and corpuscular radiation; formation of the ionosphere; heating mechanisms in the upper atmosphere. Trapped particles; interplanetary plasma; atmospheres of the planets. Measurement techniques and results of recent sounding rocket and satellite experiments.

**615. Network Synthesis II.** *Prerequisite: Elec. Eng. 515. (3).*
Synthesis for prescribed transfer functions; the approximation problem; synthesis for a prescribed time response; application to engineering problems.

**617. Network Analysis.** *Prerequisite: Elec. Eng. 510 or 515, or permission of instructor. (3).*
Stability theory and feedback amplifier design, and selected topics from the following: Hilbert transforms, band-pass analysis, Z-transforms, correlation and spectral analysis, and radar and communication-systems analysis by circuit theory concepts.

**620. Electromagnetic Field Theory III.** *Prerequisite: Elec. Eng. 420 and Math. 450. (3).*
Review of electrostatics from an advanced viewpoint; multipole fields, Green's

functions, electric and magnetic energies, volume forces, and stress tensors in material media; Maxwell's Equations, inhomogeneous vector-wave equation. Hansen's Method, Hertz potentials, radiation and scattering. Fields of point charges in uniform motion and accelerated charges.

**626. Electric and Magnetic Properties of Solids II.** *Prerequisite: Elec. Eng. 526 or permission of instructor. (3).*
Electronic processes within periodic potential fields. The origin and frequency dependence of permittivity and permeability. Metallic conduction, superconductivity and superconductive devices. Ferromagnetism and microwave ferrimagnetic devices.

**630. Microwaves II.** *Prerequisite: Elec. Eng. 530 or permission of instructor. (3).*
General field theory for wave guides; the impedance concept and the application of network theory to microwave structures, general network theorems; analytical methods for determining equivalent circuits for microwave structures, the integral equation formulation. Green's function, variational techniques, and applications to typical boundary value problems; propagation in anisotropic media, nonreciprocal devices; the scattering matrix, and the analysis of multiport networks.

**634. Information Theory in Electrical Communication.** *Prerequisite: Elec. Eng. 534 or equivalent preparation in probability and statistics. (3).*
Communication signals as random processes. Power spectra and correlation functions of various signals; entropy as a measure of information; optimum prediction and filtering; statistical inference applied to detection of signals in noise; components of communication channel; theoretical capacity of discrete and continuous channels; systems for encoding information into signals. Evaluation of amplitude, frequency and pulse modulation systems for transmission of information.

**645. Introduction to Optimal Control Systems.** *Prerequisite: Elec. Eng. 545 and Elec. Eng. 549 or permission of instructor. (3).*
Analysis and synthesis of optimal control systems utilizing classical transfer functions and state space methods; introduction of Pontryagin maximum principle, dynamic programming, method of steepest descent; function space methods for solving prescribed and probabilistic optimal system problems.

**646. Nonlinear Control-System Theory.** *Prerequisite: Elec. Eng. 545 or Instr. Eng. 570 or permission of instructor. (3).*
Analysis and design nonlinear systems; describing function techniques; approximation methods; phase- and state-space methods; stability concepts; optimal systems; introduction to Lyapunov's Second Method.

**647. Introduction to Navigation Systems.** *Prerequisite: Elec. Eng. 545 or Instr.-Eng. 570 or permission of instructor. (2).*
A theoretical study of the basic concepts which underlie celestial, Doppler, and inertial navigation systems; vehicle reference co-ordinate systems; Schuler tuning; hybrid systems; theory and application of gyroscopes, accelerometers, and astrocompasses as applied to navigation systems.

**660(Com. Sci. 660). Theory of Coding II.** *Prerequisite: Elec. Eng. 560 (Com. Sci. 560. (3).*
Continuation of Elec. Eng. 560. Finite arithmetic code theorems, finite arithmetic codes and machine arithmetic, unit distance codes, error correcting and detection properties of arithmetic codes.

**665. Digital-Computer Design Principles.** *Prerequisite: Elec. Eng. 565. (3).*
Study of the logic of series and parallel type computers; logic circuits for computation and control; characteristics of pulse circuits, memory elements, and input-output system.

**667. Theory of Networks of Switching Elements.** *Prerequisite: Elec. Eng. 467, or Philos. 414, or permission of instructor. (3).*
The use of Boolean algebra and propositional calculus in the study of two-terminal and multiterminal relay contact networks; analysis and synthesis of sequential networks and functional automata; use of predicate calculi in the theory of logical design; other current topics. The point of view is that of abstract algebra.

**673. Large Scale Systems Theory and Design.** *Prerequisite: Elec. Eng. 534 or permission of instructor. (3).*
Criteria, optimization, and synthesis methods appropriate to engineering systems. Topics may include: system representation, statistical analysis and synthesis, utilization of nonlinear techniques, modeling of specific engineering systems.

**680. Wave Propagation in Plasmas.** *Prerequisite: Elec. Eng. 580 and 620, or permission of instructor. (3).*
Generalized treatment of wave propagation in dense anistropic plasmas; surface waves on a plasma column; acoustic waves; MHD waves; instabilities; relativistic effects; power absorption and radiation; Alfvén and ion cyclotron waves in plasmas.

**686. Linear Beam-Wave Interaction Theory.** *Prerequisite: Elec. Eng. 480 and 620. (2)* without a laboratory by permission of instructor; *(3)* with a laboratory. *(2 or 3).*
Electron beam formation; Brillouin flow; confined flow; Busch's theorem; field theory of slow-wave structures; Brillouin diagrams; filter circuits; space-charge wave analysis; coupled mode theory; linear transport phenomena; linear beam devices; parametric and modulation theory. Lectures and laboratory.

**687. Nonlinear Beam–Wave Interaction Theory.** *Prerequisite: Elec. Eng. 686 or permission of instructor. (3).*
Equivalence of Kelvin and Maxwell theories; space-charge models; nonlinear Lagrangian theory of traveling-wave amplifiers, backward-wave oscillators, and crossed-field amplifiers and oscillators; beam-plasma interaction; nonlinear transport theory; stream bunching theory; emitting sole devices.

**689. Noise in Microwave and Quantum Devices.** *Prerequisite: Elec. Eng. 686 or permission of instructor. (2).*
Statistical mechanics of multistream systems; medium-like models of an electron gas applied to electron streams, gases and solids; single velocity and Maxwellian streams; generation and propagation of noise; the one-dimensional model; the transmission-line analogy; noise factor of a linear-beam device and a transistor; noise in quantum mechanical systems; quantum detectors and masers.

**699. Research Work in Electrical Engineering.** *Prerequisite: permission of program adviser. (To be arranged).*
Graduate students electing the course, while working under the general supervision of a member of the staff, are expected to plan and carry out the work themselves and to make reports in the form of theses.

**720. Electromagnetic Field Theory IV.** *Prerequisite: Elec. Eng. 620. (3).*
Individual and collective motions of charged particles in electromagnetic field. Absorption, propagation, scattering, and generation of radiation in plasmas. Least action and Fermat's principles, Eikonal Equations, and Hamilton's Canonical Equations of optics and mechanics. The concepts and techniques of Special Relativity and Lorentz Covariance are introduced.

**725. Methods of Solving Radiation and Scattering Problems.** *Prerequisite: Elec. Eng. 620 or equivalent. (3).*
Determination of approximate solutions of scattered electromagnetic fields from simple and complex shapes which have been illuminated by electromagnetic energy, such as radio waves. Solutions of various radiation problems are obtained by using the reciprocity theorem, together with the techniques developed for the scattering problem. Simple and complex antenna shapes including slotted arrays are considered. The emphasis in this course will be on recent literature and in current research.

**735. Microwave Antenna Theory.** *Prerequisite: Elec. Eng. 531 and 620 or permission of instructor. (3).*
Methods of solution of microwave antenna design problems, reciprocity theorem, circuit relationships, impedance concept, reaction concept, slots, mutual coupling.

**802. Interdisciplinary Seminar in Communication Sciences I.** *Prerequisite: permission of instructor. (3).*
General aspects of human communication. Selected topics related to the application of information theory to psychology, speech, linguistics, logical nets, and communication engineering.

**803. Interdisciplinary Seminar in Communication Sciences II.** *Prerequisite: Elec. Eng. 802. (3).*
Continuation of Elec. Eng. 802.

**810(Astron. 810). Advanced Radio Astronomy Seminar.** *Prerequisite: Elec. Eng. 536 or permission of instructor. (2).*

**815. Seminar in Network Theory.** *Prerequisite: Elec. Eng. 515, or permission of instructor.* I and II. *(2).*
Study and discussion of topics in network theory. Topics will be chosen from the following: topological methods in analysis and synthesis, N-port synthesis, analysis and synthesis of time-varying networks, synthesis of active networks.

**820. Topics in Electromagnetic Field Theory.** *Prerequisite: Elec. Eng. 620. (3).*
Differential, integral, and variational formulation of field problem; classical solutions. Method of linear operators; discontinuous solutions and theory of distributions; propagations in random medium, coherent and incoherent discrete processes; approximate solutions; theory of multiple scattering and problem of radiative transfer.

**845. Seminar on the Theory of Adaptive and Optimalizing Control Systems.** *Prerequisite: Elec. Eng. 545 or Instr. Eng. 570 or permission of instructor. (2).*
Discussion of adaptive and optimalizing control-system concepts. This seminar may be repeated for credit.

**846. Seminar on Stability Theory and its Relation to Control-System Design.** *Prerequisite: Elec. Eng. 545 or Instr. Eng. 570 or permission of instructor. (2).*
Stability concepts; stability relative to initial condition; structural stability,

stability of linear systems; Lyapunov's Second Method. Lyapunov functions; selection of Lyapunov functions; application to the design of control systems.

**865. Seminar on Research Topics in Computer Organization.** *Prerequisite: Elec. Eng. 565 or permission of instructor. (To be arranged.)*
Study and discussion of current research in computer organization, language, structure, and logic, with particular reference to recent periodical literature.

**883. Topics in Physical Electronics.** *Prerequisite: permission of instructor. (To be arranged).*
Special topics in physical electronics from the fields of gas plasmas, solid-state devices, microwave beam devices and quantum devices. Discussion of recent periodical literature and current research topics.

**895. Seminar in Space Research.** *Prerequisite: permission of instructor. (2).*
Detailed analyses of objectives, procedures, and results of research being carried out at The University of Michigan. Topics will include the following: structure of the upper atmosphere; measurement of temperature, pressure, density, composition, and winds. The ionosphere; measurement of ion and electron density and temperature. Investigation of radio waves incident on the earth at frequencies absorbed by the ionosphere by means of instrumented satellites. Interpretation of infrared data from meteorological satellites. Research in attitude control of multi-stage sounding rockets.

**990. Doctoral Thesis.** (To be arranged).

## Engineering Graphics

*Department Office:* 412 West Engineering

Drawing, the one universal language of all engineers regardless of native tongues, is presented at the college level, as distinguished from the technical or drafting levels. Engineers must be able to read drawings and, frequently, to make them. They are always dealing with drawings in one way or another.

The ability to visualize and think in three dimensions is essential to understanding atomic, molecular, crystallographic, nuclear, and outer-space relationships, as well as more commonplace ones. Such an ability is directly developed by the practice of thinking analytically to arrive at graphical results and, conversely, by the use of graphical representation to enhance and expand analytical visualization. These processes come into direct application in descriptive geometry as in few other courses of study.

Accuracy and neatness are essential to good engineering and are necessarily important aspects in the study of drawing.

**101. Engineering Drawing.** *(3).*
Elementary college-level course. Use of instruments in mechanical drafting; techniques in freehand drawing; lettering practice; geometric construction; first principles of orthographic projection, pictorial drawing; sectional and auxiliary views; conventions and simplified representation; dimensioning and threads and fasteners; detail and assembly drawings, drawn both mechanically and freehand.

**102. Descriptive Geometry.** *Prerequisite: Eng. Graphics 101. (3).*
Application of the principles of geometry and orthographic projection toward describing all engineering devices and objects accurately and usefully. The relationships of points, lines, and planes; the graphical measurement of distances and angles from all possible relative positions; the determination of intersections

of planes and curved surfaces with straight lines, planes, curved lines, and surfaces; tangent and secant surfaces; shape and size of plane areas and curved surfaces by development. Practical applications of descriptive geometry to engineering design problems.

**104. Geometry of Engineering Drawing.** *Prerequisite: Eng. Graphics 101. (2).*
Elementary principles of orthographic projection in representing relations of lines and planes, and in the graphical measurement of distances, angles, and areas. Constructions employing auxiliary views as utilized in engineering practice. Credit cannot be allowed for both this course and Eng. Graphics 102.

**141. Mechanical Drawing for Foresters.** *(1).*
Use of instruments, geometric constructions, lettering practice, orthographic projection, dimensioning, and elementary working drawings. As far as possible, drawing assignments are taken from material with which the forestry student will later have contact.

**232. Graphical Analysis and Computation.** *Prerequisite: permission of instructor, (2).*
Special geometrical constructions, graphical solutions of equations, theory of graphical scales and nomography, empirical equations, graphical calculus, and vector graphics. Theory and execution of methods followed by construction of working charts and computing aids.

**233. Advanced Engineering Drawing.** *Prerequisite: Eng. Graphics 102 or 104. (2).*
Advanced work in orthographic and pictorial representation, including engineering sketching; machine drawing; working drawings, both detail and assembly, with emphasis on auxiliary views and tolerance dimensioning; piping and structural layouts; creating and planning engineering devices.

**235. Production Illustration.** *Prerequisite: Eng. Graphics 101, or equivalent. (2).*
Advanced drawing, mechanical and freehand; lettering; emphasis on the use of orthographic, axonometric, and oblique projection in making various kinds of pictorial drawings, including sectional, exploded, assembly, and individual part views.

## Engineering Mechanics

*Department Office:* 201 West Engineering

**208. Statics.** *Prerequisite: preceded by Math. 116 and Physics 145, or written permission.* I and II. *(3).*
Fundamental principles of mechanics and their application to the simpler problems of engineering; forces, vector algebra, moments, couples, friction, hydrostatics, virtual work, and centroids.

**210. Mechanics of Material.** *Prerequisite: Eng. Mech. 208 and preceded or accompanied by Math. 214 or 215.* I and II. *(4).*
Application of mechanics to problems in stress and strain on engineering materials; resistance to direct force, bending, torque, shear, eccentric load, deflection of beams, buckling of columns, and compounding of simple stresses.

**212. Laboratory in Mechanics of Material.** *Prerequisite: preceded or preferably accompanied by Eng. Mech. 210.* I and II. *(1).*
Behavior of engineering materials under load in both the elastic and the plastic

ranges; use of testing machines; use of mechanical, optical, and electrical strain measuring instruments; tension, compression, torsion, bending, and hardness tests; column experiments; demonstrations in photoelasticity and stress coat.

**218. Statics.** *Prerequisite: Physics 153, preceded or accompanied by Math. 116.* I and II. *(3).*
Basic principles of mechanics; laws of motion, concepts of statics, vectors and vector addition 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, hydrostatics, stability of floating bodies, virtual work.

**219. Strength of Materials.** *Prerequisite: Eng. Mech. 218, preceded or accompanied by Math. 215.* I and II. *(4).*
Stress-strain relations, elastic and inelastic behavior of materials, combined stresses, introduction to theories of failure, statically determinate and indeterminate problems, axial stresses and strains including the thermal effect, torsion and bending of bars; shear center, deflection of beams, combined loading of a bar, buckling of columns, thick-walled cylinders.

**310. Statics and Stresses.** *Prerequisite: Physics 145 and Math. 214 or 316.* I and II. *(4).*
Fundamental principles of statics and their application to engineering problems; forces, moments, couples, friction, centroids, moment of inertia; application of statics to problems in stress and strain on engineering materials, including resistance to direct loads, bending, torque, shear, eccentric loads.

**314(Aero Eng. 314). Structural Mechanics I.** *Prerequisite: Eng. Mech. 210 or 219.* I and II. *(4).*
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.

**324. Fluid Mechanics.** *Prerequisite: Eng. Mech. 208 or 310 and Math. 214 or 316.* I and II. *(3).*
Principles of mechanics applied to liquids and gases. Dynamic similitude; special topics; manometers, Venturi and orifice meters, equilibrium of floating bodies, laminar and turbulent flow; resistance to flow, circulation, lift, boundary layers, free-surface flow, adiabatic flow of ideal gases in conduits.

**326. Fluid Mechanics.** *Prerequisite: Eng. Mech. 343 or 345, accompanied by Math. 316.* I and II. *(4).*
An introduction to the statics, dynamics, and thermodynamics of real and ideal fluids; laminar, turbulent, compressible and incompressible flows; the Euler, Bernoulli, and continuity equations; construction of flow nets; dimensional analysis and similitude applied to such subjects as flow in channels and conduits and lift and drag of bodies.

**328. Fluid Mechanics Laboratory.** *Prerequisite: preceded or accompanied by Eng. Mech. 324 or 326.* I and II. *(1).*
Visualizing flow of liquids; Reynolds' experiments; viscometry; hydrostatics; stability of floating bodies; photographing flow patterns; measuring flow and calibrating orifices, flow nozzles, Venturi meters; hydraulic jump and critical depth; resistance to flow, boundary layer, transition.

**343. Dynamics.** *Prerequisite: Eng. Mech. 208 or 310 and preceded by Math. 214 or 316.* I and II. *(3).*
Vectorial kinematics of moving bodies in both fixed and moving reference

frames. Kinetics of particles, assemblies of particles and of rigid bodies with emphasis on the concept of momentum. Keplerian motion, moment of inertia, tensor and its transformations, elementary vibrations and conservative dynamic systems are treated as special topics.

**345. Dynamics.** *Prerequisite: Eng. Mech. 218, accompanied by Math. 316.* I and II. *(3).*
Kinematics, rectilinear and curvilinear motion, Coriolis' acceleration, kinetics of particles and bodies, d'Alembert's principle, momentum, conservative and non-conservative systems, impact, dynamic stresses, propulsion; vibrations of rigid bodies, vibrating mass systems, electrical and acoustical analogies, gyroscopes, balancing.

**402. Experimental Stress Analysis.** *Prerequisite: Eng. Mech. 210 or 219.* I. *(2).*
Review of plane stress-strain relationships, with mechanical, optical, and electrical resistance strain-measuring techniques; applications including strain rosettes; dynamic and transient strain and displacement measurements; brittle coatings and brittle models; fundamentals of photoelasticity. Laboratory sessions with assigned experiments. Recommended as a substitute for Eng. Mech. 210.

**403. Experimental Mechanics.** *Prerequisite: Eng. Mech. 210 and 343, and Elec. Eng. 316.* 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.

**411. Structural Mechanics.** *Prerequisite: Eng. Mech. 210 or 219.* 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. Introduction to plate theory.

**412. Intermediate Mechanics of Material.** *Prerequisite: Eng. Mech. 210 or equivalent, preceded or accompanied by Math. 450 or permission of instructor.* I and II. *(3).*
Classification of materials: elasticity, viscosity, plasticity. Analysis of simple combinations. Limit theory of plasticity. Introduction to general linear elasticity; plane solutions and torsion problem. Energy principles and application to approximate systems.

**413. Photoelasticity.** *Prerequisite: Eng. Mech. 210 and Math. 316.* I and II. *(2).*
Lectures and laboratory experiments covering the fundamentals of the photoelastic method of stress determination including the use of double refraction and interference of light, determination of the maximum shear stress, methods of separating the principal stresses, and three-dimensional photoelasticity. Models to suit interest of students.

**414(Aero. Eng. 414). Structural Mechanics II.** *Prerequisite: Eng. Mech. 314.* I and II. *(4).*
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. Lectures and laboratory.

**416. Stress Analysis.** *Prerequisite: Eng. Mech. 210. (2).*
Basic concepts of stress and strain in two dimensions; curved beams and beams on elastic foundations; fundamentals of photoelasticity.

**422. Intermediate Mechanics of Fluids.** *Prerequisite: Eng. Mech. 324 or equivalent, preceded or accompanied by Math. 450 or permission of instructor.* I and II. *(3).*
Continuity, stream functions, vorticity; Euler and Bernoulli equations; irrotational flows, Laplace equation, conformal mapping, relaxation method; hydrodynamic forces and moments; compressible flows, method of characteristics; Navier-Stokes equations, elements of hydrodynamic stability, and turbulence; boundary layers, jets, wakes, drag.

**442. Intermediate Dynamics.** *Prerequisite: Eng. Mech. 343 or equivalent, Math. 450 or permission of instructor.* II. *(3).*
Analytical mechanics for particle and rigid body motions. Lagrange's equations; introduction to Hamilton's development of mechanics; small vibration theory; special relativity; Hamilton-Jacobi equations; application of variational calculus.

**507. Theory of a Continuous Medium I.** *Prerequisite: Eng. Mech. 412, 422.* II. *(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.

**514. Theory of Elasticity I.** *Prerequisite: Eng. Mech. 412 or equivalent.* I. *(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.

**515. Theory of Plates.** *Prerequisite: Eng. Mech. 412 or equivalent.* II. *(3).*
Classical linear plate theory, with application to various shapes, boundary conditions, and loading systems; refinements to account for anisotropy, shear deformations, large deflections; plastic collapse and elastic instability.

**516. Theory of Shells I.** *Prerequisite: Eng. Mech. 412. (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: Eng. Mech. 412, Math. 447 or equivalent.* II. *(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. Theory of Elastic Stability I.** *Prerequisite: Eng. Mech. 412 or equivalent.* 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: Eng. Mech. 412 or equivalent.* II. *(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. Application to problems of bending, torsion, plane strain and plane stress; technological problems.

**522. Mechanics of Inviscid Fluids I.** *Prerequisite: Eng. Mech. 422 and Math. 450.* II. *(3).*
Solution of Laplace's equation by various methods; added masses. Taylor theorem; forces and moments, Blasius and Lagally theorems; free-streamline flows, wave motion, vortex motion, and shear flows; theory of thin airfoils or projectiles; high speed flow.

**523. Mechanics of Viscous Fluids I.** *Prerequisite: Eng. Mech. 422 or equivalent and Math. 450.* I. *(3).*
Stress and rates-of-deformation tensors, dissipation function, exact solutions of the Navier-Stokes equations, very slow motion, boundary layers, jets and wakes, energy equation, forced and free convections, hydrodynamic stability, statistical theories of turbulence.

**524. Wave Motion in Fluids.** *Prerequisite: Eng. Mech. 422 or permission. (3).*
Surface waves in liquids, group velocity and dispersion; shallow-water waves, kinematic waves, method of characteristics; subcritical and supercritical flows; analogy between free-surface flows and gas flows; subsonic flows of a gas, hodographs, Molenbroek's transformation, Legendre's transformation, Chaplygin's treatment, Kármán-Tsien method; supersonic flows, Riemann's nonlinear treatment of finite waves, nonlinear expansion flows, Prandtl-Busemann method of characteristics; shock waves; wave motion of a conducting fluid in an electromagnetic field.

**525. Non-Newtonian Fluid Mechanics.** *Prerequisite: any one of the following: Eng. Mech. 326 or 422, or Civ. Eng. 524, or Mech. Eng. 524, or Aero Eng. 420, or Chem.-Met. Eng. 342.* II. *(3).*
Non-Newtonian continuous media; flow classifications, stress-strain, and rate-of-strain, laminar shear flow models for developed and boundary layer flows, stability compared to Newtonian case, turbulent flows. Flows of nonhomogeneous 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.

**527. Thermodynamics.** *Prerequisite: Math. 450 or permission of instructor.* I. *(2).*
Fundamental concepts; first and second laws of thermodynamics, equilibrium of homogeneous systems; applications to elastic and plastic deformations and fluid dynamics.

**529. Advanced Laboratory in Mechanics of Fluids.** *Prerequisite: Eng. Mech. 422 or permission of instructor.* 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 steamline flows, drag forces and moments, pressure distributions, thermal instability, slow-motion flows, and the Prandtl-Meyer flows.

**541. Intermediate Vibration Theory.** *Prerequisite: Eng. Mech. 442 or permission of instructor.* II. *(3).*
Free and forced vibration of lumped systems; vibration of multi-mass systems, normal modes, mechanical impedance, vibration control, matrix methods, Raleigh's method and energy methods for approximate solutions.

**543. History of Dynamics.** *Prerequisite: Eng. Mech. 343 and Math. 316. (2).*
A review of the important publications in which the fundamental principles of dynamics were developed from Aristotle to Lagrange. The influence of astronomical theories on the development of dynamics.

**544. Dynamics and Stability of Rotors.** *Prerequisite: Eng. Mech. 442.* II. *(3).*
Problems of balance and vibration in turbine rotors and reciprocating engine moving parts, blade and disc vibrations, harmonic analysis, vibration dampers and absorbers, vibration-stress analysis.

**545. Vibrations of Continuous Media.** *Prerequisite: Eng. Mech. 412 and 442, or permission of instructor.* I. *(3).*
Wave motion and vibration of elastic systems, including strings, bars, shafts, beams, and plates. Problems in free and forced vibrations with various end conditions and types of loading; effect of damping on the motion; applications of Rayleigh-Ritz and other methods to the approximate calculation of frequencies and normal modes of nonuniform systems.

**547. Theory of Gyroscopes.** *Prerequisite: Eng. Mech. 442, or permission of instructor.* I. *(2).*
General theory of rigid-body rotational dynamics applied to gyroscopes of one and two degrees of freedom. Various applications of gyroscopes to measurement and control problems.

**548. Micromechanics of Solids.** *Prerequisite: Eng. Mech. 442, Math. 552 or 554, or permission of instructor.* I. *(3).*
Dynamics of microscopic systems in the solid in relation to the macroscopic mechanics of continuous media. Elastic wave propagation through a vibrating lattice; electron, phonon, and defect motions; defect, disorder, and surface effects on the vibrational frequency spectrum; slow neutron scattering.

**555. Statistical Foundations of Mechanics.** *Prerequisite: Eng. Mech. 324 and 343 or equivalent, Math. 450 or permission of instructor.* II. *(3).*
The statistics and kinetics of microscopic systems in relation to the rheology of a Stokes fluid and the phenomonological mechanics of liquids and solids; conservation laws and their limits of validity; applications to the dynamics of fluids and solids.

***572. Intermediate Mechanics of Material I.** *(2).*

***573. Intermediate Mechanics of Material II.** *(2).*

***574. Intermediate Mechanics of Fluids I.** *(2).*

***575. Intermediate Mechanics of Fluids II.** *(2).*

**707. Theory of a Continuous Medium II.** *Prerequisite: Eng. Mech. 507, and Math. 777 or equivalent.* I. *(3).*
Generalization of the theory of a continuous media to general co-ordinates; compatibility and integrability relations; theory of constitutive equations; hypoelasticity.

**714. Theory of Elasticity II.** *Prerequisite: Eng. Mech. 514.* II. *(3).*
Three-dimensional elasticity problems. Derivation of approximate systems (plates, shells, etc.) from variational principles; introduction to nonlinear elasticity.

*For description, see Eng. Mech. 412 and 422 or Detroit Extension Service bulletin.

**716. Theory of Shells II.** *Prerequisite: Eng. 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.

**718. Theory of Elastic Stability II.** *Prerequisite: Eng. Mech. 518.* II. *(3).*
Linear instability theory of plates and shells. Postbuckling analysis. Dynamic stability criteria. General instability theory in three-dimensional elasticity.

**719. Theory of Plasticity II.** *Prerequisite: Eng. Mech. 519.* I. *(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.

**721. Mechanics of Inviscid Fluids II (Geophysical Fluid Mechanics).** *Prerequisite: Eng. Mech. 522 or permission of instructor.* I. *(3).*
Theory of large-amplitude motion of fluids with variable density and entropy in a gravitational field, flow of heterogeneous fluids in porus media, gravity and sound waves in stratified fluids, stability of stratified fluids. Flow in a rotating system or a magnetic field.

**723. Mechanics of Viscous Fluids II.** *Prerequisite: Eng. Mech. 523.* II. *(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.

**726. Singular Perturbation and Approximate Methods in the Mechanics of Fluids I.** *Prerequisite: Eng. Mech. 523, Math. 554 (or 552 and 555), or permission of instructor.* I. *(3).*
Review of perturbation theory: Poincaré method, Lighthill and Witham extension, elementary singular perturbation. Viscous damping of wave motion, oscillation in weakly nonlinear systems, the two-time method. Boundary layer flow, inner and outer expansions, optimal co-ordinates in singular perturbation theory; phenomena in rotating flows.

**727. Singular Perturbation and Approximate Methods in the Mechanics of Fluids II.** *Prerequisite: Eng. Mech. 523, Math. 554 (or 552 and 555), or permission of instructor.* II. *(3).*
Van Dyke's theory on viscous flows, modified Oseen method, Wiener-Hopf technique, substitute kernel methods as applied to fluid mechanics. Shock singular perturbation theory.

**741. Nonlinear Oscillations.** *Prerequisite: Eng. Mech. 442, Math. 404 and 450, or permission of instructor.* II. *(3).*
Methods of treating the motions of nonlinear mechanical systems; phase-space and phase-plane $\delta$ methods: notion of singularities; stability in the sense of Liapunov; equations integrable by elliptic integrals and functions; the perturbation method; the method of Kryloff and Bogoliuboff; Mathieu's equation and its application to the stability of nonlinear oscillations.

**745. Wave Motion in Continuous Media.** *Prerequisite: Eng. Mech. 545 or permission of instructor.* II. *(3).*
Wave propagation in bounded and extended elastic media, including trans-

mission, reflection, and refraction phenomena, transient-stress states, and analogies with acoustical and optical effects. Forced motion of continuous elastic systems such as plates, membranes, shells, and other forms.

**801. Seminar in Engineering Mechanics.** *Prerequisite: permission.* I and II. *(1 or 2).*
A series of weekly seminars. Students who contribute may elect one or two hours credit.

**811. Seminar in Mechanics of Solids.** *(To be arranged).*

**821. Seminar in Mechanics of Fluids.** *(To be arranged).*

**841. Seminar in Dynamics.** *(To be arranged).*

**855. Seminar in Molecular Mechanics.** *Prerequisite: Eng. Mech. 555 or permission of instructor. (To be arranged).*
Current research in the applications of statistical mechanics and kinetic theory to the dynamics of media in the continuum range; selected topics in dense gases, liquids, and solids.

**911. Research in Mechanics of Solids.** I and II.
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 and II.
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 and II.
Original investigation in the field of body motions such as vibrations of mechanical systems, control problems, and other fundamental problems in the mechanics of rigid body motion.

**991. Doctoral Thesis.** I and II.
For doctoral candidates only, under supervision of the doctoral committee. Credit hours to be arranged.

## English

*Department Office:* 3516 Natural Resources

The work offered in English prepares the student to write and speak effectively and to broaden and deepen his interest in literature. To these ends the department offers a variety of courses in written composition, speech, and literature.

It is presupposed that the student is adequately prepared in the fundamentals of English usage and that he has some knowledge of literature. Normally, a student will take ten hours of English: six hours in Group I, two hours in Group II, and two hours in Group III. The actual number of hours required, however, will depend in part upon the student's preparation and ability. The student of marked superiority may graduate with fewer hours in English; and, conversely, the student who needs additional training may be required to take additional hours of work in English. The student who enters with advanced credit will be required to show a proficiency equal to that of the student with the same number of hours of English credit earned in this College.

In his work for other courses in the engineering curriculum the student is also expected to maintain a satisfactory standard of English. If he fails to do so, he may be reported to the Assistant Dean who, with the student's program adviser and the chairman of the Department of English, may prescribe additional study.

### *Group I: Basic Courses*

Courses in this group provide basic instruction and practice in writing and speaking. English 111 and 121 are elected during the first term of the freshman year and English 112 during the second term. Students with outstanding ability can be exempted from one or more of these courses.

**111. Freshman Composition I.** I and II. *(3).*
A course in the essentials of composition with stress on sentence structure, paragraph development, and theme organization. Spelling, diction, punctuation, and grammatical usage are considered as the need arises. Essays and some imaginative literature are analyzed to provide models and ideas for themes and to develop skill in reading.

**112. Freshman Composition II.** I and II. *(2).*
Continuation of English 111, with further stress on the essentials of composition but with the chief emphasis on various techniques of exposition and argument, such as analysis, analogy, comparison, and definition. The student also receives instruction and practice in writing research papers. As in English 111 essays and some imaginative literature are read and analyzed.

**121. Introductory Speech.** I and II. *(1).*
A course in the preparation and delivery of short expository and persuasive speeches. It is intended to help the student develop the ability to present his ideas to a group in an orderly and effective manner. Two hours of classwork.

### *Group I-A: Nontechnical Electives*

To serve the need for three-hour nontechnical electives in the humanities for engineering students—freshmen to seniors—the English Department offers these three courses. They differ from Group II and III courses in three respects: (1) there are no prerequisites; (2) they focus almost entirely on reading and discussion and require relatively little writing; (3) they are interdisciplinary.

**114. Quest for Utopia.** II. *(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 assess the values in the present order.

**115. Literature and Philosophy.** II. *(3).*
Reading and analysis of literature as a means of introducing the student to some major philosophical issues. Authors to be read include Swift, Voltaire, Dostoevsky, and Mark Twain.

**116. Literature and Art.** II. *(3).*
Reveals and explains the close connections between the literature of a given period and its painting, sculpture, and architecture. The primary emphasis will be on reading with parallels illustrated in the fine arts.

### *Group II: Intermediate Courses—Literature*

Group II provides courses in modern literature. To satisfy the Group II requirement, the student must either elect one of these courses or present a satisfactory equivalent. The courses in this group may also be taken for credit as nontechnical electives, and they are designed to help the student read with insight as well as pleasure and gain thereby a richer understanding of the nature of man and his world. Some writing is required in each of the courses.

**251. Modern Literature.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of modern literature in its varied forms. The short story, novel, drama, and poem are treated as separate but interrelated means of expressing significant ideas. Faulkner, O'Neill, Frost, Shaw, Camus, and Chekhov are typical of the authors read.

**255. Modern Biography and Autobiography.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of biographies and autobiographies of people who are in some way extraordinary. The subjects include such figures as Henry Ford, Benito Mussolini, P. T. Barnum, Benedict Arnold, and Mary Todd Lincoln.

**256. Modern Short Story.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of modern short fiction by such significant American and European authors as Hemingway, Faulkner, Steinbeck, Maugham, and Joyce.

**263. Modern Drama.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of representative modern plays, such as Ibsen's *Ghosts,* Shaw's *Candida,* O'Neill's *The Hairy Ape,* Williams' *The Glass Menagerie,* and Miller's *Death of a Salesman.*

**265. Modern Novel.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of selected modern novels, both European and American. Writers whose works are most frequently assigned range from Zola and Flaubert to Faulkner and Hemingway.

**275. Modern Poetry.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Reading and analysis of the principal British and American poetry of the twentieth century. Robinson, Frost, Sandburg, Yeats, Auden, and Cummings are typical of the poets included in the course.

**299. Studies in Literature.** *Prerequisite: English 111, 112, and 121.* I. *(2).*
Open only to students whose native language is not English. An introduction to literature designed for the foreign student. The literature to be read, the method of presentation, and the reading and writing assignments are adapted to the particular needs of the foreign student.

### *Group III: Advanced Courses—Literature*

*Open to juniors, seniors, graduate students, and others by permission.*

Group III courses in literature are specialized and intensive and require more maturity of the student than the courses in Group II. To satisfy the Group III requirement, the student must elect one of these courses, or present a satisfactory equivalent. The courses may also be taken for credit as nontechnical electives. All courses in this group may be taken for graduate credit, provided that the student has the approval of the instructor and his program adviser and provided that he completes additional work. Some writing is required.

**300. Studies in Literature.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II. (2).*
Open only to students whose native language is not English. An introduction to literature designed for the foreign student. The literature to be read, the method of presentation, and the reading and writing assignments are adapted to the particular needs of the foreign student.

**419. Major Speeches in American History.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II. (2; 3 with permission of instructor).*
A study of selected American speakers and their speeches in relation to the history of the times. The student will read significant speeches by such men as Daniel Webster, John C. Calhoun, Abraham Lincoln, William Jennings Bryan, Woodrow Wilson, and Franklin D. Roosevelt.

**455. American Folklore.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
The life and spirit of the American people as reflected in their folksongs and ballads, tales, legends, superstitions, proverbs and sayings, games, and customs. Extensive use will be made of regional and type collections and of recordings.

**457. Great Poetry.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
Reading and critical analysis of major poetry of the Western World from Homer to our own day, with the following as objectives: to acquaint the student with the worlds of belief, meaning, and beauty that have become a part of our Western tradition; to acquaint him with the nature and place of poetry by means of which he may more adequately understand and enjoy poetry; and to sharpen his powers of analysis and expression through writing assignments.

**458. Literature of Science.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(3).*
Reading and discussion of some classics of scientific literature, such as Darwin's *Origin of Species* and Freud s *A General Introduction to Psychoanalysis,* as well as writings by contemporary scientists on the nature of the scientific method, its application in various fields, and its limitations. The course is designed to extend the student's awareness of the impact of science, especially on man's conception of himself, his society, and his place in the universe.

**461. Shakespeare.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
Twelve or more of the principal plays, with a view to acquainting the student with something of Shakespeare's breadth and variety and illustrating the growth of his mind and art.

**462. Drama.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
Significant drama in classical, Elizabethan, neoclassic, and modern western civilizations.

**467. The Novel.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
Significant works of fiction from *Robinson Crusoe* to *Moby Dick,* such as *Tom Jones, Pride and Prejudice,* and *Vanity Fair,* with emphasis upon reading with understanding and delight.

**475. American Literature.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
Readings in the works of leaders in American thought from the early eighteenth century to the present. The course concentrates on those authors who best represent the changing ideals that have dominated American life in the past and that are important for an understanding of the contemporary American scene.

**485. Literary Masterpieces.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2 or 3).*
Distinguished literary works in the western tradition, from the Greeks to our own day. Typical of the works that have been used are plays by Sophocles, Shakespeare, Ibsen, and Shaw; dialogues by Plato; selections from the Bible and from Machiavelli; poetry by Homer, Dante, Wordsworth, and Frost; fiction by Turgenev, Maupassant, and Katherine Mansfield.

**488. Literature and Modern Thought.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(3).*
The three objectives of the course are: (1) to acquaint the student with some major forces on modern thought, e.g., Marxism, Freudianism, and existentialism; (2) to acquaint him with significant works of literature which place these intellectual conceptions in humane perspective, e.g., fiction of Zola, Steinbeck, Koestler, Sartre; and (3) to encourage him to evaluate these ideas and the literature which expresses and comments upon them.

**492. Major American Writers.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
An intensive study of the works of two or three major American writers with emphasis on their ideas, their relationship to their period, their form of expression, and their literary significance. Writers are chosen who make possible an integrated exploration of significant cultural developments.

**493. Major European Writers.** *Prerequisite: English 111, 112, 121, and, ordinarily, one course in Group II.* I and II. *(2).*
An intensive study of the works of two or three European writers with emphasis on their ideas, their relationship to their period, their form of expression, and their literary significance. Writers are chosen who make possible an integrated exploration of significant cultural developments.

### *Group IV: Special Elections in Speech and Writing*

**235. The Technical Article.** *Prerequisite: English 111 and 112.* I and II. *(2).*
An advanced composition course with special emphasis on the writing of technical and scientific articles for both professional and nonprofessional readers. The course includes some study of current scientific and technical articles from such periodicals as *Scientific American.*

**241. Public Speaking.** *Prerequisite: English 111 and 121.* I and II. *(2).*
Preparation and delivery of informative and persuasive speeches. The student is given opportunity to improve his ability to speak effectively, and to listen critically. He will choose his own subjects and work with his own ideas, feelings, and experiences.

**436. Scientific and Technical Writing.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
The fundamentals of scientific and technical writing with emphasis on clear and orderly exposition.

**441. Argumentation and Debate.** *Prerequisite: English 111, 112, and 121.* I and II. *(2).*
Training in the organization and the delivery of the principal types of persuasive speeches, with emphasis on conference speaking and debating.

## Geology and Mineralogy*

*Department Office:* 2501 Natural Science

Professor Eschman; Professors Arnold, Briggs, Denning, Dorr, Goddard, Heinrich, Hibbard, Kellum, Kesling, Landes, Stumm, Turneaure, and Wilson; Associate Professors Cloke, DeNoyer, and Kelly; Assistant Professors Farrand, Peacor, and Pollack; Instructor Marcurda; Lecturer Reimann.

**111, 113. Introductory Geology.** *Not open to those who have had Geol. 218, 219, or 120.* Geol. 111, I; Geol. 113, II. *(4).*
An introduction to science through geology. The study of the materials making up the earth, the processes which act upon them, and the effects these processes have on the earth's surface; the development of the tools for the interpretation of the history of the earth; and the major geologic concepts which make geology unique from the other natural sciences. One or more Saturday field trips will be required. Lectures, laboratory, and field trips for an average weekly total of seven hours.

**120. Physical Geology.** *Prerequisite: Two years of high-school mathematics and one year of high-school chemistry. Not open to those who have had Geol. 111, 113, 218, or 219.* II. *(4)*
An introductory course in geology with emphasis on quantitative and mathematical aspects of the science. Lectures, laboratory, problems.

**218. Geology for Engineers.** II. *(3).*
Geologic processes with special emphasis on structural geology, ground water, and the relation of geology to engineering problems. Laboratory includes rock and mineral identification, and the interpretation of geologic maps and aerial photographs. Geol. 218 is required of students in civil engineering and is open to others as an elective. Lectures, laboratory, and field trips.

**219. Geology and Man.** *Not open to freshmen, or to those who have had Geol. 111, 113, 120, or 218.* II. *(4).*
Geologic processes and their effect on civilization. Lectures and demonstrations.

For other courses in geology for which students of engineering are eligible, see the *Announcement* of the College of Literature, Science, and the Arts. It is suggested that Geol. 112, Introductory Geology; Geol. 280, Minerals and World Affairs; and Geol. 447, Ground Water Geology, are especially useful for engineering students.

## Industrial Engineering

*Department Office:* 231 West Engineering

**371. Stochastic Industrial Processes.** *Prerequisite: Math 466.* I and II. *(2).*
Elementary concepts in renewals, compound processes, Markov processes, queueing and related topics. Applications of the concepts to replacement strategy, machine repair strategy, demand and service analysis and other areas of industrial processes.

**375. Engineering Linear Programming.** *Prerequisite: preceded or accompanied by Math. 466.* I and II. *(2).*

* College of Literature, Science, and the Arts.

An introduction to formulation of linear optimization models, the simplex algorithm, transportation and assignment algorithms, and their engineering applications.

*400. **Industrial Management.** *Prerequisite: junior standing or permission of department.* I and II. *(3).*
Management problems and methods involved in the operation of manufacturing institutions, including location, layout, equipment selection, methods, work measurement, methods of wage payment, inspection, organization procedures, production and material control, budgets. A Business Game is used to study dynamic aspects of industrial decisions.

401. **Introduction to Management Sciences.** *Prerequisite: preceded or accompanied by Ind. Eng. 371 and 375, or permission of department.* II. *(3).*
Current studies in management problems, including management games, management design and control of research programs, organization and information theories.

431. **Administrative Procedures.** *Prerequisite: Ind. Eng. 400 and 463.* I and II. *(3).*
Management organization structures, personnel relations, supervisory methods and procedures, and general management control methods.

*433. **Human Factors in Engineering Systems.** *Prerequisite: Ind. Eng. 400 or permission of instructor.* I. *(3).*
The application to engineering of the information available concerning vision, illumination, color, noise, atmospheric conditions, physical measurements, and the arrangement of controls and equipment in the areas of work place and equipment design. Emphasis will be placed on sources and methods of collection and analysis of the available information.

*441. **Production and Inventory Control I.** *Prerequisite: Ind. Eng. 371 and 375.* I and II. *(3).*
The methods and concepts involved in the forecasting, routing, scheduling, dispatching, planning, and controlling production systems as well as the contemporary methods of implementation and control of inventory and distribution systems.

447. **Plant Layout and Materials Handling.** *Prerequisite: Ind. Eng. 451, 463, and 441.* I and II. *(3).*
Analysis and planning of the layout of physical facilities. The analysis and selection of materials handling equipment as influenced by material, processing, production equipment, building, economic considerations, and related factors.

451. **Engineering Economy I.** *Prerequisite: Math. 315.* I and II. *(3).*
Economic selection of equipment, consideration of costs, methods of financing, depreciation methods, and the economics of production estimating.

463. **Work Methods and Measurements I.** *Prerequisite: Ind. Eng. 400 and Math. 465.* I and II. *(4).*
The analysis and prediction of the performance of humans in industrial and

* Students not enrolled in the industrial engineering program and not presenting the usual prerequisite may elect courses indicated by * with the permission of the department.

service type 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.

**464. Work Simplification.** *Prerequisite: Ind. Eng. 463 or permission of department.* II. *(3).*
Application of tools and techniques of work simplification to improve work systems requiring the integration of people, machines, methods, and procedures. Current literature and cases are studied.

**466. Quality Control.** *Prerequisite: Ind. Eng. 461.* II. *(3).*
Surveys of current practices in acceptance sampling and control charts. Some of the more important quality measuring equipment is discussed and used in experiments. Emphasis is placed on the economics of alternative quality control procedures. Two-hour lecture and two-hour demonstration.

**469. Industrial Engineering Computations.** *Prerequisite: Math. 465 and 466.* I and II. *(2).*
Deals with computational aspects of common statistical problems. About five computational projects will be assigned during the term. All computational work can be done in the laboratory on desk calculators. One-hour lecture and three-hour laboratory session each week.

**472. Operations Research.** *Prerequisite: preceded or accompanied by Math. 465.* I and II. *(3).*
Introduction to operations research; the methodology of mathematical models and its application to various industrial problems, including queueing theory, game theory, linear programming, inventory theory, and Monte Carlo processes. Two one-hour lectures and a two-hour recitation section.

**473. Data Processing.** *Prerequisite: Math. 315 and 273 or equivalent.* I and II. *(3).*
The use of data processing methods in industrial systems and an introduction to computer simulations of industrial operations. Two-hour lecture and two-hour demonstration.

**483(Mech. Eng. 483). Numerical Control of Manufacturing Processes.** *Prerequisite: Ind. Eng. 473 or Mech. Eng. 482 and permission of instructor.* II. *(3).*
Basic elements of numerical control of metal processing systems: development of programming languages for point to point and contouring machines; interaction between geometry and machinability decisions. Laboratory experiments in optimizing part programming and equipment utilization. Two one-hour lectures and one two-hour laboratory.

**491. Study in Selected Industrial Engineering Topics I.** *Prerequisite: permission of department.* I and II. *(To be arranged, 3 maximum).*
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 industrial engineering including management, work measurement, methods, organization, industrial sciences, industrial mathematics, systems, and procedures.

**495. Seminar in Hospital Systems.** *Prerequisite: permission of department.* I and II. *(3).*
Individual or group study of hospital systems. Topics may be chosen from any of the areas of industrial engineering including management, work measurement, methods, organization, systems, and procedures.

**522. Theories of Administration.** *Prerequisite: Ind. Eng. 431 or graduate standing.* II. *(3).*
Provides insight into the present theories concerning the administration of research and industrial organizations. Decision criteria, conflict resolution, status systems, concepts of organization, communications, efficiency criteria, wage concepts, problems of change, and aspects of motivation are presented and discussed.

**523. Industrial Engineering Readings.** *Prerequisite: graduate standing.* II. *(2 or 3).*
Origins and creative processes of the industrial engineering profession. The works of the founders of scientific management and original papers by outstanding men in the field are studied and discussed.

**524. Industrial Systems—Field Work.** *Prerequisite: Ind. Eng. 463.* I and II. *(3).*
Principles of management are applied to specific problems in industrial operations. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A fee is required.

**527. Decision Simulations.** *Prerequisite: Ind. Eng. 472 and 473 or permission of department.* I. *(3).*
Design of representative total enterprise and functional decision simulations. Relation between game theory and decision simulations for research in bargaining, competition, and economics. Applications to industrial systems design and to training.

**528. Industrial Engineering Problems.** *Prerequisite: Ind. Eng. 400.* I and II. *(3).*
Problems and the application of the principles of industrial engineering, using the case method in solving typical management situations. The application of engineering methods to the study and analysis of management in an era of rapid scientific and technical advance.

**533. Problems Concerning Human Factors in Engineering Systems.** *Prerequisite: Ind. Eng. 433 or permission of department.* **II. *(3).***
Problems and field exercises on the application of human factors to engineering systems. Students will formulate problems, select the experimental or other procedures for their solution, and report the findings.

**541. Analysis of Inventory Systems I.** *Prerequisite: Ind. Eng. 472 or permission of department.* I and II. *(3).*
The study of models for control of single item inventory. Deterministic lot size models, reorder point and periodic models with probabilistic demand. Extensions to dynamic inventory problems and analysis of steady state behavior using dynamic programming.

**542. Analysis of Inventory Systems II.** *Prerequisite: Ind. Eng. 541 and one year of statistics.* I. *(3).*
Continuation of Ind. Eng. 541. Inventory and production control models for systems with multiple items and with stations in series. Applications of linear and nonlinear programming to production smoothing and economic lot scheduling.

**546. Industrial Procurement.** *Prerequisite: Ind. Eng. 400.* I. *(3).*
Consideration of proper selection of sources of supply, price, and value analysis. Standards and specifications. Purchasing department organization, buying policies. Case problems will be presented and discussed in detail.

**547. Plant-Flow Analysis.** *Prerequisite: Ind. Eng. 447, 472, and 473, or permission of department.* II. *(3).*
Study of assembly line balancing and machine loading, optimal path and network flow analysis using integral linear programming approaches. Equipment and activity location problems. Use of simulation in plant layout and scheduling studies.

**549. Automatic Process Control I.** *Prerequisite: Math. 404.* II. *(3).*
Introduction to automatic control of manufacturing processes; Laplace transformations and their application to design of process control systems; numerically controlled machine tool synthesis, application and programming problems.

**551. Engineering Economy II.** *Prerequisite: Ind. Eng. 451, or permission of department.* II. *(2 or 3).*
Economic analysis procedures relating to company growth, consideration of various replacement models, product and new enterprise analysis, capital budgeting. Case problems.

**561. Analysis of Industrial Experiments.** *Prerequisite: six hours of statistics.* II. *(3).*
Analysis of variance and regression analysis with application to industrial experiments. Two-hour lecture and two-hour demonstration.

*__562. Industrial Systems—Field Work.__ *Prerequisite: Ind. Eng. 463.* I. *(3).*
Principles of industrial systems and instrumentation are applied to specific problems in factory operation. Inspection trips to manufacturing plants with problems and discussion based on these trips. A fee is required.

**563. Work Methods and Measurements II.** *Prerequisite: Ind. Eng. 463.* I. *(2 or 3).*
Application of work sampling and memo-motion techniques as methods of work measurement; use of standard data-time standards and their determination by actual time-study, motion pictures, predetermined time-standards systems. Recitations and demonstrations.

**567. Linear Statistical Models and Their Application I.** *Prerequisite: Math. 466.* I. *(3).*
Study of linear statistical models applicable to industrial problems. Multivariate normal distribution, noncentral F distribution. General linear-hypothesis model of full rank, including estimation of parameters and tests of hypotheses about the parameters using analysis of variance.

**568. Linear Statistical Models and Their Application II.** *Prerequisite: Ind. Eng. 567.* II. *(3).*
Continuation of Linear Statistical Models I. Linear regression models; fixed-effects, random-effects, and mixed effects analysis of variance models. Factorial experiments and their relation to linear models. The use of linear models to analyze fractional replicates of factorial experiments. Strong emphasis will be placed on the choice of models to fit real situations and the appropriate analysis of data.

**571. Queueing Systems Analysis I.** *Prerequisite: one year of statistics.* I. *(3).*
Simple single channel and multichannel queueing problems subject to Poisson input and negative exponential service times. Waiting times, busy period lengths, and state probabilities. General service time, systems, and Pollaczek's formula. Applications and extensions.

* Students not enrolled in the industrial engineering program and not presenting the usual prerequisite may elect courses indicated by * with the permission of the department.

**572. Optimization in General Systems.** *Prerequisite: Ind. Eng. 473, Math. 517, or Ind. Eng. 575.* II. *(2 or 3).*
The problem of searching for an optimum policy when it cannot be solved by a standard programming code. Various general extreme-value search procedures, with and without estimation errors, and self-improving codes are considered.

**573. Simulation.** *Prerequisite: Ind. Eng. 473.* I. *(3).*
The use of a digital computer as a stimulator of industrial processes. Construction of flow charts, fixed time increment and time status register methods of organization. Experimental designs for computer experiments are considered and students will run simple simulations.

**575. Linear Programming.** *Prerequisite: preceded or accompanied by Math. 517.* I. *(3).*
An introduction to programming. Primary attention is focused on linear programming. The abstract structure of the problem is discussed. A number of examples of uses of linear programming are introduced. Machine codes for solution are discussed and used.

**576. Nonlinear Programming.** *Prerequisite: Ind. Eng. 472 and six hours of statistics or permission of department.* II. *(3).*
Various integer and nonlinear problems. Gradient methods and the concepts of dynamic programming.

**591. Study in Selected Industrial Engineering Topics II.** *Prerequisite: Ind. Eng. 491.* I and II. *(To be arranged).*
Continuation of Ind. Eng. 491.

**600(Hosp. Admin. 800). Research Seminar in Hospital and Medical Systems.** *Prerequisite: permission of instructor.* I and II. *(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. Use of outside speakers for presentation of selected research topics. Student involvement through readings, surveys, and development of research projects.

**631. Advanced Management Controls.** *Prerequisite: Ind. Eng. 431 or permission of department.* I. *(3).*
Studies of current methods for analyzing management control problems. The course uses actual cases as well as current publications and consists of further investigations and solutions of those cases.

**641. Production and Inventory Control II.** *Prerequisite: Ind. Eng. 441 and one year of statistics.* II. *(3).*
The use of operations research techniques in production smoothing and scheduling. Applications of mathematical methods of sequencing and loading to optimization of facility utilization, interaction with inventory policies, and design of complex production-control systems.

**644. Production Design.** *Prerequisite: Ind. Eng. 447 and 524 or permission of department.* II. *(3).*
The co-ordination of product design with the necessary manufacturing processes. Evaluation of the available facilities is made with possible alternatives to aid management decisions. Case studies are selected from actual industrial situations.

**645. Executive Compensation and Incentives.** *Prerequisite: Ind. Eng. 445.* I. *(3).*
Considerations in the selection and design of executive salary and fringe benefit policies. Problems of motivation and morale, development, recruitment and performance measurement. Effect of management environment on performance.

**671. Queueing Systems Analysis II.** *Prerequisite: Ind. Eng. 571 or permission of department.* II. *(3).*
Multichannel queues, Erlang input and service times. Embedded Markov chain analysis and inclusion of supplementary variables. Lindley's Integral Equation, time dependent solutions and approximations, elements of renewal theory, Markov chains, and the Feller-Kolomogorov equations.

**691. Graduate Study in Selected Problems.** *Prerequisite: permission of graduate committee.* I and II. *(To be arranged).*

**741. Industrial Dynamics.** *Prerequisite: Ind. Eng. 641 or permission of department.* I. *(3).*
Concerned with problems involved in planning and controlling industrial change. Considers the firm as a unit continuously integrating production, marketing, investment, and research operations. Computer simulations are used to study the behavior of the firm under alternative policies.

**749. Automatic Process Control II.** *Prerequisite: Ind. Eng 649.* II. *(3).*
Continuation of Ind. Eng. 649 into study of multiple process system control and use of real time computers.

**752. Replacement and Maintenance.** *Prerequisite: Ind. Eng. 451 and 671.* II. *(3).*
Interrelation of equipment and maintenance policies, effects of uncertain product demands and possible equipment design changes on replacement policies, preventive maintenance policies and echelon maintenance systems.

**806. Seminar in Special Industrial Engineering Topics.** *Prerequisite: Ind. Eng. 463 or permission of department.* II. *(To be arranged).*

**819. Seminar in Stochastic Programming I.** *Prerequisite: permission of department.* I. *(1 or 2).*

**820. Seminar in Stochastic Programming II.** *Prerequisite: permission of department.* II. *(1 or 2).*

**836. Seminar in Human Factors Engineering.** *Prerequisite: Ind. Eng. 433 or Psych. 560.* I and II. *(To be arranged).*
Case studies of techniques used in the human engineering field. Reading, surveys, and reports on the areas of specific interest of the student.

**876. Seminar in Operations Research I.** *Prerequisite: permission of department.* I. *(1 or 2).*

**878. Seminar in Operations Research II.** *Prerequisite: permission of department.* II. *(1 or 2).*

**906. Research in Industrial Engineering.** *(To be arranged).*

**992. Thesis Project.** *(To be arranged).*

## Instrumentation Engineering

*Department Office:* 1525 East Engineering

**510. Applications of the Electronic Differential Analyzer I.** *Prerequisite: a course in differential equations.* I and II. *(3).*
Basic theory and principles of operation of electronic differential analyzers. Applications to one and two degree-of-freedom vibration problems, automatic control systems, heat-flow, eigenvalue problems, nonlinear vibration problems, and other selected topics. Lecture and laboratory. Laboratory consists of the solution of problems on the electronic differential analyzer.

**530. Probability in Instrumentation.** *Prerequisite: Math. 450.* I and II. *(2).*
Probability theory and probability distributions as applied to measurements; averages, moments, correlation, and independence; the gaussian distribution; statistics of measurements; propagation of precision indices; maximum likelihood estimation and confidence intervals; least squares fitting of data; reliability.

**570. Principles of Automatic Control I.** *Prerequisite: Math. 404 or equivalent.* I and II. *(3).*
Transient and steady-state analysis of linear control systems; transfer operators; stability determination. Synthesis of linear control systems using the root-locus diagram. Nyquist plots, and gain-phase methods. Analysis of nonlinear control systems, including phase-plane and describing-function methods.

**571. Automatic Control Laboratory I.** *Prerequisite: preceded or accompanied by Instr. Eng. 570.* I and II. *(1).*
Introduction to the differential analyzer; its application to simulation of control systems presented in Instr. Eng. 570; the differential analyzer as a design tool. Examples of actual feedback systems, a.c. carrier systems.

**610. Applications of the Differential Analyzer II.** *Prerequisite: Instr. Eng. 510 or equivalent. (3).*
Analog computer solutions of a wide variety of static and dynamic engineering problems. Solution of linear and nonlinear partial differential equations using separation of variables and lumped-parameter techniques; hybrid solution of optimization problems; error analysis of analog and hybrid computers. Lecture and laboratory.

**612. Design of Electronic Analog Computers.** *Prerequisite: Elec. Eng. 438 or equivalent and Instr. Eng. 570 or Elec. Eng. 545. (3)*
Theory of operational amplifiers, including stability, reliability, and drift-effects and their influence on d.c. amplifier circuitry. Drift-stabilized d.c. amplifiers. Design of integrators, summers, and operational amplifier circuits. Design of servomultipliers, time-division multipliers, function-generators, drift-stabilized power supplies, and other selected topics. Lectures and laboratory.

**620. Introduction to Nonlinear Systems.** *Prerequisite: Math. 404 and 450.* I and II. *(3).*
Study of systems represented by nonlinear autonomous (unforced) differential equations, including the following: concept of phase space; equilibrium points and their stability; conservative systems; limit cycles; jump phenomena; Van der Pol's equation; index of Poincare; theorems of Bendixson; the direct stability method of Liapunov. Many physical examples are used to illustrate the theory. Solutions are illustrated on the electronic differential analyzer.

**621. Simulation and Solution of Nonlinear Systems.** *Prerequisite: Instr. Eng. 510 and preceded or accompanied by Instr. Eng. 620 or permission of instructor. (1).*
Supervised work on assigned problems and problems of interest to the student of the types treated in Instr. Eng. 620 and 720. The principal tool used is the electronic differential analyzer.

**630. Random Processes in Linear Systems.** *Prerequisite: Math. 448 and a course in probability.* I and II. *(2).*
The concept of random signals and noise as applied to problems in communication and control; autocorrelation functions and wide-sense stationarity; the random telegraph wave, amplitude and phase modulation by random signals, and other examples; the notion of ergodicity and experimental measurement of autocorrelations; spectral density and its computation; linear systems with noise or random signal inputs; representation of band-pass filter outputs; design of simple optimum (Wiener) predictors.

**640. Information Theory and Data Transmission.** *Prerequisite: Instr. Eng. 630, Elec. Eng. 438, and Math. 448. (3).*
Role and characteristics of transmission links; modulation and multiplex theory in the light of signal-to-noise improvement, crosstalk, and improvement thresholds. Modulation and multiplex methods include amplitude, frequency, phase, subcarrier, pulse-amplitude, pulse-width, pulse-position, and pulse-code. Information efficiencies of the above methods; transducers and various methods of data recording.

**641. Radio Telemetry Laboratory.** *Prerequisite: to be taken concurrently with or following Instr. Eng. 640. (1).*
Laboratory experiments involving the various modulation and multiplex methods and associated instrumentation described in Instr. Eng. 640.

**660. Theory and Design of Measuring Systems.** *Prerequisite: Instr. Eng. 630 and Math. 448. (2).*
The nature of measurement, dimensional analysis and units, physical theories and models. Analysis of dynamic response and errors. Statistical aspects of measurement including estimation of parameters and information theory. Design of measuring systems. Analysis of instruments and systems to measure such things as displacement, velocity, acceleration, and orientation.

**661. Measurement Laboratory.** *Prerequisite: to be taken concurrently with or following Instr. Eng. 660. (1).*
Laboratory experiments covering the measurement theory given in Instr. Eng. 660.

**670. Principles of Automatic Control II.** *Prerequisite: Instr. Eng. 570 and Math. 448 or equivalent.* I and II. *(3).*
Time domain description of linear and nonlinear systems; system state, vector differential equations, matrix methods for solution of linear systems. Time domain design procedures. Application of Liapunov's direct method to the stability analysis and design of linear and nonlinear systems. State space treatment of nonlinear systems; optimum systems, the Pontryagin principle. Sampled-data control systems; the z-transform, the advanced z-transform, stability determination, time and frequency domain synthesis procedures, the digital computer as a control element.

**671. Automatic Control Laboratory II.** *Prerequisite: preceded or accompanied by Instr. Eng. 670.* I and II. *(1).*
Design and use of operational amplifiers as control system elements. Experiments on the describing function, simulation of nonlinear systems, the Pontryagin principle, sampling, and sampled-data feedback systems.

**700. Theory of Linear Time-Variant Systems.** *Prerequisite: Math. 448. (2).*
Linear time-variant systems with finite number of degrees of freedom; general theory of linear dynamical systems, Green's function, adjoint systems, perturbation equations and methods, Floquet theory, the Brillouin-Wentzel-Kramers method, matrix methods, the time-variant impulse response and transfer function, operational methods, and computer techniques. Applications to automatic control and filtering.

**720. Theory of Nonlinear System Response.** *Prerequisite: Instr. Eng. 620. (2).*
Principally considered are forced systems with nonlinearities and a finite number of degrees of freedom, as represented by systems of nonlinear ordinary differential equations containing functions of the independent variable. Harmonic and subharmonic response and synchronization and entrainment of oscillatory systems are considered. Various methods of analysis are treated.

**730. Random Processes in Systems Analysis.** *Prerequisite: Instr. Eng. 630 or equivalent, Math. 448. (3).*
Axiomatic treatment of probability and random processes; stationarity and ergodicity; characteristic functions; multivariate gaussian distributions and moments; linear and nonlinear systems with gaussian inputs; estimation of spectra from measurements; Poisson processes and the shot effect; integral equations for filtering and prediction; application of the Karhunen-Loeve expansion to the design of optimum systems.

**732. Special Topics in Random Processes.** *Prerequisite: Math. 448 or equivalent; Instr. Eng. 730 or Elec. Eng. 634 or equivalent. (3).*
Topics of current research interest to be selected from among the following: detection theory, nonlinear devices with random inputs, generalizations of Wiener optimum filtering, estimation of spectra, noise in sampled-data systems.

**771. Principles of Automatic Control III.** *Prerequisite: Instr. Eng. 670, Math. 448, or permission of instructor. (3).*
Review of problems in modern control theory. Foundations: mathematical models of physical systems, matrices and finite dimensional vector spaces, solution of equations of motion. Some linear control problems; the concept of controllability. Optimum control theory: the calculus of variations, the principle of optimality, the Hamilton-Jacobi equation, the Pontryagin principle, existence theory and related topics, applications. The computation of optimal controls, including the gradient method and dynamic programming.

**772. Special Topics in Automatic Control.** *Prerequisite: Instr. Eng. 771 or permission of instructor. (To be arranged).*
Topics of current research interest to be selected from such areas as: computer control, multivariable system design, theory of optimalizing systems, and theory of adaptive and stochastic systems.

**800. Seminar.** *(To be arranged).*

**810. Seminar on Electronic Analog Computers.** *Prerequisite: open only to graduates and seniors who receive special permission. (To be arranged).*
Study of selected topics in design and application of electronic analog computers.

**820. Seminar in Nonlinear Systems.** *(To be arranged).*

**830. Seminar in Random Processes.** *(To be arranged).*

**840. Seminar in Data Transmission.** *(To be arranged).*

**870. Seminar in Automatic Control.** *(To be arranged).*

**900. Directed Study.** *(To be arranged).*
Individual study of specialized aspects of instrumentation engineering.

**902. Research.** *(To be arranged).*
Specialized individual or group problems of research or design instrumentation supervised by a member of the staff.

## Mathematics*

*Department Office:* 3216 Angell Hall

Professor Hay; Professors Bartels, M. Brown, Brumfiel, Cesari, Churchill, Coburn, Copeland, Craig, Darling, Dolph, Dushnik, Dwyer, Fischer, Gehring, Halmos, Harary, Heins, Higman, P. S. Jones, Kaplan, Kazarinoff, LeVeque, Lewis, Lyndon, McLaughlin, Mayerson, Nesbitt, Piranian, Rainville, Reade, Savage, Shields, Thrall, Titus, Wendel, and Wilder; Associate Professors A. Brown, Clarke, Dickson, Galler, Halpern, Hill, Kincaid, Kister, Leisenring, Livingstone, Minty, Raymond, Ullman, and Wesler; Assistant Professors Berk, Bennett, Cohn, Douglas, Duren, Eggan, Goldberg, Hedstrom, Hicks, D. A. Jones, Lee, O'Neill, Pearcy, Ramanujan, and Rosen; Instructors Brumer, Gundy, Krause, Natzitz, Smith, Smoller, and Stark. Lecturer Arden.

**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.

**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).* (No credit for students presenting high school credit for trigonometry).
Includes the trigonometry of Math. 105.

**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 and II. *(4).*
Review of school algebra, binomial theorem; functions and graphs; derivatives, differentiation of algebraic and trigonometric functions, applications; definite and indefinite integrals, applications to polynomial functions.

**116. Analytic Geometry and Calculus II.** *Prerequisite: Math. 115.* I and II. *(4).*
Differentiation and integration of logarithmic and exponential functions; formal integration; determinants; polynomials and curve sketching; conic sections; rotation of axes, polar co-ordinates.

* College of Literature, Science, and the Arts. Other courses in mathematics are listed in the *Announcements* of that College and of the Horace H. Rackham School of Graduate Studies.

**185, 186. Analytic Geometry and Calculus I and II.** *Prerequisite: permission of the Honors or the Unified Science counselor, or instructor.* 185, I; 186, 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, 215, and 315.

**195, 196. Analytic Geometry and Calculus.** *Prerequisite: permission of the Honors counselor or instructor.* 195, I; 196, II. *(4 each).*
For superior students having outstanding high school records in mathematics. The sequence Math. 195, 196, 295, 296, 495 includes the content of Math. 115, 116, 315, 316, 451, with deeper penetration into many topics and with additional material.

**213, 214. Calculus I and II.** *Prerequisite: for 213, a semester of college analytic geometry; for 214, 213.* I and II. *(4 each).*
This sequence includes the calculus content of Math. 115, 116 and the material of Math. 215 and 315.

**215. Analytic Geometry and Calculus III.** *Prerequisite: Math. 116.* I and II. *(4).*
Vector algebra, solid analytic geometry, partial derivatives, vector calculus, multiple integrals.

[**216. Calculus and Differential Equations.** Not offered 1965–66.] Students should elect Math. 315 *(2)*, and 316 *(2)*.

**273. Elementary Computer Techniques.** *Prerequisite: to be preceded by or taken concurrently with Math. 186, 196, 213, or 215.* I and II. *(1).*
To cover mathematical methods used on electronic computers and the ways one communicates with a computer. Students will have the opportunity to write a program for the computer.

**285. Analytic Geometry and Calculus III.** *Prerequisite: Math. 186.* I. *(4).*
Continuation of the sequence Math. 185, 186.

**286. Differential Equations.** *Prerequisite: Math. 285.* II. *(3).*
For well-qualified students. Material covered is approximately that included in Math. 316 and 404, with some deeper penetrations.

**295, 296, 495. Analysis I, II, III.** *Prerequisite: Math. 195, 196.* 295, I; 296, II; 495, I. (295, 296, *4 each;* 495, *3*).
Designed primarily for mathematics Honors students who have had Math. 195 and 196. The material covered is approximately that of Math. 315, 316, and 451, but there is a deeper penetration into many topics.

**315. Infinite Series.** *Prerequisite: Math. 215.* I and II. *(2).*
A re-examination of the limit concept; infinite sequences; infinite series; power series; trigonometric series.

**316. Introduction to Differential Equations.** *Prerequisite: to be preceded by or taken concurrently with Math. 214 or Math. 315.* I and II. *(2).*
Solutions and applications of differential equations of the first order, linear equations with constant coefficients, solutions by means of power series.
NOTE.—Math. 315 and 316 together are equivalent to Math. 216.

**404. Differential Equations.** *Prerequisite: Math. 316.* I and II. *(3).*
Systems approach to linear differential equations and physical applications. Simultaneous linear equations, solution by matrices. Power series solutions. Numerical methods. Phase plane analysis of nonlinear differential equations.

**405. Differential Equations.** *Prerequisite: freshman and sophomore mathematics, including a full treatment of calculus.* I. *(4; 3 for students with full credit for Math. 316).*
The material on differential equations covered in Math. 316 and 404.

**412. Theory of Equations and Determinants.** *Prerequisite: to be preceded or accompanied by Math. 315.* I and II. *(3).*
Integers, rational numbers, real numbers, complex numbers; fields and domains; polynomials; divisibility; solution of polynomial equations; symmetric functions; determinants.

**425. Mathematical Theory of Probability I.** *Prerequisite: Math. 316.* I and II. *(3).*
Sample spaces, axioms of probability, combinatorial and geometrical probability. Random variables, expectations. Independence, conditional probability, Bayes' theorem. Markov chains. Continuous and discrete distribution functions; various special distributions. Sequences of independent trials, random walks. DeMoivre-LaPlace theorem, weak law of large numbers.

**426. Mathematical Theory of Probability II.** *Prerequisite: Math. 425 and 450 or 451.* II. *(3).*
Characteristic functions; applications of uniqueness and continuity theorems; central limit theorem. Other limit theorems; three series theorem, strong law of large numbers. Poisson process and introduction to Markov processes. Random walks, recurrent events, renewal theory, first passage problems. Introduction to infinitely divisible distributions.

**440. Vector Analysis.** *Prerequisite: Math. 316.* I. *(2).*
The formal processes of vector analysis with applications to mechanics and geometry. Students cannot receive credit for both Math. 440 and 450.

**445. Celestial Mechanics.** *Prerequisite: Math. 404 and 441 or equivalent.* II. *(3).*
Mathematical theory of the motion of astronomical bodies. Problems of two, three, and n bodies.

**447. Modern Operational Mathematics.** *Prerequisite: Math. 316 and preceded by or taken concurrently with Math. 450 or 451.* I and II. *(2).*
Laplace transformation, with emphasis on its application to problems in ordinary and partial differential equations of engineering and physics; vibrations of simple mechanical systems, of bars and shafts, simple electric circuits, transient temperatures, and other problems.

**448. Operational Methods for Systems Analysis.** *Prerequisite: Math. 316 and 450 or 451.* I and II. *(4).*
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.

**450. Advanced Mathematics for Engineers I.** *Prerequisite: Math. 316.* I and II. *(4).*
Topics in advanced calculus including vector analysis, improper integrals, line integrals, partial derivatives, directional derivatives, infinite series. Students cannot receive credit for both Math. 450 and 451.

**451. Advanced Calculus.** *Prerequisite: Math. 316.* I and II. *(4).*
Continuity and differentiation properties of functions of one and several variables; the definite integral and improper definite integrals, surface integrals and line integrals, Stokes' and Green's theorem; infinite series. Students cannot receive credit for both Math. 450 and 451.

**461. Statistical Analysis I.** *Not open to students in mathematics.* I. *(3).*
Nature of statistics, distributions, measures of central value and dispersion, sampling, normal distribution, statistical inference, estimation and tests of hypotheses. Methods of computation, applications. Math. 461, followed by Math. 462, gives the student an introduction to basic methods of statistical analysis.

**462. Statistical Analysis II.** *Prerequisite: Math. 461.* II. *(3).*
Analysis of variance, regression and correlation, analysis of covariance, use of $x^2$, binomial distribution, Poisson distribution, power of a text, nonparametric statistics. Methods of computation, applications.

**465, 466. Introduction to Statistics I and II.** *Prerequisite: preceded by or taken concurrently with Math. 214 or 315.* I and II. *(3).*
Basic concepts of probability; expectation, variance, covariance; distribution functions; bivariate, marginal and conditional distributions; treatment of experimental data; normal sampling theory; confidence intervals and tests of hypotheses; introduction to regression, and to analysis of variance. Applications to problems in science and engineering are emphasized. No credit for graduate students in mathematics; such students should elect the sequence Math. 425, 562.

**473. Introduction to Digital Computers.** *Prerequisite: Math. 316; Math. 273 recommended.* I and II. *(3).*
Characteristics and logic of general purpose high-speed digital computers; introduction to logical design. The concept of algorithm, language, and symbol manipulation as applied to computer instruction. Computational methods for linear systems, differential equations, linear programming, etc. Laboratory work in programming the IBM 7090 computer.

**474. Numerical Analysis.** *Prerequisite: Math. 404, 513 or 515, and 473, or equivalent.* I. *(3).*
The mathematics used with high-speed electronic computing machines. Presents attacks on: integration of ordinary differential equations, solution of large-scale linear systems, determination of eigenvalues and eigenvectors, integration of partial differential equations, function evaluation; coding and solution of problems on IBM 7090 computer.

**513. Introduction to Matrices.** *Prerequisite: Math. 412 or permission of instructor.* I and II. *(3).*
Vector spaces; linear transformations and matrices, equivalence of matrices and forms, canonical forms; application to linear differential equations.

**517. Introduction to Linear Algebra and Its Application.** *Prerequisite: one course beyond calculus or permission of instructor.* I and II. *(3).*
Boolean algebra and elements of set theory; matrix operation; equivalence, congruence, and similarity of matrices and forms; emphasis on applications. Intended primarily for students in engineering and social sciences.

**518. Optimization in Linear Systems.** *Prerequisite: Math. 517 or permission of instructor.* II. *(3).*
Solution of linear equations; linear inequalities and convex geometry; linear programming; simplex method; two-person zero-sum games, n-person games. Emphasis on applications of these topics. Students in mathematics should elect Math. 627.

**540. Theory of Potential Function.** *Prerequisite: Math. 450 or 451.* II. *(3).*
Newtonian attraction, Newtonian and logarithmic potentials, equations of Laplace and Poisson, harmonic functions, principle of Dirichlet, problems of Dirichlet and Neumann, and Green's function.

**552. Fourier Series and Applications.** *Prerequisite: Math. 450 or 451.* I and II. *(3).*
Orthogonal functions, Fourier series, Bessel functions, Legendre polynomials, and their application to boundary value problems in mathematical physics.

**554. Advanced Mathematics for Engineers II.** *Prerequisite: Math. 450.* I and II. *(4). Not open to students with credit for Math. 552 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).*
Complex numbers; limit, continuity; derivative; conformal representation; integration; Cauchy theorems; power series; singularities; applications to engineering and mathematical physics.

**557. Intermediate Course in Differential Equations.** *Prerequisite: Math. 450 or 451.* I and II. *(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.

**560. Theory of Survey Sampling.** *Prerequisite: Math 466 or 562, or permission of instructor.* I. *(3).*
The mathematical theory of the principal sampling methods used in social and economic surveys. Simple random sampling, stratified sampling, ratio and regression estimates, systematic sampling, subsampling and double sampling, cost functions and choice of optimum sample designs, estimational procedures.

**562. Mathematical Statistics.** *Prerequisite: Math. 425 and preferably 517.* I and II. *(3).*
Theories of statistical inference, distributions important in statistics, estimation and testing of hypotheses. Students may not receive credit for both Math. 466 and 562.

**563. Quality Control and Engineering Statistics.** *Prerequisite: Math. 466 or equivalent.* I. *(3).*
Process control; properties and applications of control charts. Acceptance sampling plans by attributes and by variables. Introduction to the analysis of variance and to linear regression.

**565. Least Squares and the Analysis of Variance.** *Prerequisite: Math. 562 or permission of instructor.* I. *(3).*
Geometry and statistics of linear hypotheses. Geometrical aids to least squares computation: illustrated by multiple regression, escalator methods, analysis of variance in various simple layouts (blocks, latin squares, factorial layouts), missing and extra observations, the analysis of covariance, and confounding. Related statistical situations; components of variance, split plots; randomized layouts; transformation of variables.

**566. Design of Experiments.** *Prerequisite: Math. 565.* II. *(3).*
The goals and devices of design with special reference to layouts and the analysis of covariance. The main combinatorial layouts, their uses and limitations. Sequential aspects of design, especially in the search for conditions of maximal yield; optimal allocation of observations; design considerations remote from layouts; and parallels with the theory of sampling.

**573. Automatic Programming.** *Prerequisite: Math. 473.* II. *(3).*
Topics in automatic programming of digital computers, including the structure of compilers and assemblers, the use of macroinstructions, the structure and use

of executive systems, list storage, threaded lists, and automatic programming languages.

**590. Introduction to General Topology.** *Prerequisite: Math. 451.* I and II. *(3).*
General topological spaces and their properties; mappings, connectedness; metrization; compactifications; completions; product spaces; imbedding; quotient spaces.

**594. Intermediate Analysis for Engineers.** *Prerequisite: Math. 450.* I. *(3).*
Basic ideas of advanced calculus, such as uniform continuity, with emphasis on rigorous proofs; some set theory and introduction to metric spaces; some linear algebra.

**653. Tensor Analysis.** I. *(3).*
Definition of tensors; tests for tensor character; manifolds; geodesics; absolute derivatives, covariant and controvariant derivates; the curvature tensor; relative tensors; Cartesian tensors; applications to mechanics, elasticity, hydrodynamics, heat conduction, electricity, and magnetism.

**654. Mathematics of Relativity.** II. *(3).*
Special relativity, general relativity, theories of the universe, unified field theories.

**749. Methods of Partial Differential Equations.** *Prerequisite: Math. 447, 552, and 555.* I and II. *(3).*
Theory and application of the solution of boundary value problems in the partial differential equations of engineering and physics by various methods; orthogonal functions, Laplace transformation, other transformation methods. Green's functions.

**751. Methods of Mathematical Physics I.** *Prerequisite: Math. 450, 552, and 555.* I. *(3).*
Regular integral equations, Sturm-Liouville systems. Asymptotic developments by saddle point and stationary phase methods. First-order partial differential equations.

**752. Methods of Mathematical Physics II.** *Prerequisite: Math. 751 or permission of instructor.* II. *(3).*
Classification of partial differential equations, representation theorems. Selected topics, such as direct methods and singular differential and integral equations.

**754. Advanced Partial Differential Equations.** *Prerequisite: Math. 701 or permission of instructor.* II. *(3).*
Modern developments in the theory of partial differential equations.

**757. Special Functions in Classical Analysis.** *Prerequisite: permission of instructor.* I. *(3).*
Gamma, Bessel, Legendre, hypergeometric, and elliptic functions. Polynomials of Legendre, Hermite, Laguerre, and Jacobi. The Sheffer classification and Sister Celine's technique.

**758. Ordinary Differential Equations.** *Prerequisite: Math. 602.* I. *(3).*
Existence theorems, linear systems, Sturm-Liouville theory.

**773. Advanced Numerical Analysis.** *Prerequisite: Math. 474 or permission of instructor.* II. *(3).*
Truncation, round-off and propagation error analysis for the solution of linear and nonlinear functional equations using a large hyphen-scale digital computer. Solution of partial differential equations by numerical techniques. Laboratory work in solution of one or more of such problems using the IBM 7090 computer.

## Mechanical Engineering

*Department Office:* 225 West Engineering

**251. Manufacturing Processes I.** *Prerequisite: Chem.-Met. Eng. 250 and preceded or accompanied by Eng. Mech. 210 or Eng. Mech. 310.* I and II. *(3).*
Fundamentals of manufacturing processes. Effect of the process on surface condition, residual stresses, strain hardening, wear, and failure. Influence of the mechanical properties of materials on the process. Material selection for processing and design. Two recitations and one three-hour laboratory.

**252. Engineering Materials and Manufacturing Processes.** *Prerequisite: Chem.-Met. Eng. 250.* I and II. *(2).*
Correlation of the structure of metals with their mechanical properties; control of mechanical properties by modifying the microstructure; mechanical properties of commonly used metals; failure by corrosion; relations between mechanical properties and the manufacturing processes of casting, welding, plastic working, machining, and heat-treating. One lecture, one problem period, and two hours of laboratory.

**324. Fundamentals of Fluid Machinery.** *Prerequisite: Mech. Eng. 335 and Eng. Mech. 324.* I and II. *(4).*
Review of fundamental laws of fluid mechanics. Control volume analyses. One-dimensional compressible flow theory. Basic principles of turbo-machines. Compressor, turbine, and pump analyses. Three lectures and one three-hour laboratory.

**331. Classical and Statistical Thermodynamics.** *Prerequisite: Physics 145 and Math. 215.* I and II. *(4).*
Basic thermodynamics, first law, second law, properties of a pure substance, ideal gases and gaseous mixtures, application to heat-power machinery. Introduction to statistical thermodynamics and evaluation of thermodynamic properties. Not open to mechanical engineering students.

**333. Thermodynamics.** *Prerequisite: Physics 145 and Math. 215.* I and II. *(3).*
Basic thermodynamics, first law, second law, properties of a pure substance, ideal gases, and gaseous mixtures. Application to heat-power cycles. Not open to mechanical engineering students.

**335. Thermodynamics I.** *Prerequisite: Physics 145 and Math. 116.* I and II. *(3).*
Basic course in engineering thermodynamics. First law, second law, properties of a pure substance, ideal gases, mixtures of ideal gases and vapors, availability.

**336. Thermodynamics II.** *Prerequisite: Mech. Eng. 335 and Math. 316 and 273.* I and II. *(4).*
Continuation of Mech. Eng. 335. Power and refrigeration cycles; general thermodynamic relations, equations of state, and compressibility factors; chemical reactions; combustion; gaseous dissociation. Three one-hour lectures and one three-hour laboratory.

**337. Mechanical Engineering Laboratory.** *Prerequisite: preceded or accompanied by Mech. Eng. 335.* I and II. *(2).*
Demonstration and application of basic principles in various areas of mechanical engineering; instrumentation and the reliability of measurements; behavior and nature of typical machinery and equipment. One four-hour period. Not open to mechanical engineering students.

**340. Dynamics of Mechanical Systems.** *Prerequisite: Eng. Mech. 343.* I and II. *(4).*
The principles of kinematics and dynamics applied to the analysis of mechanical

systems. Transient and steady-state vibrations of simple mechanical systems. Three one-hour periods and one three-hour laboratory.

**343. Mechanical Design.** *Prerequisite: Eng. Mech. 343, 210 or 310. Not open to mechanical engineering students.* I and II. *(3).*
Application of the fundamentals of engineering science to mechanical design and analysis. Dynamic force analysis. Transient and steady state vibrations in simple mechanical systems. Combined stresses, fatigue, failure theories. Analysis and design of representative mechanical components and systems.

**344. Mechanical Analysis Laboratory.** *Prerequisite: accompanied by Mech. Eng. 343. Not open to undergraduate mechanical engineering students.* I and II. *(1).*
Study of dynamic characteristics of various mechanical systems. Instrumentation used includes double beam cathode ray oscilloscopes, potentiometers, transformers, solar cells, photo-tubes, strain gages and other electro-mechanical transducers.

**362. Mechanical Design I.** *Prerequisite: Eng. Mech. 210 or 310 and preceded or accompanied by Mech. Eng. 251 or 381.* I and II. *(3).*
Introduction to the design process; morphology of design, creativity; optimization. Conceptual problems in mechanical design. Application of the fundamentals of engineering mechanics, materials, and manufacturing to the analysis and design of mechanical elements and systems.

**381. Manufacturing Processes II.** *Prerequisite: Mech. Eng. 251.* I and II. *(4).*
Correlations between material properties and the manufacturing processes; analysis of forces, energy requirements, and temperature effects; design specifications economically obtainable in terms of dimensional accuracy, surface finish, and material properties; functional characteristics of equipment. Three recitations and one two-hour laboratory.

**398. Heating and Ventilating.** I and II. *(3).*
Theory, design, and construction of warm-air, steam, hot-water, and fan-heating systems; air conditioning and temperature control. Lectures, recitations. For architects only.

**408. Experimental Research in Mechanical Engineering.** *Prerequisite: senior standing and permission of instructor.* I and II. *(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. Two four-hour laboratories per week. Time to be arranged.

**417. Plastic Forming of Metals I.** *Prerequisite: Mech. Eng. 251 and Math. 316.* I. *(3).*
Plastic deformation of metals with respect to their mechanical properties and metallurgical characteristics. Introduction to Cartesian tensors; analysis of stress, strain, and displacement; elastic stress-strain relations; yielding criteria; theory of dislocation and slip mechanism; plastic stress-strain relations, theory and experimental data; temperature and strain-rate effect; work of deformation; slip line fields.

**421. Dynamics and Thermodynamics of Compressible Flow.** *Prerequisite: Mech. Eng. 366 and 471.* I and II. *(3).*
Review of basic equations of fluid mechanics and thermodynamics in control

volume form, one dimensional, compressible flow involving area change, normal shocks, friction, heat transfer, and combined effects. Two dimensional supersonic flow including linearization, method of characteristics, and oblique shocks. One dimensional, constant area, unsteady flow.

422. **Design Theory and Fluid Machinery.** *Prerequisite: Mech. Eng. 324.* I. *(3).*
Advanced development of the laws of thermodynamics, laws of motion and flow of fluids as applied to the design theory of axial- and radial-flow turbo-machinery.

432. **Combustion.** *Prerequisite: Mech. Eng. 336, preceded or accompanied by Mech. Eng. 471 or equivalent.* II. *(3).*
Introduction to combustion processes, reaction kinetics, ignition and flame propagation. Combustion of sprays. Detonation, temperature, and radiation. Spectographic analysis. Optical methods for combustion studies. Otto, diesel, gas turbine, and rocket combustion.

437. **Applied Energy Conversion.** *Prerequisite: Mech. Eng. 336 or equivalent.* II. *(3).*
Economic conversion of natural energy in stationary power plants. Major topics treated: combustion practice, steam generation, steam turbines, diesel engine power plants, hydraulic power plants, gas turbines, nuclear energy power plant economics, load curves, energy rates. Selected power plant problems are assigned.

**439(Chem.-Met. Eng. 439). Combustion and Air Pollution Control.** *Prerequisite: permission of instructor.* II. *(3).*
Fundamentals of combustion as related to furnaces, internal combustion engines and process plants, emphasizing formation and control of gaseous and particulate air contaminants.

**460. Mechanical Design IIa.** *Prerequisite: Mech. Eng. 340 and 362.* I and II. *(4).*
Continuation of the study of mechanical elements and systems. Design project with emphasis on the structure and dynamics of a mechanical system, including synthesis analysis, critique, layout and report. Two lectures and one two-hour design period.

**461. Automatic Control.** *Prerequisite: Math. 404, Mech. Eng. 340, Elec. Eng. 442.* I or II. *(3).*
Analysis of linear feed-back control with emphasis on mechanical systems. Transient and steady-state frequency response. Stability criteria. Systems performance compensation methods. Analysis of hydraulic, pneumatic, and inertial guidance components and systems. Introduction to nonlinear systems.

**462. Mechanical Design IIb.** *Prerequisite: Mech. Eng. 324, 336, 362, preceded or accompanied by Mech. Eng. 471.* I and II. *(4).*
Continuation of the study of mechanical elements and systems. Design project with emphasis on the thermal and fluid aspects of mechanical systems, including synthesis, analysis, critique, layout, and report. Two lectures and one two-hour design period.

**463. Wear Considerations in Design.** *Prerequisite: Mech. Eng. 343 or 362.* II. *(3).*
Design of machine members to avoid surface damage due to wear, pitting, scoring, frettage, and cavitation. Application to the design of press-fitted, keyed, and bolted assemblies; bearings, gears, cams, pumps, and liners.

**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.

**467. Theory of Lubrication.** *Prerequisite: Math. 404, and preceded or accompanied by Mech. Eng. 324.* I. *(3).*
Modes of lubrication, physical chemistry and rheology of lubricants, hydrostatic and hydrodynamic lubrication in journal and thrust bearings including gas bearings, thin film hydrodynamic and boundary lubrication, dry friction, grease lubrication, lubrication of rolling surfaces, bearing materials.

**471. Heat Transfer I.** *Prerequisite: Mech. Eng. 335 and Eng. Mech. 324.* I and II. *(4).*
Study of the mechanisms of heat-transfer processes. Steady and transient conduction in solids, numerical and graphical methods; heat-exchanger design, performance; thermal radiation; convective processes, turbulent and laminar flow, steady and transient diffusion, mass transfer between phases. Three one-hour lectures and one three-hour laboratory.

**480. Design of Manufacturing Equipment.** *Prerequisite: Mech. Eng. 362.* I. *(3).*
Specification, design, construction, and operation of production machines and allied tooling. Consideration of bearings, lubrication, motors, controls and materials. Hydraulic and electric control units and circuits.

**482. Manufacturing Engineering.** *Prerequisite: Mech. Eng. 381.* I and II. *(4).*
Application of fundamental principles to problems arising in manufacturing. Particular attention is devoted to planning operations, designing special equipment, statistical quality control, cost analysis and reduction, and similar functions which engineers perform in connection with manufacturing. Two lectures and two three-hour laboratories.

**483(Ind. Eng. 483). Numerical Control of Manufacturing Processes.** *Prerequisite: Ind. Eng. 473 or Mech. Eng. 482 and permission of instructor.* II. *(3).*
Basic elements of numerical control of metal processing systems: development of programming languages for point to point and contouring machines; interaction between geometry and machinability decisions. Laboratory experiments in optimizing part programming and equipment utilization. Two one-hour lectures and one two-hour laboratory.

**484. Gas Welding Processes.** *Prerequisite: Mech. Eng. 251 or 252 or permission of instructor.* I and II. *(2).*
Principles and applications in gas welding, brazing, flame cutting and metallizing. Welding metallurgy, stress analysis, heat treatment, and inspection techniques. Equipment, plant layout, supervision, certification, production procedures, cost analysis, and safety practices. One-hour lecture and a three-hour laboratory. Graduate credit not allowed for mechanical and industrial engineering students.

**485. Electric Welding Processes.** *Prerequisite: Mech. Eng. 251 or 252 or permission of instructor.* I and II. *(2).*
Electric arc, inert arc, automatic arc, and resistance welding techniques and applications. Welding metallurgy, stress analysis, micro-preparations and examinations. Testing and inspection of weldments. Welding of aluminum and high-temperature alloys. Introduction of research problems. One-hour lecture and a three-hour laboratory. Graduate credit not allowed for mechanical and industrial engineering students.

**486. Manufacturing Considerations in Design.** *Prerequisite: Mech. Eng. 343 or 362.* II. *(3).*
Correlation between functional specifications and process capabilities. Study of tolerances on basis of fabricability. Case studies in process engineering, including standards application. Problems in redesign for producibility.

**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. Machinability Theory.** *Prerequisite: Mech. Eng. 340 and 381.* I. *(3).*
Metal cutting theory and its relation to practical problems. Basic theories on mechanics of the shear zone, flow stress, friction, energy conversion, temperature, vibration, and wear mechanisms. Study of current literature on problems concerning size control, residual stresses, surface finish, and tool life.

**491. Heating and Air Conditioning.** *Prerequisite: Mech. Eng. 335* I. *(3).*
Theory and design of warm-air, steam, hot-water, and radiant-heating systems; moisture and temperature control; cooling and air conditioning; fans, air flow; exhaust systems.

**492. Design of Heating and Air-Conditioning Systems.** *Prerequisite: Mech. Eng. 491.* II. *(3).*
The student is given the usual data furnished the heating and ventilating engineer. He then makes a layout of piping, ducts, and auxiliary apparatus, with computations for the size of principal equipment. Two four-hour periods.

**496. Internal-Combustion Engines I.** *Prerequisite: Mech. Eng. 336.* I and II. *(3).*
Comparison of characteristics and performance of the 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. *(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.

**501 to 513, inclusive.**
These courses are offered at University of Michigan Centers outside of Ann Arbor. For course titles, prerequisites, and credits see the *Announcement* of the Horace H. Rackhom School of Graduate Studies. For complete descriptions, see the *Announcement* of the University of Michigan Dearborn Center. These courses will also be scheduled in the Extension Service bulletins. They are approximately equivalent to Ann Arbor campus courses as follows: Mech. Eng. 501 and 502 to Mech. Eng. 540; Mech. Eng. 503 and 504 to 556; Mech. Eng. 505 and 506 to 535; Mech. Eng. 507 and 508 to Mech. Eng. 571; Mech. Eng. 509 and

510 to Mech. Eng. 524; Mech. Eng. 511 and 512 to Mech. Eng. 550. Credit will not be granted to students who have completed the corresponding courses.

**516. Special Topics in Mechanical Engineering.** *Prerequisite: senior standing and permission of instructor. (To be arranged).*
Selected topics pertinent to mechanical engineering.

**517. Plastic Forming of Metals II.** *Prerequisite: Mech. Eng. 417 or equivalent.* II. *(3).*
Application of the principles of plasticity to the forming processes. Analysis of extrusion of ideal plastic materials and strain hardening materials. Analysis of wire drawing, rolling, forging, and deep drawing. Application of slip lines to extrusion and forging. Bendability of metals.

**524. Fluid Mechanics II.** *Prerequisite: Eng. Mech. 324 and Math. 450 or 451.* I. *(3).*
Derivation of the basic differential equations of fluid mechanics. Special types of flow; viscous flows; incompressible boundary layer flow; methods of solution; flow stability, applications.

**531. Statistical Thermodynamics.** *Prerequisite: Mech. Eng. 331 or 336, Math. 316.* 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 II. *(3).*
Definitions and scope of thermodynamics; first and second laws. Maxwell's relations, Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.

**539. Cryogenics and Refrigeration.** *Prerequisite: Mech. Eng. 336 and preceded or accompanied by Mech. Eng. 471.* II. *(3).*
Theoretical and design aspects of producing temperatures below ambient. Vapor compression systems; absorption systems; liquefaction and separation of air; liquefaction and properties of cryogenic fluids; insulation problems; and unique phenomena at extremely low temperatures.

**540. Mechanical Vibrations.** *Prerequisite: Math. 404, Mech. Eng. 340 or 343.* I and II. *(3).*
A study of shock and impact on mechanical systems and machines. Analysis, reduction, and isolation of vibrations. Mounting of machines and equipment; critical speeds and torsional vibrations of rotors; vibration absorbers and dampers. Solution of steady-state and transient vibration problems by mathematical, graphical, and analog solutions.

**541. Synthesis of Mechanisms.** *Prerequisite: Math. 216 and Mech. Eng. 340 or 343.* I. *(3).*
Vector and complex function analysis of mechanisms with emphasis on space mechanisms. A survey of various methods used in synthesis of linkages. Kinematically equivalent linkages. Analysis and design of cams. Mechanical computing mechanisms. Mechanism trains.

**550. Mechanical Behavior of Solids I.** *Prerequisite: Mech. Eng. 381.* I. *(3).*
Atomic mechanisms involved in plastic deformation and fracture of solids. Quantum theory and atomic bonding forces. Behavior of single crystals and polycrystalline solids. Dislocation theories and observations. Elastic and plastic stress-strain relationships. Fundamentals of brittle and ductile fracture.

**551. Mechanical Behavior of Solids II.** *Prerequisite: Mech. Eng. 550.* II. *(3).*
Mechanisms of fatigue in solids. Internal friction. Surface phenomena. Effects of extreme environments on the mechanical behavior of solids. Radiation damage.

**556. Stress Considerations in Design.** *Prerequisite: Mech. Eng. 343 or 362.* I and II. *(3).*
Treatment of stress and strength aspects of machine design. Analytic and experimental determination of stresses in machine members. Evaluation of strength under steady and fatigue loadings. Post-yield behavior, residual stresses, temperature and corrosion effects.

**562. Dynamic Behavior of Thermal-Fluid Systems.** *Prerequisite: Mech. Eng. 461 and 471.* II. *(3).*
Dynamic response of heat exchangers to thermal and flow transients; thermal circuits; analyses of the dynamic behavior of thermal-fluid systems with the analog computer.

**563. Instrumentation and Control.** *Prerequisite: a degree in engineering or permission of instructor.* II. *(3).*
Automatic controls; fluid metering; measurements of temperature, humidity, pressure, displacement, strain, speed, sound, etc.

**567. Reliability Consideration in Design.** *Prerequisite: Mech. Eng. 343 or 362 or equivalent.* I. *(3).*
Design of machines and machine members to insure reliability in field and service. The concept of value, system, and system effectiveness. Design reliability versus quality control. Techniques for predicting reliability. Design of experiments. The feedback approach to reliability. Statistical tolerances. Failure analysis.

**571. Heat Transfer II.** *Prerequisite: Mech. Eng. 471 and Math. 404.* I and II. *(3).*
Conduction heat transfer in steady and transient state, including heat sources. Analytical, numerical, graphical, and analog methods of solution for steady and fluctuating boundary conditions. Thermal stresses.

**588. Machinability Research.** *Prerequisite: Mech. Eng. 488.* II. *(4).*
Lecture and laboratory on metal-cutting research techniques. Design of dynamometers, temperature measuring methods, analysis of residual stresses, vibrations, cutting forces, chip formation, and tool wear. Two lectures and two three-hour laboratory periods per week.

**594. Internal-Combustion Engines II.** *Prerequisite: Mech. Eng. 496.* II. *(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.

**595. Automotive Engineering Research.** *Prerequisite: Mech. Eng. 497 and permission of instructor.* I and II. *(3).*
Advanced experimental and research work. Laboratory and reports.

**600. Study or Research in Selected Mechanical Engineering Topics.** *Prerequisite: graduate standing; permission of instructor who will guide the work should be obtained before classification.* I and II. *(Credit to be arranged).*
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.

**607. Mechanical Engineering Problems.** *Prerequisite: preceded by Math. 404.* I and II. *(3).*
Analysis of problems in mechanical vibrations, resonance and critical speeds, fluid-flow, thermodynamics, heat-flow, weight distribution, and strength of materials, processing, and materials.

**625. Introduction to Viscous Flow Theory.** *Prerequisite: Mech. Eng. 524 or Eng. Mech. 422 or permission of instructor.* II. *(3).*
Compressible viscous flow theory; methods of solutions of boundary layer equations; turbulent flow phenomena; turbulent boundary layer analyses; applications to problems in mechanical engineering.

**642. Simclation of Mechanical Systems.** *Prerequisite: Mech. Eng. 540.* II. *(3).*
Analysis, synthesis, and optimization of linear, multilinear, and nonlinear mechanical systems with the electronic analog computer.

**672. Heat Transfer III.** *Prerequisite: Mech. Eng. 471.* II. *(3).*
Study of the nature of convective processes involving the transfer of heat, mass, and momentum. Boundary layer theory; flow inside ducts; laminar and turbulent flow. Natural convective processes and viscous heating effects.

**673. Heat Transfer IV.** *Prerequisite: Mech. Eng. 471.* I. *(3).*
Thermal radiation process. Physics of monocromatic and total radiation. Emission and absorption. Exchange factors for black and gray surfaces and enclosures. Radiant exchange involving absorbing and emitting media, including gases and flames. Properties of solar radiation and thermal transfer in space.

**700. Professional Problems.** I and II. *(9).*
Professional degree candidate only. Student selects a problem in research, analysis, or design in any field of mechanical engineering and submits a written proposal to the Graduate Committee for approval before enrolling in course. Letter from staff member who will direct work must accompany proposal.

**772. Heat Transfer V.** *Prerequisite: Mech. Eng. 571 and 672, Math. 552, or equivalents.* I and II. *(3).*
Generalized methods of analysis applied to advanced problems in heat and mass transfer including the influence of magnetic field phenomena; transient processes in distributed fluid-solid systems having mixed boundary conditions; systems undergoing ablation and melting, transient thermal stresses.

**820. Fluids Machinery Seminar.** *Prerequisite: graduate standing and permission of instructor. (To be arranged).* I or II. Offered upon sufficient demand.
Reports and discussions on library study and laboratory research in selected topics.

**835. Seminar in Thermodynamics.** *Prerequisite: Mech. Eng. 531 and 535 or permission of instructor.* I and II. *(3).*
P-V-T behavior of pure substances and mixtures; chemical and phase equilibrium; electrochemistry and fuel cells; nonequilibrium thermodynamics; thermoelectricity; special topics.

**838. Heat-Power Seminar.** *Prerequisite: graduate standing and permission of instructor. (To be arranged).* Offered upon sufficient demand.
Reports and discussions on library study and laboratory research in selected topics.

**990.Doctoral Thesis.** *prerequisite: permission of thesis committee.* I and II. *(To be arranged.)*
Dissertation for the degree of Doctor of Philosophy supervised by the candidate's doctoral committee.

## Meteorology and Oceanography

*Department Office:* 2038 East Engineering

NOTE—*Extra work is required for graduate credit in Meteorology and Oceanography 432, 440, 441, 445, 452, and 470.*

**202. Weather, Climate, and Life.** I and II. *(3).*
An elementary description of the atmosphere, its characteristics, and behavior; weather and climate as basic factors in life and civilization.

**304. Introduction to Atmospheric and Oceanic Sciences I.** *Prerequisite: preceded or accompanied by Math. 115.* I. *(3).*
The various aspects of meteorology and oceanography with emphasis on a description of the composition, structure, and motion of the atmosphere and oceans. A nonmathematical treatment of the principles upon which the sciences are based. Lectures, term papers.

**305. Introduction to Atmospheric and Oceanic Sciences II.** *Prerequisite: Meteor.-Ocean. 304.* II. *(3).*
An introduction to the physical, chemical, biochemical, and geological processes in the atmosphere and oceans. Special emphasis on selected topics introducing the student to the various branches of aeronomy, meteorology, and oceanography. Lectures, term paper.

**306. Laboratory in Geophysical Data I.** *Prerequisite: preceded or accompanied by Meteor.-Ocean. 304.* I. *(2).*
An introduction to atmospheric and oceanic data, and their practical treatment; exercises in the analysis of geophysical data in space and time, methods of observation of different elements.

**307. Laboratory in Geophysical Data II.** *Prerequisite: preceded or accompanied by Meteor.-Ocean. 305.* II. *(1).*
Analysis of meteorological and oceanographic data, measurements of currents and winds, vertical distributions of different elements in the oceans and atmospheres, data analysis in aeronomy.

**408. Mathematical Meteorology for Engineers and Scientists.** *Prerequisite: Math. 404 and Physics 146.* I. *(3).*
Introduction to the basic thermodynamic, radiative, and dynamic processes in the atmosphere; physical analysis of wind and turbulence; cloud, precipitation, and evaporation physics; physics of the high atmosphere.

**412. Physical Climatology.** *Prerequisite: preceded or accompanied by Meteor.-Ocean. 408 or 432 or 445.* I. *(3).*
A survey of the general circulation of the atmosphere; the physical processes governing climate; solar radiation and the terrestrial heat balance; influence of large scale condensation and evaporation processes; the formal classification of climates according to zones and types; the application of climatic concepts.

**415. Statistical Methods in Meteorology I.** *Prerequisite: one year of calculus.* I. *(3).*
Distributions in time and space of meteorological elements; measures of central tendency and dispersion; distributions of scalar and vector quantities; introduction to statistical inference and significance tests; fiducial limits; regression analysis; trends and cycles; forecast verification. Lectures and laboratory exercises.

**422. Introductory Microclimatology.** II. *(3).*
The physical processes which govern microweather and microclimate; tempera-

ture, humidity, and wind near the ground in relation to height, time, soil, vegetation, and topography. Lectures and field experiments.

**432. Atmospheric Thermodynamics and Radiation.** *Prerequisite: Math. 214 and Physics 146 or equivalent.* I. *(3).*
Composition of the atmosphere; atmospheric statics; thermodynamic diagrams; solar and terrestrial radiation; the heat balance of the earth. Lectures and problems.

**440. Principles of Weather Analysis.** *Prerequisite: preceded or accompanied by Meteor.-Ocean. 408 or 432 or 445.* I. *(3).*
Air mass analysis, representative and conservative properties; detailed three-dimensional structure of fronts and pressure systems; principles of construction of prognostic pressure charts; procedures for forecasting the weather elements; the verification of weather forecasts. Lectures and problems.

**441. Laboratory in Weather Analysis I.** *Prerequisite: preceded or accompanied by Meteor.-Ocean. 440.* I. *(3).*
Construction of meteorological charts from current and past weather data. Analytical codes; measurement of geostrophic and gradient winds; graphical determination of thickness patterns; jet-stream analysis; principles of prognosis from thermodynamic diagrams, isallobaric and isobaric analyses.

**443(Zool. 443, Fish. 443). Limnology and Oceanography.** *Prerequisite: permission of instructor.* I. *(3).*
Lectures on the environmental conditions which affect the biotic assemblages in the world's aquatic habitats.

**444(Zool. 444, Fish. 444). Investigations in Limnology and Oceanography.** *Prerequisite: permission of instructor.* I. *(3).*
Discussion, laboratory, and field work dealing with interpretation of the interaction of environmental factors in natural waters. Emphasis on local habitats.

**445. Dynamic Meteorology.** *Prerequisite: Math. 214 and Physics 146 or equivalent.* II. *(3).*
The stratification of the atmosphere; the hydrostatic equation; virtual temperature; the equations of motion; barotropy and baroclinicity; stream function; circulation and vorticity; local change of pressure; atmospheric turbulence; the jet stream; weather prediction by high-speed computing methods.

**449. Marine Geology.** *Prerequisite: permission of instructor.* I. *(4).*
Characteristics of the oceanic segments of the earth's crust; basic topography and structure, sediments, sedimentary processes and environments of the oceans.

**452. Physical Meteorology.** *Prerequisite: Meteor.-Ocean. 408 or 432 or 440.* II. *(3).*
Cloud and precipitation physics; aircraft icing; radar meteorology; atmospheric electricity; atmospheric optics and visibility. Lectures and problems.

**453. Dynamic Oceanography.** *Prerequisite: Meteor.-Ocean. 305.* II. *(4).*
A general introduction to dynamic oceanography. Statics and kinematics of the oceans. Equations of motion, continuity and energy. Oceanic tides; diffusion in the ocean; ocean currents and waves; air-sea interaction; exchange processes.

**462. Meteorological Instrumentation.** *Prerequisite: Meteor.-Ocean. 408 or 432 or 445 or equivalent.* I. *(3).*
Principles of meteorological instruments; methods of measurement of pressure, temperature, humidity, precipitation, evaporation, and wind; analysis of response

characteristics; introduction to the design of single instruments and of instrument systems. Lectures, laboratory, and field trips.

**464(Aero. Eng. 464). Aeronomy I.** *Prerequisite: senior or graduate standing.* I. *(3).*
An introduction to physical processes in the upper atmosphere. The structure of the upper atmosphere: density, temperature, composition, and winds. Accoustical propagation and visible phenomena; the ionosphere. The physical basis of the techniques of satellite meteorology: solar, terrestrial and atmospheric radiation processes including transfer and heat balance.

**465(Aero. Eng. 465). Aeronomy II.** *Prerequisite: Meteor.-Ocean. 464.* II. *(3).*
High altitude observations of aeronomical and meteorological phenomena. The physical basis and need for aerodynamic, mass spectrometric and radiative experiments. Sensor characteristics. Current balloon, aircraft, rocket and satellite techniques.

**470. Applied Meteorology.** *Prerequisite: Meteor.-Ocean. 304 or 408 or equivalent.* II. *(2).*
Topics in applied meteorology, selected in accordance with the requirements of the class. Representative topics; meteorological aspects of air pollution; atmospheric phases of the hydrologic cycle; wind and precipitation loading of structures. Lectures and problems.

**472. Hydrometeorological Design.** *Prerequisite: Math. 214 and Physics 146.* I. *(2).*
Selected topics relating meteorology and hydrology; typical problems of wind and waves, intensity and persistence of drought, snow melt and stream runoff, cloud seeding. Recitation and laboratory.

**475. Meteorological Analysis and Design Criteria.** *Prerequisite: Math. 214 and Physics 146.* II. *(2).*
Statistical and graphical techniques used in meteorology; binomial, Poisson, and normal distributions; correlation and regression; statistical tests of significance; construction of nomographs. Basic concepts applied to air pollution, microwave transmission, and other fields. Recitation, laboratory, and problems.

**500. Meteorology for Teachers.** Not open to engineering students. *(2-3).*
Lectures and discussions on elementary meteorology, combined with workshop on problems of introducing meteorology into individual school programs; survey of material sources, demonstration methods, laboratory and field exercises and equipment design. For science teachers of all levels.

**531(Zool. 531). Advanced Oceanography.** *Prerequisite: permission of instructor.* II. *(4).*
Lectures and outside study of the physical, chemical, and geological factors in marine environment. Designed to bridge from simple principles to the status of present research. Waves, tides, seiches, ocean basin tectonics comprise the framework of the course.

**541. Laboratory in Weather Analysis II.** *Prerequisite: Meteor.-Ocean. 441.* II. *(3).*
Applications of prognostic methods from analyses of vorticity patterns; trajectories and fallout computations; streamlines and isogons as used in tropical analyses; vertical cross sections; vertical motion calculation; introductory demonstration of numerical weather prediction; long waves and hemispheric weather.

**566. Micrometeorological Instrumentation.** *Prerequisite: permission of instructor.* II. *(3).*
Analysis of requirements for instrumentation; measurement of radiation, tem-

perature, humidity, and wind velocity near the ground and of their fluctuations and vertical gradients; exposure and ventilation of instruments in relation to soil, terrain, vegetation, and water surfaces. Lectures, laboratory, and field studies.

**573. Air Pollution Meteorology.** *Prerequisite: permission of instructor.* I. *(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.

**595(Elec. Eng. 595). Topics in Space Research.** *Prerequisite: permission of instructor. (3).*
Significant processes in the ionosphere and upper atmosphere (e.g. ionization, dissociation, diffusion, etc.). Solar electromagnetic and corpuscular radiation. Formation of the ionosphere; heating mechanisms in the upper atmosphere; trapped particles; interplanetary plasma; atmospheres of the planets. Measurement techniques and results of recent sounding rocket and satellite experiments.

**605. Current Topics in Meteorology.** *Prerequisite: permission of instructor.* I, II, III*a*, and III*b*. *(3).*
Advances in specific fields of atmospheric and oceanic sciences, as revealed by recent research. Lectures, discussion, and assigned reading.

**615. Statistical Methods in Meteorology II.** *Prerequisite: permission of instructor.* II. *(3).*
Homogeneity of climatometric series; forecast economics; stochastic prediction; multiple regression; statistical screening; orthogonal representations; harmonic analysis; filtering and rectification of time series; power spectra; extreme values. Lectures and the solution of problems on desk calculators and on the IBM 7090.

**622. Micrometeorology.** *Prerequisite: Meteor.-Ocean. 432 or 445 or permission of instructor.* II. *(3).*
Physical processes in the atmosphere near the ground; laminar and turbulent flow; transfer of heat, mass and momentum; eddy diffusion; evaporation from natural surfaces. Lectures and problems.

**675(Zool. 675). Current Problems in Limnology and Oceanography.** *Prerequisite: permission of instructor.* I. *(2).*
Discussion of current concepts and problems varying in content and designed to put the student in touch with recent advances and with areas of uncertainty presently under investigation. Designed to rotate the student through dynamics, biology, sedimenation, and other major areas of the field. Student expected to register more than one year.

**676(Zool. 676). Current Problems in Limnology and Oceanography.** *Prerequisite: permission of instructor.* II. *(2).*
Discussion of current concepts and problems varying in content and designed to put the student in touch with recent advances and with areas of uncertainty presently under investigation. Designed to rotate the student through dynamics, biology, sedimentation, and other major areas of the field. Student expected to register more than one year.

**701. Special Problems in Atmospheric Science.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Supervised analysis of selected problems in various areas of meteorology and associated fields.

**804. Interdisciplinary Seminar on Atmospheric Sciences.** *Prerequisite: permission of instructor.* I and II. *(1-3).*
Reading, preparation of term papers, and seminar discussion of fundamental atmospheric properties and characteristics and their relation and interaction with other disciplines. Course credit assigned each student on registration.

**990. Meteorological Research.** *Prerequisite: permission of graduate adviser.* I and II. *(To be arranged).*
Assigned work in meteorological research; may include field measurements, analysis of data, development in physical or applied meteorology.

**994. Doctoral Thesis.** I and II. *(To be arranged).*

## Naval Architecture and Marine Engineering

*Department Office:* 450 West Engineering

**200. Introduction to Practice.** *Prerequisite: Eng. Graphics 101.* I and II. *(3).*
Types of ships and propulsion systems, nomenclature, methods and materials of construction, shipyard and drawing-room practices. The lines of a vessel are faired, and drawings prepared for typical ship structures and machinery arrangements.

**201. Form Calculations and Static Stability I.** *Prerequisite: Nav. Arch. 200, Math. 215, and Eng. Mech. 208.* I and II. *(3).*
Methods of determining areas, volumes, centers of buoyancy, displacement, and wetted surface; the use of hydrostatic curves; trim; initial stability; stability in damaged condition; launching; and watertight subdivision.

**300. Form Calculations and Static Stability II.** *Prerequisite: Nav. Arch. 201 and Math. 273.* I and II. *(2).*
Programming of hydrostatic curves; other problems for digital and analog computers.

**310. Structural Design I.** *Prerequisite: Eng. Mech. 210 and Nav. Arch. 201.* I and II. *(3).*
Design of the ship's principal structure to meet general and local strength requirements. Analysis of framing, shell, decks, bulkheads, welding, and testing.

**330. Marine Propulsion Machinery.** *Prerequisite: Mech. Eng. 335 and preceded or accompanied by Eng. Mech. 324.* I and II. *(3).*
The principles of design and operation of the ship's boilers, turbines, and other major machinery items.

**331. Marine Auxiliary Machinery.** *Prerequisite: Nav. Arch. 330 or Mech. Eng. 336 and preceded or accompanied by Elec. Eng. 316.* I and II. *(3).*
The principles of design of piping systems; electrical distribution; engine-room and deck auxiliaries.

**400. Shipbuilding Contracts and Cost Estimating.** *Prerequisite: junior standing.* I and II. *(2).*
Principal features of ship specifications and contracts; methods and practices of cost estimating and production control of shipbuilding.

**401. Small Craft Design.** *Prerequisite: preceded or accompanied by Nav. Arch. 420.* II. *(2).*
Design of motorboats, sailboats, hydrofoils, and other small craft.

**402. Small Commercial Vessel Design.** *Prerequisite: preceded or accompanied by Nav. Arch. 420.* I. *(2).*
Design of small commercial craft such as fishing boats, tugs, towboats, barges, and coasters.

**410. Stress Analysis of Ship Structures.** *Prerequisite: Eng. Mech. 411.* I. *(2).*
Beams under action of axial and lateral loads, beams on elastic supports; analysis of bulkheads, plating supported by a grillage system of stiffeners; effective width of plating, closed frame analysis.

**420. Resistance, Propulsion, and Propellers.** *Prerequisite: Nav. Arch. 201 and Eng. Mech. 324.* I and II. *(5).*
Fundamentals of the resistance and propulsion of ships including the theory of model testing. Theory and practice of propeller design with reference to model propeller testing. Ship powering predictions and calculations. Four recitations and one three-hour laboratory.

**430. Design of Marine Power Plants I.** *Prerequisite: Nav. Arch. 331.* I and II. *(2).*
Preliminary heat balance and other problems encountered in marine power-plant design.

**440. Ship Dynamics.** *Prerequisite: Nav. Arch. 201, Eng. Mech. 343, and Math. 404.* I. *(2).*
The motion of ships at sea, rolling, pitching, sea-keeping qualities; steering and maneuvering.

**446. Theory of Ship Vibrations I.** *Prerequisite: Eng. Mech. 343 and Math. 214 or 316.* I. *(3).*
General outline of vibration theory; vibration of masts, longitudinal and torsional vibration of propulsion machinery; hull vibrations, vertical, lateral, longitudinal, and torsional; other selected problems.

**470. Ship Design I.** *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.

**471. Ship Design II.** *Prerequisite: Nav. Arch. 470 and accompanied by Nav. Arch. 472.* I, II, and III*a*. *(2).*
Basing his work on the design started in Nav. Arch. 470, the student prepares the preliminary design drawings and final calculations for the subject vessel.

**472. Structural Design II.** *Prerequisite: Nav. Arch. 310 and accompanied by Nav. Arch. 471.* I, II, and III*a*. *(2).*
Student develops the midship section for the vessel designed in Nav. Arch. 470 and Nav. Arch. 471 and makes freeboard, strength, and steel weight calculations.

**473. Design of Marine Power Plants II.** *Prerequisite: Nav. Arch. 430.* I and II. *(3).*
Design calculations to establish the heat balance of an approved machinery installation. Preliminary machinery arrangement and piping diagrams are prepared.

**510. Advanced Structural Design.** *Prerequisite: Nav. Arch. 410.* I and II. *(To be arranged).*

**511. Directed Research in Ship Structure.** *Prerequisite: Nav. Arch. 510.* I and II. *(To be arranged).*

**520. Advanced Ship Model Testing.** *Prerequisite: Nav. Arch. 420.* I and II. *(2 to 3).*
Special problems in ship model testing will be investigated, varying with the student's interest.

**521. Research in Ship Hydrodynamics.** *Prerequisite: Nav. Arch. 520.* I and II. *(To be arranged).*

**522. Theory of Wave Resistance.** *Prerequisite: Eng. Mech. 422, Math. 552, accompanied by Math. 555.* II. *(3).*
Formulation of the inviscid potential flow problem for a surface vessel. Solution of the linearized boundary value problem for steady flow by Fourier analysis and by method of Greene's functions. Determination of wave resistance by pressure integral, energy, and momentum. Methods of evaluating the Mitchell integral.

**530. Theory of Ship Vibrations II.** *Prerequisite: Eng. Mech. 422, Nav. Arch. 446, Math. 450.* II. *(2).*
Hydrodynamic masses of vibrating ships. Calculation of natural frequencies of a ship's hull. Calculation of hull response to exciting forces. Vibratory forces produced by a propeller. Vibration of panels. Problems of hydroelasticity in ship design.

**540. Theory of Ship Motions.** *Prerequisite: Eng. Mech. 422, Nav. Arch. 440, Math. 450.* I. *(3).*
The general dynamic theory of a ship moving with six degrees of freedom with and without the exciting forces of surface waves. Coupled pitching and heaving, linear and nonlinear rolling. Motion stabilizers.

**571. Advanced Ship Drawing and Design.** I and II. *(To be arranged).*

**572. Economics of Ship Design and Operation.** *Prerequisite: Nav. Arch. 470.* II. *(2).*
Review of mathematics of finance, estimating ship construction and operating costs and income; interpretation of data; profitability; optimum design conditions; replacement; intangible factors.

**590. Advanced Reading and Seminar in Marine Engineering.** I and II. *(To be arranged).*

**591. Advanced Reading and Seminar in Naval Architecture.** I and II. *(To be arranged).*

**592. Master's Thesis.** *Prerequisite: Nav. Arch. 470 or design course in Option 2 and Nav. Arch. 420.* I and II. *(3).*

**620. Advanced Propeller Theory and Cavitation.** *Prerequisite: Eng. Mech. 422 and Nav. Arch. 420.* I and II. *(2).*
Fundamentals of circulation theory of screw-propeller design; propeller cavitation; supercavitating propellers.

**630. Nuclear Ship Propulsion.** *Prerequisite: Nuc. Eng. 400 or 470 or equivalent.* I. *(3).*
A discussion of the basic problems encountered in the application of nuclear reactors to ships. Brief review of the nontechnical problems of nuclear merchant ship propulsion.

**900. Doctoral Thesis.** I and II. *(To be arranged).*

## Nuclear Engineering

*Department Office:* 300 Automotive Engineering Laboratory

**400. Elements of Nuclear Engineering.** *Prerequisite: senior standing or permission of instructor.* I and II. *(3).*
A quantitative survey of nuclear engineering for those in fields other than nuclear engineering. Elementary nuclear physics, neutron mechanics, the nuclear reactor, radiation shielding, instrumentation and control, and nuclear power plant systems are the principal topics surveyed.

**470. Introduction to Nuclear Engineering.** *Prerequisite: preceded or accompanied by Math. 450.* I, II, and III*a*. *(3).*
A treatment of those aspects of atomic and nuclear physics prerequisite to an understanding of neutron processes.

**500. Special Topics in Nuclear Engineering I.** *Prerequisite: permission of instructor.* I and II. *(To be arranged).*
Selected topics offered at the senior-first year graduate level. The subject matter may change from term to term.

**520. Introduction to Thermonuclear Theory.** *Prerequisite: one intermediate course in electricty and magnetism.* II. *(3).*
Properties of thermonuclear plasmas from the standpoint of magneto-fluid mechanics. Typical parameters in a hypothetical thermonuclear reactor. Orbit theory; hydromagnetic equations of motion; generalized Ohms law problems; energy principle for stability. Plasma waves; survey of experimental techniques applied to problems of plasma confinement and heating.

**550. Handling and Use of Radioactive Materials.** *Prerequisite: senior standing or permission of instructor.* I and II. *(3).*
Uses of nuclear radiation in industry and research. Procedures in the safe handling of radioactive materials, hazard evaluations, and design of radiation facilities. One-hour lecture, demonstrations, and experiments with high-level sources.

**560. Nuclear Radiation Detection and Measurement.** *Prerequisite: Nuc. Eng. 470, preceded or accompanied by a course in electronics.* I and II. *(3).*
Nuclear radiation detection methods and instrument systems in nuclear engineering; basic concepts of health physics and statistics; basic nuclear phenomena and the characteristics of nuclear radiations. Lectures and laboratory.

**570. Quantum Mechanics in Neutron-Nuclear Reactions.** *Prerequisite: Nuc. Eng. 470 and Math. 450.* I and II. *(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 problems, masers, and lasers.

**630. Nuclear Power Plant Engineering I.** *Prerequisite: preceded or accompanied by Nuc. Eng. 680, or preceded by Nuc. Eng. 400.* II. *(3).*
Application of reactor theory, reactor control, fluid-flow, heat transfer, thermodynamics, stress and strain, and economic parameters to integrated nuclear power plant designs. Examination of significant nuclear power plant concepts and applications.

**631. Nuclear Power Plant Laboratory.** *Prerequisite: preceded or accompanied by Nuc. Eng. 630, or permission of instructor.* I. *(1).*
The application of heat transfer, fluid-flow, thermodynamics, and the stresses of special importance to nuclear power plant engineering. Techniques of research in these areas. An idea of the present state of the art. Lecture and laboratory.

**640. Application of the Analog Computer in Nuclear Engineering.** *Prerequisite: preceded or accompanied by Nuc. Eng. 680, or preceded by Nuc. Eng. 400.* I. *(2).*
Basic theory and principles of operation of the electronic analog computer. Practice in the operation of the computer. Solution of linear and nonlinear problems in nuclear engineering such as fission product buildup and decay, nuclear reactor kinetics and control. Lecture and laboratory.

**641. Nuclear Reactor Instrumentation and Control.** *Prerequisite: preceded or accompanied by Nuc. Eng. 680, or preceded by Nuc. Eng. 400.* II. *(3).*
Reactor kinetics, reactor stability studies; measurement of reactor power level and period; automatic control methods for thermal and fast reactors; temperature effects; accident studies; the use of analog computers in studying reactor dynamics; the loaded reactor.

**660. Nuclear Reactor Laboratory.** *Prerequisite: Nuc. Eng. 560, preceded or accompanied by Nuc. Eng 680.* II and III*a*. *(4).*
Characteristics and operation of a nuclear reactor and the use of a reactor as a radiation source, using the two-megawatt Ford Nuclear Reactor in the Phoenix Memorial Laboratory. Lectures and laboratory.

**670. Interaction of Radiation and Matter.** *Prerequisite: Nuc. Eng. 570.* I and 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.

**680. Nuclear Reactor Theory I.** *Prerequisite: preceded or accompanied by Nuc. Eng. 570; Math. 448 or 554, or Phys. 451.* II. *(3).*
A study of the behavior of nuclear reactors based on the diffusion equation. Derivation of the one-speed diffusion equation, and its solution. Elementary theory of neutron slowing down in infinite media. Age theory. Criticality of bare, homogeneous reactors. Reflected reactors and group diffusion methods. Elementary theory of reactor kinetics, fission product poisoning and control.

**690. Master's Project.** *(1–6).*
Individual or group investigations in a particular field or on a problem of special interest to the student. The program will be arranged at the beginning of each term by mutual agreement between the student and a staff member. Attendance at a weekly seminar is required. The student will write a final report and may be required to make a seminar presentation.

**700. 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.

**720. Thermonuclear Theory I.** *Prerequisite: Nuc. Eng. 680.* I. *(3).*
Fundamentals of the physics of fusion and of ionized gases. The basic equations describing the collective behavior of charged particles are formulated. Some general physical implications of these equations are examined.

**721. Thermonuclear Theory II.** *Prerequisite: Nuc. Eng. 720.* II. *(3).*
Investigations in plasma dynamics based on the Boltzmann and Fokker-Planck equations. Development of the equations of magnetohydrodynamics. Study of problems of containment-pinch effect, plasma oscillation, diffusion.

**730. Nuclear Power Plant Engineering II.** *Prerequisite: Nuc. Eng. 630 or permission of instructor.* I. *(3).*
Analytical investigation of areas of special importance to the design of nuclear power plants. Includes interrelations between the nuclear performance and the fluid flow and heat transfer characteristics of the reactor system.

**731. Nuclear Power Plant Engineering III.** *Prerequisite: Nuc. Eng. 730 or permission of instructor. (3).*
Selected topics in nuclear reactor power plant engineering. Designed to prepare and assist students at the level of advanced research. Subject matter will vary according to student interest.

**750. Radiation Shielding.** *Prerequisite: Nuc. Eng. 560, preceded or accompanied by Nuc. Eng. 670.* I. *(3).*
A macroscopic study of the absorption of nuclear radiation in dense materials 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.

**751. Radiation Effects in Solids.** *Prerequisite: Nuc. Eng. 670.* I. *(3).*
Study of the effects of high-energy radiations in solids, such as germanium and silicon. Topics such as the theory of atomic displacements, ionization effects in solids, and others relating to nuclear solid-state devices.

**752. Selected Topics in Radiation Effects.** *Prerequisite: Nuc. Eng. 751.* II. *(3).*
Luminescence and scintillation properties of solids, as applied to the detection of high energy radiations, and the examination of other solid-state phenomena and their application in nuclear technology.

**770. Theory of Nuclear Reactions I.** *Prerequisite: Nuc. Eng. 670.* I. *(3).*
Introduction to nuclear forces and the two-body problem; neutron-proton scattering and the ground state of the deuteron. Discussion of nuclear models, survey of nuclear ground states and low-lying excited states. Introduction of cross sections to describe low energy nuclear reactions.

**771. Theory of Nuclear Reactions II.** *Prerequisite: Nuc. Eng. 770.* II. *(3).*
Study of neutron-nuclear reactions with some attention to medium effects, charged-particle nuclear reactions, photon-nuclear reactions, and beta decay. Development of neutron balance relations incorporating appropriate neutron-nuclear cross sections.

**780. Nuclear Reactor Theory II.** *Prerequisite: Nuc. Eng. 680 and Math. 552 or 557 or Phys. 452.* I. *(3).*
Perturbation theory and variational methods; asymptotic reactor theory; neutron slowing down in the infinite medium and the theory of resonance capture. Space-dependent slowing down theory. The theory of multigroup calculations.

Neutron thermalization and the theory of pulsed neutron measurements. Discussion of cell calculations in heterogeneous reactors.

**781. Neutron Transport Theory.** *Prerequisite: Math. 448 or Phys. 451. (3).*
Properties and solution of the one-speed neutron transport equation. Invariance properties; escape probabilities and self-shielding; singular eigenfunction expansions; infinite medium and half-space problems, with particular emphasis on the Milne Problem. The spherical harmonics, double spherical harmonics, and $S_n$ methods, time dependent problems. Brief discussion of spectral problems and transport problems in other fields, such as radiative transfer and plasma physics.

**880. Seminar in Nuclear Reactor Design.** *Prerequisite: permission of instructor. (3).*
Application of transport theory and nuclear reactor theory to specific design of reactor cores and shields. The use of digital computers and survey of existing reactor codes.

**991. 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.

**999. Doctoral Thesis.** *(1–6).*

## Physics*

*Department Office:* 1049 Randall

Professor Dennison; Professors Case, Crane, Franken, Hazen, Jones, Katz, Krimm, Laporte, McCormick, Parkinson, Ross, Sanders, Sawyer, Weinreich, Wiedenbeck, Wolfe; Associate Professors Coffin, Ford, Hecht, Hendel, Lewis, Meyer, Peters, Roe, Sands, Sherman, Sinclair, Terwilliger, Tickle, VanderVelde; Assistant Professors Fischbeck, Fontana, Kenefick, Krisch, Longo, Murphy, Overseth, Worthington, Wu, Zorn.

**145. Mechanics, Sound, and Heat.** *Prerequisite: preceded by Math. 115.* I and II. *(5).*
Two lectures, three recitations, and one two-hour laboratory.

**146. Electricity and Light.** *Prerequisite: Physics 145.* I and II. *(5).*
Two lectures, three recitations, and one two-hour laboratory.

**153. Elementary Mechanics.** *Prerequisite: preceded or accompanied by Math. 115 or equivalent.* I. *(4).*
Mechanics of particles, kinematics, Newton's laws of motion, wave motion in mechanical systems, special relativity. One lecture, three recitations, and one laboratory.

**154. Electricity, Light, and Modern Physics.** *Prerequisite: Physics 153 and preceded or accompanied by Math. 316 or equivalent.* II. *(4).*
Electricity and magnetism, physical optics, atomic and nuclear structure. One lecture, three recitations, and one laboratory.

*College of Literature, Science, and the Arts.

**303. Introduction to the Use of Radioactive Isotopes.** *Prerequisite: Physics 126 or 146.* II. *(2).*
Sources, properties, and methods of measuring radiations; determination of safe dosage; tracer techniques and their applications.

**305. Modern Physics.** *Prerequisite: Physics 126 or 146.* I. *(2).*
A discussion of fundamental experiments on the nature of matter and electromagnetic radiation. Survey of special relativity. Bohr's quantum theory, and wave mechanics of simple systems.

**307. Modern Physics II.** *Prerequisite: Physics 126 or 146 and calculus, preferably Math. 316.* I and II. *(3).*
The level of sophistication is between the levels of Physics 305 and Physics 453.

**401. Intermediate Mechanics.** *Prerequisite: Physics 126 or 146 and Math. 316 or equivalent.* I and II. *(3).*
Study of the motion of single particles, systems of particles, and rigid bodies. Harmonic oscillators, coupled oscillators, rockets; central force laws including planetary motion, Rutherford scattering and perturbed orbits using center-of-mass co-ordinates; rotating co-ordinate systems, Coriolis force. Introduction to Lagrange's equations.

**402. Light.** *Prerequisite: Physics 126 or 146 and Math. 316 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.

**405. Intermediate Electricity and Magnetism.** *Prerequisite: Physics 126 or 146 and Math. 316 or equivalent.* I and II. *(3).*
The laws and principles of electrostatics, moving electric charges, and electromagnetism; alternating-current circuit theory, including transients.

**406. Heat and Thermodynamics.** *Prerequisite: Physics 126 or 146 and Math. 316 or equivalent.* II. *(3).*
Fundamental physical facts and concepts, thermodynamic variables, equations of state. The zeroth, first, second, and third law of thermodynamics and their mathematical consequences; the concepts of internal energy, enthalpy, entropy, functions of Helmholtz and of Gibbs. Thermodynamics of irreversible processes. Applications to various branches of physics, e.g. magnetic cooling, thermoelectricity, etc.

**409. Classical Physics Laboratory.** *Prerequisite: admission primarily to physics, astronomy, and other science majors in the junior year by permission of instructor.* II. *(2)*
Designed to develop experimental skills as well as to acquaint the student with some of the subject matter of heat, light, and classical atomic phenomena. Completed experimental apparatus will be available for standard experiments. Technical facilities and components will be available for experiments designed by the students or for improvement of existing experiments.

**411. Mechanics of Fluids.** *Prerequisite: Physics 401.* II. *(3).*
The Navier-Stokes equation is developed and is used to treat several classical problems. The student is introduced to elementary aspects of turbulence, shock waves, and hydromagnetics.

**417. Physical Techniques in Biophysics.** *Prerequisite: Physics 126 or 146.* I. *(3).*
A survey of the physical techniques used to study the ultrastructure of biological materials. An elementary treatment of microscopy and diffraction methods using light, electrons, and X rays; light scattering and spectroscopy.

**418. Introduction of Physics of Macromolecules.** *Prerequisite: Math 214 and Physics 402 or permission of instructor.* II. *(3).*
A discussion of methods of structure determination and a survey of our knowledge of the physical structures of macromolecules and the principles underlying their formation. This is followed by an introduction to theories which relate structure to physical properties. Emphasis is placed on biological systems where possible.

**425. Introduction to Infrared Spectra.** *Prerequisite: Physics 126 or 146 and Math. 214.* I. *(2).*
A discussion of the elements of vibrational spectroscopy, both infrared and Raman, followed by a survey of their application to the study of the structure and internal force fields of molecules, both simple and complex.

**427, 428. Advanced Physics for Engineers.** *Prerequisite: Math. 450, Phys. 401, 406 or equivalent.* 427, I; 428, II. *(3 each).*
Intended for honors seniors and graduate students in engineering. The first term will be advanced classical physics (particle dynamics, Maxwell equations, hydrodynamics, and kenetic theory). The second term will be primarily quantum physics, with emphasis on atomic, molecular, and nuclear structure.

**451, 452. Introduction to Theoretical Physics.** *Prerequisite: Physics 401 and Math. 450 or 554.* 451, I; 452, II. *(3 each).*
A survey of mathematical methods employed in theoretical physics, e.g., vectors, tensors, matrices, tensor fields, boundary value problems, approximation and variational methods.

**453. Atomic and Nuclear Physics I.** *Prerequisite: Physics 401, Physics 405, or five hours of physical chemistry.* I and II. *(3).*
Presentation of some concepts of quantum mechanics; theory of the simpler atoms, molecules and nuclei in terms of the Schroedinger equation. Discussions of fundamental experiments and of current research in atomic physics.

**455. Electron Tubes.** *Prerequisite: Physics 405.* I. *(4).*
The characteristics of electron tubes and transistors, and their functions in electric circuits such as amplifiers and oscillators. Three lectures and a laboratory.

**456. Electronic Circuits.** *Prerequisite: Physics 455.* II. *(3).*
A study of circuit elements, amplifiers, coincidence and scaling circuits, and the various types of detectors and circuits used in experimental nuclear physics. Two lectures and a laboratory.

**457. Atomic and Nuclear Physics II.** *Prerequisite: Physics 453.* I and II. *(3).*
Further developments of quantum theory, such as symmetry properties and scattering theory, applied to the more complex atoms and nuclei; discussion of current research in nuclear and elementary particle physics. Given as a sequence with Physics 453.

**458. Methods and Apparatus of Nuclear and Elementary Particle Experimental Physics.** *Prerequisite: Physics 401, 405.* I. *(2).*
A discussion of the experimental devices and techniques of nuclear and particle physics including ionoptic and particle beams, accelerators, and detectors.

**459. Modern Physics Laboratory.** *Prerequisite: by permission.* I. *(2).*
Same general organization and philosophy as the Physics 409 laboratory. The subject matter will emphasize instrumentation and topics that are closely related to present-day research.

**461. Introduction to Quantum Theory.** *Prerequisite: Physics 401 and 453.* II. *(3).*
An introduction to the concepts of quantum theory. Development of Schroedinger's wave mechanics and Heisenberg's matrix mechanics with applications to simple systems.

**463. Introduction to Physics of the Solid State.** *Prerequisite: Physics 453 or permission of instructor.* II. *(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.

**505, 506. Electricity and Magnetism.** *Prerequisite: Physics 405 and Math. 450 or 451.* 505, I; 506, II. *(3 each).*
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. *(3).*
Lagrange equations of motion; the principle of least action. Hamilton's principle, the Hamilton-Jacobi equation; Poisson brackets.

**509. Thermodynamics.** *Prerequisite: Physics 406.* II. *(2).*
The two laws and their foundation; gas equilibra and dilute solutions; phase rule of Gibbs; theory of binary mixtures.

**510. Kinetic Theory of Matter.** *Prerequisite: Physics 509.* 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, 512, 513. Quantum Theory.** *Prerequisite: Physics 453. Physics 511 is a prerequisite for Physics 512.* 511, I; 512, 513, II. *(3 each).*
Wave mechanics, matrix mechanics, and methods of quantizations, with applications.

**618. Physics of Continuous Media.** II. *(3).*

**619. Physics of the Solid State.** I. *(3).*

**624. Cosmic Radiation.** II. *(3).*

**625. Theory of Neutron Diffusion.** I. *(3).*

**626. High-Energy Nuclear Physics.** II. *(3).*

**633. Special Problems in Fluid Dynamics.** I. *(3).*

**634. Stochastic Processes in Physics.** II. *(3).*

**638. Nuclear Theory.** II. *(3).*

**641. Magnetic Resonance.** I. *(2 or 3).*

**642. Advanced Atomic Physics.** II. *(2 or 3).*

**656. Molecular Spectra and Molecular Structure.** II. *(3).*

**715. Special Problems.** I and II. *(To be arranged).*
Qualified graduate students who desire to obtain research experience in work supervised by members of the staff may, upon consultation, elect these courses.

**806, 807. Seminar.** Topic to be announced each term. I and II. *(2 or 3).*

**809, 810. Advanced Nuclear Physics Seminar.** I and II. *(2 or 3).*

**811, 812. Experimental Seminar.** I and II. *(2 or 3).*

**813, 814. Advanced Theoretical Physics Seminar.** I and II. *(2 or 3).*

**815, 816. High-Energy Physics Seminar.** I and II. *(2 or 3).*

## Science Engineering

*Office:* 4211 East Engineering

The following courses have been developed through interdepartmental co-operation specifically for the Science Engineering degree program. Since these courses may be taught by staff members of various departments of instruction, they are listed separately rather than placed among the offerings of any one department. They may be elected by any student who presents prerequisites equivalent to those stated in the course definitions.

**101. Engineering Concepts and Perspective.** *Prerequisite: high school algebra, trigonometry, chemistry, and physics.* I and II. *(3).*
A study of engineering concepts and solution of a wide variety of problems to give perspective, orientation, and foundation for engineering study and practice. Two lectures, two problem solving periods.

**280. Engineering Design.** *Prerequisite: Math. 115.* I and II. *(3).*
A study of the general principles of engineering applicable to all fields of engineering. Analysis and definition of the problem, synthesis and formulation of a solution, evaluation of components and the over-all system, and presentation of the finished design.

**330. Thermodynamics.** *Prerequisite: Math. 215 and 273 and Chem. 194 or 265.* I. *(4).*
Introduction to thermodynamic properties, generalized gas equations, mass, energy, and entropy balances, with examples from various fields of engineering.

**340. Rate Processes.** *Prerequisite: Sci. Eng. 330 and Math. 216.* II. *(4).*
A unified study of heat, mass, and momentum transfer and chemical kinetics, with emphasis on description, measurement, correlation, and process design.

# Committees and Faculty*

## Executive Committee

Dean S. S. Attwood, *Chairman*
ex officio

L. H. Van Vlack, term, 1961–65
H. Benford, term, 1962–66
A. B. Macnee, term, 1963–67
C. Kikuchi, term, 1964–68

## Standing Committee

Dean S. S. Attwood, *Chairman,* H. Benford, R. E. Burroughs, S. W. Churchill, R. B. Couch, J. W. Daily, H. W. Farris, G. V. Edmonson, W. M. Hancock, A. R. Hellwarth, H. T. Jenkins, W. Kerr, C. Kikuchi, G. M. McEwen, A. B. Macnee, J. C. Mouzon, W. C. Nelson, A. C. Wiin-Nielsen, F. E. Richart, L. H. Van Vlack, and G. J. Van Wylen.

## Committee on Classification

A. W. Lipphart, *Chairman,* E. A. Glysson, and C. W. McMullen.

## Committee on Scholastic Standing

R. C. Porter, *Chairman,* F. J. Beutler, H. S. Bull, J. J. Carey, W. R. Debler, D. C. Douglas. R. A. Loomis, G. Parravano, W. S. Rumman, S. S. Stanton, R. E. Townsend, and P. F. Youngdahl.

## Committee on Discipline

A. Marin, *Chairman,* E. F. Brater, and A. R. Hellwarth.

## Committee on Scholarships and Loans

R. E. Carroll, *Chairman,* H. Bradley, H. Diamond, R. Harris, A. R. Hellwarth, E. J. Lesher, D. R. Mason, J. C. Mouzon, and J. E. Shigley.

## Committee on Curriculum

L. N. Holland, *Chairman,* E. E. Hucke, F. C. Michelsen, H. J. Smith, and F. H. Westervelt.

## Committee on Combined Courses with College of Literature, Science, and the Arts

W. C. Bigelow, *Chairman,* R. B. Harris, and A. R. Hellwarth.

## Committee on Freshman Counseling

C. W. Johnson, *Chairman,* R. W. Berkeley, W. C. Bigelow, H. Colby, W. Goddard, A. R. Hellwarth, R. H. Hoisington, M. J. Kaldjian, A. W. Lipphart, J. C. Mouzon, D. C. Ray, W. Raymond, M. Sichel, C. A. Siebert, Q. Vines, and H. J. Welch.

* Listed for the academic year, 1964-65.

**Committee on Placement**

J. G. Young, *Chairman,* H. Benford, R. W. Berkeley, H. Buning, S. K. Clark, G. C. Gill, F. G. Hammitt, R. B. Harris, L. F. Kazda, G. B. Williams, and P. Youngdahl.

## Aeronautical and Astronautical Engineering

Wilbur Clifton Nelson, M.S.E., *Professor of Aeronautical and Astronautical Engineering and Chairman of the Department of Aeronautical and Astronautical Engineering*

Thomas Charles Adamson, Jr., Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Frederick Joseph Beutler, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

Harm Buning, M.S.E., *Professor of Aeronautical and Astronautical Engineering*

Elmer Grant Gilbert, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

Donald Theodore Greenwood, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

Robert Milton Howe, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Leslie McLaury Jones, B.S.E. (E.E.), *Professor of Aeronautical and Astronautical Engineering*

Arnold Martin Kuethe, Ph.D., *Felix Pawlowski Professor of Aerodynamics*

Vi-Cheng Liu, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Richard Boyd Morrison, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

James Arthur Nicholls, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Rudi Siong-Bwee Ong, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Lawrence Lee Rauch, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

William Lucas Root, Ph.D., *Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*

William Walter Willmarth, Ph.D., *Professor of Aeronautical and Astronautical Engineering*

Joe Griffin Eisley, Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*

Edgar James Lesher, M.S.E., *Associate Professor of Aeronautical and Astronautical Engineering*

Arthur Frederick Messiter, Jr., Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*

Pauline Mont Sherman, M.S., *Associate Professor of Aeronautical and Astronautical Engineering*

Martin Sichel, Ph.D., *Associate Professor of Aeronautical and Astronautical Engineering*

WILLIAM JUDSON ANDERSON, Ph.D., *Assistant Professor of Aeronautical and Astronautical Engineering*
ALFRED CHRISTIAN ROBINSON, Ph.D., *Assistant Professor of Instrumentation, Department of Aeronautical and Astronautical Engineering*
HAROLD FREDERICK ALLEN, Ph.D., *Lecturer in Aeronautical and Astronautical Engineering and Research Engineer, Sponsored Research*
FREDERICK LESTER WILLIAM BARTMAN, M.S., *Lecturer in Aeronautical and Astronautical Engineering and Research Engineer, Sponsored Research*
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## Chemical and Metallurgical Engineering

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LLOYD L. KEMPE, Ph.D., *Professor of Chemical Engineering*
JOSEPH J. MARTIN, D.Sc., *Professor of Chemical and Metallurgical Engineering*
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MAURICE JOSEPH SINNOTT, Sc.D., *Professor of Metallurgical Engineering*
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JESSE LOUIS YORK, Ph.D., *Professor of Chemical and Metallurgical Engineering*
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LEO LEHR CARRICK, Ph.D., *Professor Emeritus of Chemical Engineering*

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Richard Emory Townsend, Ch. E., *Associate Professor of Chemical and Metallurgical Engineering*
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Walter Bertram Pierce, *Assistant Professor of Foundry Practice, Department of Chemical and Metallurgical Engineering*
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William Allen Spindler, M.S., *Assistant Professor of Metallurgical Engineering*
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Dudley Albert Saville, M.S.E., *Instructor in Chemical Engineering*

## Civil Engineering

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Glenn Leslie Alt, C.E., *Professor of Civil Engineering*
Glen Virgil Berg, Ph.D., *Professor of Civil Engineering*
Ralph Moore Berry, B.C.E., *Professor of Geodetic Engineering, Department of Civil Engineering*
Jack Adolph Borchardt, Ph.D., *Professor of Civil Engineering*
Ernest Frederick Brater, Ph.D., *Professor of Hydraulic Engineering, Department of Civil Engineering*
William Stuart Housel, M.S.E., *Professor of Civil Engineering*
Bruce Gilbert Johnston, Ph.D., *Professor of Structural Engineering, Department of Civil Engineering*
John Clayton Kohl, B.S.E. (C.E.), *Professor of Civil Engineering and Director of the Transportation Institute*
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## Electrical Engineering

WILLIAM GOULD DOW, M.S.E., *Professor of Electrical Engineering and Chairman of the Department of Electrical Engineering* (on retirement furlough, 1965)

HANSFORD WHITE FARRIS, Ph.D., *Professor of Electrical Engineering and Chairman of the Department of Electrical Engineering* (January 1, 1965)

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## Engineering Graphics

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FRANCIS X. LAKE, Ph.D., *Assistant Professor Emeritus of Engineering Graphics*

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## Engineering Mechanics

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JOHN HERMANN ENNS, Ph.D., *Professor of Engineering Mechanics*
ROBERT MORPHET HAYTHORNTHWAITE, Ph.D., *Professor of Engineering Science, Department of Engineering Mechanics*
ROBERT LAWRENCE HESS, Ph.D., *Professor of Engineering Mechanics and Associate Director, Institute of Science and Technology* (Absent on leave from Engineering Mechanics)
JESSE ORMONDROYD, A.B., *Professor of Engineering Mechanics*
HADLEY JAMES SMITH, Ph.D., *Professor of Engineering Mechanics*
CHIA-SHUN YIH, Ph.D., *Professor of Fluid Mechanics, Department of Engineering Mechanics*
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YOUNG KING LIU, Ph.D., *Assistant Professor of Engineering Mechanics*
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DEAN TRITCHLER MOOK, M.S., *Instructor in Engineering Mechanics*
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MERLE CLARENCE POTTER, M.S. (E.M.), *Instructor in Engineering Mechanics*

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## Mechanical Engineering

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GLENN VERNON EDMONSON, M.E., *Professor of Mechanical Engineering and Associate Dean of the College of Engineering*

RUNE L. EVALDSON, Ph.D., *Professor of Mechanical Engineering and Associate Director, Institute of Science and Technology* (absent on leave from Mechanical Engineering)

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FINN CHRISTIAN MICHELSEN, Ph.D., *Associate Professor of Naval Architecture and Marine Engineering*

RAYMOND A. YAGLE, M.S.E., *Associate Professor of Naval Architecture and Marine Engineering*

HORST GUNTHER NOWACKI, Dr.-Ing., *Assistant Professor of Naval Architecture and Marine Engineering*

HUN CHOL KIM, M.S.E., *Instructor in Naval Architecture and Marine Engineering*

NILS SALVESEN, M.S.E., *Instructor in Naval Architecture and Marine Engineering*

JOHN BROCKENBROUGH WOODWARD III, M.S.E., *Instructor of Naval Architecture and Marine Engineering*

## Nuclear Engineering

WILLIAM KERR, Ph.D., *Professor of Nuclear Engineering and Chairman of the Department of Nuclear Engineering*

LLOYD EARL BROWNELL, Ph.D., *Professor of Nuclear Engineering and of Chemical and Metallurgical Engineering*

HENRY JACOB GOMBERG, Ph.D., *Professor of Nuclear Engineering*

FREDERICK GNICHTEL HAMMITT, Ph.D., *Professor of Nuclear Engineering*

CHIHIRO KIKUCHI, Ph.D., *Professor of Nuclear Engineering*

JOHN SWINTON KING, Ph.D., *Professor of Nuclear Engineering*

RICHARD KENT OSBORN, Ph.D., *Professor of Nuclear Engineering*

DIETRICH HERMANN VINCENT, Dr. Rer. Nat., *Professor of Nuclear Engineering*

GEORGE LAUMAN WEST, JR., B.S.E. (Nav.Arch.&Mar.E.), *Professor of Nuclear Engineering and of Naval Architecture and Marine Engineering*

PAUL FREDERICK ZWEIFEL, Ph.D., *Professor of Nuclear Engineering*

DAVID RUDOLPH BACH, Ph.D., *Associate Professor of Nuclear Engineering*

GEZA LESLIE GYOREY, Ph.D., *Associate Professor of Nuclear Engineering*

TERRY B. KAMMASH, Ph.D., *Associate Professor of Nuclear Engineering*

EDWARD ANTHONY MARTIN, Ph.D., *Associate Professor of Nuclear Engineering and of Electrical Engineering*

ZIYA A. AKCASU, Ph.D., *Assistant Professor of Nuclear Engineering*

JOHN MARLAND CARPENTER, Ph.D., *Assistant Professor of Nuclear Engineering*

GLENN FREDERICK KNOLL, Ph.D., *Assistant Professor of Nuclear Engineering*

FRED CHARLES SHURE, Ph.D., *Assistant Professor of Nuclear Engineering*

GEORGE C. SUMMERFIELD, Ph.D., *Assistant Professor of Nuclear Engineering*

# Registration Schedules, 1965—1966

Each of the following groups of students is allotted a definite period for admission to the gymnasiums for registration. Please complete all registration forms distinctly and according to directions on the forms *before you enter the gymnasium.* Elections should be approved previously as specified in the *Announcement* of your school or college.

## FALL TERM, 1965

**Wednesday August 25, 1965**

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | Waq | –Waz | 1:00– 1:10 | Bas | –Bea |
| 8:10– 8:20 | Wb | –Wein | 1:10– 1:20 | Beb | –Benn |
| 8:20– 8:30 | Weio | –Wer | 1:20– 1:30 | Beno | –Bh |
| 8:30– 8:40 | Wes | –White, K. | 1:30– 1:40 | Bi | –Bla |
| 8:40– 8:50 | White, L. | –Wilc | 1:40– 1:50 | Blb | –Bon |
| 8:50– 9:00 | Wild | –W'ms, Q. | 1:50– 2:00 | Boo | –Boz |
| 9:00– 9:10 | W'ms, R. | –Wim | 2:00– 2:10 | Bp | –Bron |
| 9:10– 9:20 | Win | –Wok | 2:10– 2:20 | Broo | –Bub |
| 9:20– 9:30 | Wol | –Woq | 2:20– 2:30 | Buc | –Burz |
| 9:30– 9:40 | Wor | –Wz | 2:30– 2:40 | Bus | –Can |
| 9:40– 9:50 | X | –Yoz | 2:40– 2:50 | Cao | –Cat |
| 9:50–10:00 | Yp | –Zeg | 2:50– 3:00 | Cau | –Chil |
| 10:00–10:10 | Zeh | –Zz | 3:00– 3:10 | Chim | –Cle |
| 10:10–10:20 | A | –Adz | 3:10– 3:20 | Clf | –Coll |
| 10:20–10:30 | Ae | –Alf | 3:20– 3:30 | Colm | –Coq |
| 10:30–10:40 | Alg | –Amo | 3:30– 3:40 | Cor | –Cre |
| 10:40–10:50 | Amp | –An | 3:40– 3:50 | Crf | –Cz |
| 10:50–11:00 | Ao | –Arz | 3:50– 4:00 | D | –Davis, L. |
| 11:00–11:10 | As | –Bab | 4:00– 4:10 | Davis, M. | –Deh |
| 11:10–11:20 | Bac | –Bal | 4:10– 4:20 | Dei | –Die |
| 11:20–11:30 | Bam | –Barz | 4:20– 4:30 | Dif | –Dou |

**Thursday August 26, 1965**

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | Dov | –Duq | 1:00– 1:10 | Kar | –Kelln |
| 8:10– 8:20 | Dur | –Ele | 1:10– 1:20 | Kello | –Kil |
| 8:20– 8:30 | Elf | –Eva | 1:20– 1:30 | Kim | –Kln |
| 8:30– 8:40 | Evb | –Fe | 1:30– 1:40 | Klo | –Kop |
| 8:40– 8:50 | Ff | –Foo | 1:40– 1:50 | Kor | –Krn |
| 8:50– 9:00 | Fop | –Frid | 1:50– 2:00 | Kro | –Laa |
| 9:00– 9:10 | Frie | –Gar | 2:00– 2:10 | Lab | –Larr |
| 9:10– 9:20 | Gas | –Gill | 2:10– 2:20 | Lars | –Led |
| 9:20– 9:30 | Gilm | –Goo | 2:20– 2:30 | Lee | –Levi |
| 9:30– 9:40 | Gop | –Green | 2:30– 2:40 | Levj | –Lio |
| 9:40– 9:50 | Greeo | –Gz | 2:40– 2:50 | Lip | –Lou |
| 9:50–10:00 | H | –Hanl | 2:50– 3:00 | Lov | –Lz |
| 10:00–10:10 | Hanm | –Hasl | 3:00– 3:10 | M | –Malj |
| 10:10–10:20 | Hasm | –Hel | 3:10– 3:20 | Malk | –Mars |
| 10:20–10:30 | Hem | –Hill, Z. | 3:20– 3:30 | Mart | –Maw |
| 10:30–10:40 | Hilla | –Holt | 3:30– 3:40 | Max | –McDa |
| 10:40–10:50 | Holu | –Hue | 3:40– 3:50 | McDb | –McMo |
| 10:50–11:00 | Huf | –Ir | 3:50– 4:00 | McMp | –Mer |
| 11:00–11:10 | Is | –Jer | 4:00– 4:10 | Mes | –Miller, J. |
| 11:10–11:20 | Jes | –Jor | 4:10– 4:20 | Miller, K. | –Mof |
| 11:20–11:30 | Jos | –Kaq | 4:20– 4:30 | Mog | –Moro |

**Friday August 27, 1965**

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | Morp | –Mun | 1:00– 1:10 | Schl | –Schu |
| 8:10– 8:20 | Muo | –Nd | 1:10– 1:20 | Schv | –Sel |
| 8:20– 8:30 | Ne | –Nib | 1:20– 1:30 | Sem | –Sheo |
| 8:30– 8:40 | Nic | –Nz | 1:30– 1:40 | Shep | –Sie |
| 8:40– 8:50 | O | –Om | 1:40– 1:50 | Sif | –Siz |
| 8:50– 9:00 | On | –Pag | 1:50– 2:00 | Sj | –Smith, E. |
| 9:00– 9:10 | Pah | –Pas | 2:00– 2:10 | Smith, F. | –Sni |
| 9:10– 9:20 | Pat | –Pep | 2:10– 2:20 | Snj | –Spe |
| 9:20– 9:30 | Peq | –Phi | 2:20– 2:30 | Spf | –Sted |
| 9:30– 9:40 | Phj | –Polk | 2:30– 2:40 | Stee | –Stez |
| 9:40– 9:50 | Poll | –Pre | 2:40– 2:50 | Stf | –Stua |
| 9:50–10:00 | Prf | –Raf | 2:50– 3:00 | Stub | –Sv |
| 10:00–10:10 | Rag | –Ree | 3:00– 3:10 | Sw | –Tar |
| 10:10–10:20 | Ref | –Rice | 3:10– 3:20 | Tas | –Thog |
| 10:20–10:30 | Ricf | –Robertsn | 3:20– 3:30 | Thoh | –Til |
| 10:30–10:40 | Robertso | –Rol | 3:30– 3:40 | Tim | –Tra |
| 10:40–10:50 | Rom | –Ross J. | 3:40– 3:50 | Trb | –Tz |
| 10:50–11:00 | Ross, K. | –Ruh | 3:50– 4:00 | U | –Vanc |
| 11:00–11:10 | Rui | –Salm | 4:00– 4:10 | Vand | –Vok |
| 11:10–11:20 | Saln | –Sau | 4:10– 4:20 | Vol | –Wap |
| 11:20–11:30 | Sav | –Schk | | | |

## WINTER TERM, 1966

### Monday January 3, 1966

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | Bas | –Baz | 1:00– 1:10 | Conp | –Cot |
| 8:10– 8:20 | Bb | –Beg | 1:10– 1:20 | Cou | –Cru |
| 8:20– 8:30 | Beh | –Benn | 1:20– 1:30 | Crv | –Dam |
| 8:30– 8:40 | Beno | –Bern | 1:30– 1:40 | Dan | –Daz |
| 8:40– 8:50 | Bero | –Bil | 1:40– 1:50 | Db | –Den |
| 8:50– 9:00 | Bim | –Bla | 1:50– 2:00 | Deo | –Doc |
| 9:00– 9:10 | Blb | –Boh | 2:00– 2:10 | Dod | –Dre |
| 9:10– 9:20 | Boi | –Bor | 2:10– 2:20 | Drf | –Dz |
| 9:20– 9:30 | Bos | –Boz | 2:20– 2:30 | E | –Ele |
| 9:30– 9:40 | Bp | –Brif | 2:30– 2:40 | Elf | –Er |
| 9:40– 9:50 | Brig | –Brown, F. | 2:40– 2:50 | Es | –Faz |
| 9:50–10:00 | Brown, G. | –Bub | 2:50– 3:00 | Fb | –Fin |
| 10:00–10:10 | Buc | –Burk | 3:00– 3:10 | Fio | –Foo |
| 10:10–10:20 | Burl | –Bz | 3:10– 3:20 | Fop | –Fred |
| 10:20–10:30 | C | –Can | 3:20– 3:30 | Free | –Fz |
| 10:30–10:40 | Cao | –Cart | 3:30– 3:40 | G | –Gee |
| 10:40–10:50 | Caru | –Cham | 3:40– 3:50 | Gef | –Gill |
| 10:50–11:00 | Chan | –Chil | 3:50– 4:00 | Gilm | –Gold |
| 11:00–11:10 | Chim | –Clap | 4:00– 4:10 | Gole | –Gram |
| 11:10–11:20 | Claq | –Cof | 4:10– 4:20 | Gran | –Grif |
| 11:20–11:30 | Cog | –Cono | 4:20– 4:30 | Grig | –Gz |

### Tuesday January 4, 1966

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | H | –Haml | 1:00– 1:10 | Mas | –Mb |
| 8:10– 8:20 | Hamm | –Hars | 1:10– 1:20 | Mc | –McGo |
| 8:20– 8:30 | Hart | –Heik | 1:20– 1:30 | McGp | –Meb |
| 8:30– 8:40 | Heil | –Hib | 1:30– 1:40 | Mec | –Mh |
| 8:40– 8:50 | Hic | –Holk | 1:40– 1:50 | Mi | –Millh |
| 8:50– 9:00 | Holl | –Hox | 1:50– 2:00 | Milli | –Monz |
| 9:00– 9:10 | Hoy | –Hz | 2:00– 2:10 | Moo | –Mor |
| 9:10– 9:20 | I | –Jar | 2:10– 2:20 | Mos | –Mur |
| 9:20– 9:30 | Jas | –Jones, I. | 2:20– 2:30 | Mus | –Neir |
| 9:30– 9:40 | Jones, J. | –Kaq | 2:30– 2:40 | Nels | –Ni |
| 9:40– 9:50 | Kar | –Kens | 2:40– 2:50 | Nj | –Oa |
| 9:50–10:00 | Kent | –Kla | 2:50– 3:00 | Ob | –Or |
| 10:00–10:10 | Klb | –Kop | 3:00– 3:10 | Os | –Pao |
| 10:10–10:20 | Kor | –Kug | 3:10– 3:20 | Pap | –Paz |
| 10:20–10:30 | Kuh | –Lanf | 3:20– 3:30 | Pb | –Pes |
| 10:30–10:40 | Lang | –Led | 3:30– 3:40 | Pet | –Pik |
| 10:40–10:50 | Lee | –Lez | 3:40– 3:50 | Pil | –Por |
| 10:50–11:00 | Lf | –Lom | 3:50– 4:00 | Pos | –Pt |
| 11:00–11:10 | Lon | –Lz | 4:00– 4:10 | Pu | –Ran |
| 11:10–11:20 | M | –Mano | 4:10– 4:20 | Rao | –Rei |
| 11:20–11:30 | Manp | –Marz | 4:20– 4:30 | Rej | –Ricz |

### Wednesday January 5, 1966

| A.M. | | | P.M. | | |
|---|---|---|---|---|---|
| 8:00– 8:10 | Rid | –Robz | 1:00– 1:10 | Thomp | –Tol |
| 8:10– 8:20 | Roc | –Ror | 1:10– 1:20 | Tom | –Triz |
| 8:20– 8:30 | Ros | –Rots | 1:20– 1:30 | Trj | –Uz |
| 8:30– 8:40 | Rott | –Rus | 1:30– 1:40 | V | –Var |
| 8:40– 8:50 | Rut | –Sanc | 1:40– 1:50 | Vas | –Vz |
| 8:50– 9:00 | Sand | –Scg | 1:50– 2:00 | W | –Wap |
| 9:00– 9:10 | Sch | –Schn | 2:00– 2:10 | Waq | –Wed |
| 9:10– 9:20 | Scho | –Scn | 2:10– 2:20 | Wee | –Wer |
| 9:20– 9:30 | Sco | –Sg | 2:20– 2:30 | Wes | –Whz |
| 9:30– 9:40 | Sh | –Shil | 2:30– 2:40 | Wi | –W'ms, Q. |
| 9:40– 9:50 | Shim | –Sil | 2:40– 2:50 | W'ms, R. | –Wir |
| 9:50–10:00 | Sim | –Sla | 2:50– 3:00 | Wis | –Woq |
| 10:00–10:10 | Slb | –Smith, L. | 3:00– 3:10 | Wor | –Yg |
| 10:10–10:20 | Smith, M. | –Soh | 3:10– 3:20 | Yh | –Zeg |
| 10:20–10:30 | Soi | –Sq | 3:20– 3:30 | Zeh | –Adal |
| 10:30–10:40 | Sr | –Stei | 3:30– 3:40 | Adam | –Alf |
| 10:40–10:50 | Stej | –St | 3:40– 3:50 | Alg | –Ande |
| 10:50–11:00 | Stp | –Sug | 3:50– 4:00 | Andf | –Arz |
| 11:00–11:10 | Suh | –Swei | 4:00– 4:10 | As | –Baj |
| 11:10–11:20 | Swej | –Td | 4:10– 4:20 | Bak | –Barz |
| 11:20–11:30 | Te | –Thomo | | | |

# Index

## University of Michigan Official Publication

University of Michigan Official Publication is the title given to the series of administrative bulletins published by the University. This series includes the following:

### Bulletins for Prospective Students

The prospective student should have, in addition to a copy of the bulletin *General Information,* a copy of one or more of the announcements or bulletins listed under this head. These will be sent, without charge, on request to The University of Michigan.

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Dearborn Campus
Dentistry, School of
Education, School of
Engineering, College of
Flint College
Graduate Dentistry, W. K. Kellogg Foundation Institute
Graduate Studies, Horace H. Rackham School of
Law School
Literature, Science, and the Arts, College of
Medical School
Music, School of
Natural Resources, School of
Nursing, School of
Pharmacy, College of
Postgraduate Dentistry, W. K. Kellogg Foundation Institute
Public Administration, Institute of
Public Health, School of
Social Work, School of
Summer Session

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