The UNIVERSITY of MICHIGAN

COLLEGE OF ENGINEERING

ANNOUNCEMENT 1960 / 1961

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College of Engineering

1960-1961

Announcement

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Office Directory

GENERAL UNIVERSITY OFFICES

Automobile permits, 3011 Student Activities Building
Business Office, information desk, second floor, Administration
Cashier's Office, 1015 Administration
Dean of Faculties, 2522 Administration
Dean of Men, 2011 or 2038 Student Activities Building
Dean of Women, 1011 Student Activities Building
Director of Admissions, 1524 Administration
D.O.B., 3553 Administration
Eligibility for activities, Student Activities Building
Employment:
- Hospital employment, 2002 Hospital
- University offices, 1020 Administration
- men students, Personnel Office, 1020 Administration

Extension Service, 4524 Administration
Foreign Student Counselors, International Center
Fraternities, information about, Student Activities Building and Michigan Union
Graduate School, Rackham Building
Health Service, Fletcher Avenue
Housing:
- married students, Student Activities Building
- men students, Student Activities Building
- women students, Student Activities Building

Information desk, first floor, Administration
Occupational Information, Bureau of, 3528 Administration
Office of Student Affairs, Student Activities Building
Office of Veterans Affairs, 142 Administration
Orientation, 113 Administration
President's Office, 2522 Administration
Print Lending Library, Student Activities Building
Refund of semester fees, 1015 Administration
Residence Halls:
- Business Manager, 1056 Administration
- fees, payment of, 1015 Administration
- men students, Student Activities Building
- staff, Student Activities Building
- women students, Dean of Women, Student Activities Building

Scholarship bulletins, Student Activities Building
Secretary of the University, 2552 Administration
Sororities, information about, Dean of Women, Student Activities Building
Student activities, Student Activities Building
Summer Session, Administrative Office, 3510 Administration

COLLEGE OFFICES

Admissions: Advanced Standing, 259 West Engineering
Head Freshman Counselor:
- J. G. Young, 128H West Engineering

Deans of the College:
- Dean Stephen S. Attwood, 255 West Engineering
- Associate Dean G. V. Edmonson, 247 West Engineering
- Associate Dean J. C. Mouzon, 248 West Engineering
- Assistant Dean and Secretary, A. R. Hellwarth, 259 West Engineering
- Assistant to the Dean, R. H. Hoisington, 259 West Engineering
- Assistant to the Dean: J. G. Young, 128H West Engineering

Lost and Found:
- Information desk, second floor lobby, Administration

Office of the Assistant Dean, 259 West Engineering
Placement, students and alumni, 128H West Engineering, J. G. Young, and department offices
Records, 263 West Engineering
Transcripts, 263 West Engineering
Transfer students, admission of, 259 West Engineering

Contents

Calendar, 1960-61

SUMMER SESSION, 1960

Registration	June 16–18, Thursday–Saturday
Summer session classes begin	June 20, Monday
Independence Day, a holiday	July 4, Monday
Summer session ends	August 13, Saturday

FIRST SEMESTER

Orientation period	September 12–17, Monday–Saturday
*Registration	September 14–17, Wednesday–Saturday
First semester classes begin	September 19, Monday
Thanksgiving recess begins	November 23, Wednesday (evening)
Classes resume	November 28, Monday (morning)
Christmas recess begins	December 17, Saturday (noon)

1961

Classes resume	January 3, Tuesday (morning)
Classes end	January 21, Saturday
Study period	January 22, Sunday
Examination period	January 23–February 2, Monday–Thursday
Midyear Graduation	January 21, Saturday
First semester ends	February 4, Saturday

SECOND SEMESTER

Orientation period	February 6–11, Monday–Saturday
*Registration	February 8–11, Wednesday–Saturday
Second semester classes begin	February 13, Monday
Spring recess begins	April 1, Saturday (noon)
Classes resume	April 10, Monday (morning)
Classes end	May 31, Wednesday
Study period	June 1, Thursday
Examination period	June 2–13, Friday–Tuesday
Commencement	June 17, Saturday

SUMMER SESSION, 1961

Registration	June 22–24, Thursday–Saturday
Summer session classes begin	June 26, Monday
Independence Day, a holiday	July 4, Tuesday
Summer session ends	August 19, Saturday

This calendar is subject to revision.

*For registration schedules, see pages 176 and 177.

COLLEGE OF ENGINEERING

HARLAN HATCHER, Ph.D., Litt.D., LL.D., *President of the University*

MARVIN L. NIEHUSS, LL.B., *Vice-President and Dean of Faculties*

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 and Secretary of the College of Engineering*

ARLEN R. HELLWARTH, M.S., *Assistant Dean and Secretary of the College of Engineering*

ROBERT H. HOISINGTON, M.S., *Assistant to the Dean*

JOHN G. YOUNG, B.S.E., *Assistant to the Dean and Head Freshman Counselor*

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 knowledge, including mathematics, the utilization of natural resources and capital, and the management of men. The engineer is a practitioner. He brings to bear on each problem all available science and experience or judgment to arrive at the best practical 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 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. The successful engineer must develop sound judgment by his willingness to try, to recognize failures, and to keep on trying until he arrives at a satisfactory solution. Only through continued practice and exercise of judgment can one acquire the stature of an engineer.

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, administrators, investigators, or teachers. But the useful knowledge and mental discipline gained from such educational programs are so broad and fundamental as to constitute excellent preparation for other careers.

The undergraduate programs lay a sound foundation of science, sufficiently broad and deep to enable a graduate to enter understandingly into

*On retirement furlough, 1959–60.

scientific investigations and, at the same time, they provide a background that will make him immediately useful in engineering practice. Many qualified graduates will continue their formal education at the postgraduate 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 for research 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 first-hand experiences.

Teaching is often at its best when the student and teacher work together in developing new relationships of fundamental scientific 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 in the University of Michigan Research Institute. The Institute was initially established as the Department of Engineering Research in 1920, for the purpose of encouraging research in engineering. It serves as an agency for stimulating co-operation with industry and government and for making the abilities of the staff and the facilities of the University more readily available for public service.

To profit satisfactorily by an engineering education, a student should have mental ability and alertness of a high order, good health, and perseverance. A good criterion for predicting success is superior grades in high school, particularly in mathematics, science, and English. 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 any possible service in assisting students with career planning.*

*A vocational booklet entitled *Engineering — A Creative Profession* may be obtained (25 cents per copy) from Engineers' Council for Professional Development, 29 West 39th Street, New York 18, N.Y. It answers many questions commonly experienced by high school students who are considering engineering as a career, and describes in particular five general fields of the engineering profession — civil, mining and metallurgical, mechanical, electrical, and chemical.

The fourteen undergraduate degree programs offered by the College of Engineering cover a wide spectrum. They are listed in the Contents on page 3. The time at which a student should select a particular program is covered under Freshman Program.

ACCREDITATION

The several degree programs have been examined by the Engineers' Council for Professional Development. The following have been accredited: Aeronautical, Chemical, Civil, Electrical, Engineering Mechanics, Industrial, Materials, Mechanical, Metallurgical, Naval Architecture and Marine Engineering, Physics, and Science.

FACILITIES

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

The **West Engineering Building** (1904) contains the offices of the College; sanitary and structural laboratories of the Civil Engineering Department; fluid mechanics and physical testing laboratories of the Engineering Mechanics Department; drafting, computing, and design rooms of the Engineering Graphics Department and other departments; 360-foot naval tank with dynamometers used by the Naval Architecture and Marine Engineering Department for studies on ship models; and facilities for industrial engineering demonstrations for courses offered by the Industrial Engineering Department.

Directly across the street, the **East Engineering Building** (1923) houses well-instrumented machine-tool and machinability laboratories; gaging and measuring laboratory of the Mechanical Engineering Department; 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, plastics, semiconductor, nuclear metallography, and measurements laboratories of the Chemical Engineering Department; and the highway and soil mechanics laboratory of the Civil Engineering Department.

The **East Engineering Addition** (1947) contains two subsonic wind tunnels, supersonic jet, structures, propulsion, and instrumentation laboratories of the Aeronautical and Astronautical Engineering Department; energy converters and power systems, communications, electronics, feedback controls, computers, space and electron physics research, radiation and propagation, and solid-state devices laboratories of the Electrical Engineering Department; and the meteorological laboratory for the program in Meteorology.

The **North Campus** now houses the following laboratories for instruction and research:

The memorial **Mortimer E. Cooley Building** (1953) serves the University of Michigan Research Institute and the Industrial Program of the Engineering College as well as providing conference rooms for other activities, and space for an electronic systems and circuits laboratory of the Electrical Engineering Department.

Phoenix Memorial Laboratory (1955) and the accompanying Ford Nuclear Reactor (1956) provides facilities for the Nuclear Engineering Department as well as research in the field of atomic energy.

Supersonic and low turbulence wind tunnels and aircraft propulsion laboratories (1957) provide additional facilities for studies by Aeronautical and Astronautical Engineering Department in aerodynamics and propulsion.

The **Automotive Laboratory** (1957), generously supplied with equipment by the industry of the state, provides laboratories for Chemical, Electrical, and Mechanical Engineering departments for work on reciprocating and rotary engines, on chassis, body, and suspension systems, and for combustion and electrical systems studies, and provides space for Civil and Nuclear Engineering departments.

The **Fluids Engineering Laboratory** (occupied 1958) provides space for all departments in the study of fluid flow problems; for the Mechanical Engineering Department on heat transfer, thermodynamics, and power generation studies; for the Chemical Engineering Department on process operation and heat transfer problems; and for the Electrical Engineering Department on plasma engineering.

The Fluids Engineering Laboratory contains a memorial plaque to the late Dean George Granger Brown, whose dreams became a reality in the development of the North Campus which will ultimately provide classroom, office, and laboratory facilities for all engineering programs as well as research.

Camp Davis is situated in the valley of the Hoback River, twenty miles southeast of the city of Jackson, Wyoming, and seventy-five miles south of Yellowstone National Park. The University of Michigan was the pioneer in the establishment and maintenance of a camp for field work in surveying. The first camp was organized in 1874 under the supervision of the late Professor J. B. Davis. Several sites were occupied in Michigan until 1929 when the University purchased land for the location of the present camp. The elevation of the camp, more than six thousand feet above sea level, the nature of the surrounding area, and the climate combine to make the location nearly ideal for summer instruction in surveying and geology.

Buildings at the Willow Run Airport contain the **Lake Hydraulic Laboratory**, equipped with a large wave tank and wave-making machine and the instruments required for the study of problems arising from the action of water along shores, and a propulsion laboratory equipped with stands for testing various types of jet and rocket motors.

A new radio telescope, dedicated in 1959 and situated sixteen miles from Ann Arbor, provides opportunities for electrical engineering students interested in the engineering aspects of radio astronomy.

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 System, the object of which is to create the standard of honor which is essential to a successful engineer and a good citizen. Students are expected to uphold the system 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 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."

COMBINED PROGRAMS AND OTHER INSTITUTIONS

The College of Engineering has agreements with Albion College, Alma College, Calvin College, Central Michigan University, Emmanuel Missionary College, Kalamazoo College, and Eastern Michigan University, under which a student who has been in residence at one of these institutions for three years, and who has completed with a good record a prearranged program, including substantially the work of the first two years of the College of Engineering, may be admitted to the College of Engineering, and after the completion of the requirements of the selected program may be graduated in engineering.

Under this agreement these colleges, with the exception of Calvin College, accept the first year at the College of Engineering, if the record is satisfactory, in lieu of the senior year and grant the student his degree at the end of this fourth year. Calvin College grants its degree upon completion of the requirements for the degree in engineering at the University.

In co-operation with the College of Literature, Science, and the Arts of the University, combined programs are regularly scheduled in the fields of chemical engineering and civil engineering. Each of the programs requires five years and one summer session for completion and leads to baccalaureate degrees in both the College of Engineering and the College of Literature, Science, and the Arts. Requirements are stated on pages 39 and 43.

Students interested in the possibility of arranging similar programs with emphasis on other subjects should discuss their interests with the Engineering College Committee on Combined Courses with the College of Literature, Science, and the Arts.

Students may be admitted with advanced standing from junior colleges or other institutions (see Advanced Standing).

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 semesters 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, arranged by several companies and public organizations, have been approved. Also, the College is willing to consider the proposals of students who find it possible to arrange for alternate semesters 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 obviously such experience is desirable in many ways and, when approved and adopted by the College, constitutes a part of a student's degree program and is entered upon his records.

DEARBORN CENTER

The Dearborn Center, 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, mechanical, and industrial engineering. 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 another accredited college or university. A student desiring further information should write: Admissions Office, Dearborn Center, 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 provides opportunities for interviewing engineering employers on campus, announcements of position openings received by mail for both graduates and experienced alumni, placement counseling service, and published information on engineering careers and employers.

Meetings for students are also conducted by the Placement Service at the beginning of each semester 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 Institute of Electrical Engineers, student chapter
American Institute of Metallurgical Engineers, student chapter

American Military Engineers (University of Michigan Post)
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 Radio Engineers, student branch
Institute of the Aeronautical Sciences, student branch
Mechanical Engineering 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, student branch of Society of Naval Architects and Marine Engineers
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 for the Advancement of Management, student branch
Society of Automotive Engineers, student branch
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, AND STUDENT GRANTS AND LOANS

Numerous scholarships, fellowships, and prizes, as well as adequate loan funds, are available to the engineering students. A list of these, with the conditions governing them, is given in the special bulletin *University Scholarships, Fellowships, and Prizes,* which is available upon request. For information regarding scholarships, write to the Office of Student Affairs, 2011 Student Activities Building. March 1 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 students in engineering. Applications may be addressed directly to this committee at the office of the Dean.

Other student loans are under the jurisdiction of the Office of Student Affairs, to whom application for them should be made.

Qualified graduate students are frequently given the opportunity to teach in the capacity of teaching fellows.

A number of student assistants are also appointed each semester and assigned to work in the several departments. For the most part, these assistants are graduate students and seniors who are proficient along certain lines.

FEES AND EXPENSES

Semester Fees:	**Michigan students**	**$125**
	Non-Michigan students	**$300**

The semester fees must be paid before classification, and no student can enter upon his work until after such payment. (Requirements on enrollment deposit are stated under Admission).

Students are urged to provide themselves with money orders or bank drafts to cover semester fees. For the convenience of students, the Cashier's Office will cash or accept, in payment of semester 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.

Semester fees are the student's contribution to the cost of class instruction, use of libraries, 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 $20) *must* be paid at the time of registration. This coverage extends for a full twelve months.

Reduced Program Fees. The election of nine hours or fewer is considered a reduced program. Before a student may elect such a program he must obtain permission from the Assistant Dean. Those electing such a reduced program must pay each semester the appropriate fee as set forth in the bulletin *General Information,* which should be consulted for further information.

Indebtedness to the University. All accounts due the University, including loans which fall due during a semester or summer session, must be paid not later than the last day of classes of the semester or summer session. Student loans not yet due are exempt. Any unpaid accounts at the close of business on the last day of classes will be reported to the Cashier of the University and until such accounts are paid:

a) All academic credit will be withheld, the grades for the semester or summer session just completed will not be released, and no transcripts of credit will be issued.

b) No student owing such accounts will be allowed to register in any subsequent semester or summer session until payment has been made.

Admission

Applicants for admission should be at least sixteen years of age. They must present satisfactory evidence of good moral character and satisfy the requirements as covered under Health Service Approval.

A freshman must present an application for admission to the Director of Admissions, 1524 Administration Building. An applicant desiring to transfer from another college should write to the Assistant Dean, College of Engineering, for instructions.

Applications for admission in September should be submitted by March 1 to receive equal consideration with other applicants.

Enrollment Deposit. In order to make best use of its facilities and staff in a period of expanding enrollment, the University must know accurately which newly admitted students are likely to enroll. *New undergraduate students, both freshmen and transfers, and former students returning after an absence of one or more semesters,* are required to make in advance a nonrefundable enrollment deposit of fifty dollars ($50), in order to hold the admission granted them.

The deposit will be applied to each student's fees in the semester for which he has been admitted. It will not be an additional cost for attending the University. Details of the enrollment deposit plan and directions for making the advance payment will be sent to the student at an appropriate time by the admissions officer who granted the admission. No student is to send money until instructed to do so by the University. Since there is no application fee, no money should be sent when making application for admission.

ADMISSION AS A FRESHMAN

Requirements for admission are stated in units, a unit being defined as a course covering an academic year and including in the aggregate not less than the equivalent of 120 sixty-minute hours of classroom work. Two to three hours of laboratory, drawing, or shopwork are counted as equivalent to one hour of recitation.

Applicants for admission as freshmen without entrance deficiency must present a minimum of fifteen units which shall include at least three units each from Groups A and B, two units from Group C, and three units from Group D.

A. ENGLISH	UNITS
At least three units are required	3
B. MATHEMATICS GROUP	
At least three units are required, including algebra, one and one-half units; plane geometry, one unit; and solid geometry, one-half unit	3
(In addition, trigonometry, one-half unit, is urgently advised, because, if not offered for admission, it must be elected in the first year of college.)	
C. 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
D. 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	4
Total	15

Four units of English, four units of mathematics, including one-half unit of trigonometry, and one unit of chemistry should be presented whenever feasible since, with excellent preparation, some acceleration is possible at the University, as stated under Planning the Student's Program.

Applicants who do not meet the preceding requirements for admission without deficiency are advised to consult the Director of Admissions concerning their particular problems. 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.

ADMISSION BY CERTIFICATE

Only those applicants are admitted by certificate who are officially recommended graduates of accredited high schools and who have completed in an accredited high school a full four-year curriculum covering at least fifteen units of acceptable entrance credit.

In the recommendation of graduates for admission to the University, it is expected that principals of secondary schools will take into consideration the character, scholarship interests and attainments, seriousness of purpose, and intellectual promise of the individuals concerned.

The principals of accredited schools are urged to send direct to the Director of Admissions, as soon as reasonable after the beginning of the senior year, upon the blank furnished by the University, the application of each prospective graduate intending to enter the freshman class at the beginning of the ensuing year. If the applicant's credentials are satisfactory, he will receive admission to the University without examination, contingent only upon his satisfactory completion of the secondary school program.

ADMISSION BY CERTIFICATE AND EXAMINATION

Michigan applicants whose high school backgrounds are somewhat below the usual standards may be asked to take examinations, if the Committee on Admissions feels they can be given further consideration for admission. Such applicants may be invited to the campus for tests and an interview after the initial review of their applications. All out-of-state freshmen applicants are required to take the College Board Scholastic Aptitude Test, preferably in December or January of the senior year. The decision on admission, however, will not be made on the basis of test results alone.

ADVANCED STANDING

A student in another college or university who intends 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. The applicant must present to the Assistant Dean evidence of honorable dismissal from an approved college, together with an official transcript of his college work and preparatory studies. The transcript must list the subjects studied, the grade earned in each subject, and the basis upon which grades are assigned. A scholastic average corresponding to at least a C grade in this College is required. For admission without deficiencies, the applicant must satisfy the requirements for admission from high school as stated under Admission as a Freshman.

The student usually is able to complete the required work in English, mathematics, physics, chemistry, physical education, and nontechnical subjects. He may also complete the work in engineering graphics, engineering materials, and some of the engineering mechanics if his institution offers adequate instruction in these fields.

The student is urged to write to the program adviser in the program he wishes to elect for advice and for information not found in this *Announcement*. The Assistant Dean of the College of Engineering will be glad to give information concerning admission requirements or other matters of a general nature.

A graduate of the University or of an approved college is admitted without examination to advanced standing as a candidate for a degree in engineering. He should present to the Assistant Dean an official certificate of graduation — not a diploma — and an official transcript of his studies. If the course completed has covered substantially the equivalent of the required work in the first three years of the program he desires to follow at The University of Michigan, and if his record meets the scholastic standards of our College, he may be admitted as a senior. The courses to be taken during residence at the University will depend on the program concerned. Upon the satisfactory completion of such courses, covering at least one year's residence and 30 hours of credit, the student will be recommended for the degree of Bachelor of Science in Engineering.

FOREIGN STUDENTS

The University does not admit foreign students whose native language is other than English directly from their secondary schools into the first year or freshman class. It is recommended that they remain at a home university, preferably for two years, to obtain their basic subjects before applying to the University as transfer students. In some cases, foreign students enter smaller liberal arts colleges in the United States as freshmen before transferring to the University. This enables them to earn credit in such subjects as mathematics, chemistry, physics, drawing, etc., to become accustomed to the educational system of this country, and, also, to improve their proficiency in English.

Those foreign students who feel that they meet the admission requirements as stated under Advanced Standing are welcome to file applications. They are advised to submit them, together with complete detailed scholastic transcripts, as early as possible. Considerable time is required for a review of each case. If the candidate is found to be eligible, the English test abroad, as outlined below, remains to be arranged and the results reported to the Admissions Officer before the formal certificate of admission is issued.

All students, of whatever nationality, attend the same classes and must maintain the same scholastic standards. Thus, foreign students must possess or acquire a degree of proficiency in English sufficient to enable them to carry on their studies without serious handicap.

They should know in advance of their arrival whether or not their control of English is adequate. Therefore, in order that students and the University may plan intelligently, the University requires all foreign students whose native language is not English to take an English proficiency examination during the process of admission. These tests are prepared and regularly administered abroad by the English Language Institute. Information concerning the place and time for the test will be sent to the candidate by the English Language Institute upon request. The charge for the examination is $5.00.

A second English proficiency examination, parallel to the first, will be required of all foreign students whose native language is not English, after their arrival in Ann Arbor. The English Language Institute administers this examination also. There is no charge for this second examination.

Students who arrive and whose English is not considered adequate may be required to take an intensive course in English at the English Language Institute before beginning credit studies, thus delaying attainment of the desired objective.

In his first semester every foreign student is considered to be on trial. It is generally desirable that he elect a rather light schedule of studies in the first semester, since he is living in an unfamiliar environment and is studying under an educational system which is new to him. At the end of the semester, credit will be given if he passes his work. If, in spite of conscientious effort, he fails in his studies and his failure is due primarily, in the judgment of his instructors and adviser, to his lack of proficiency in the English language, his record will be disregarded and he will be required to elect additional remedial study of English as may be deemed necessary.

For statement on health insurance requirements for foreign students, see Fees and Expenses, page 13.

ADJUSTMENT OF ADVANCED CREDIT

During the period of registration preceding each session, records of studies taken elsewhere are reviewed by representatives of the several teaching departments of the College, or by the Assistant Dean in the case of certain nonengineering subjects. Advanced credit is allowed as appears justified but is granted upon a tentative basis, subject to review and revision if, at any time, it develops that the student is unable to continue successfully with more advanced studies because of inadequate preparation. In general, credit will not be allowed for courses with a D or equivalent low grade.

Students desiring excuse from courses in engineering graphics may be required to submit for examination all drawings completed previous to entrance.

Advanced credit is adjusted in terms of semester hours completed without scholastic grade being assigned to this credit. The student's scholastic average is determined by 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 from taking such course.

SPECIAL STUDENTS

Students who are pursuing work in college and who are not candidates for a degree are designated special students.

Persons over twenty-one years of age who wish to pursue particular studies in engineering and who show, by examination or by the presentation of satisfactory certificates, that they are prepared to do good work in the selected courses may be admitted as special students on the recommendation of the adviser of the program in which they wish to study. The object of this rule is to enable young men who are beyond the high school age to secure technical training along special lines when they are properly prepared for the work. Two or more years of successful experience as teacher, draftsman, surveyor, technician, or operative in engineering work will be given considerable weight in determining the fitness of the candidate. In general a good working knowledge of English, algebra, and geometry is required for success in engineering studies. Applicants for admission as special students should send, as early as possible, to the appropriate program adviser letters of recommendation, certificates of scholarship, and an exact statement of the courses desired. They should state their age, education, and experience and should bring drawings or other evidence that will demonstrate their experience and ability.

College graduates are also admitted as special students and may take those courses for which their preparation is sufficient.

Special students pay the same fees as regular students. Their work is assigned and regulated by the adviser for the program in which they register.

A special student may become a candidate for a degree by fulfilling the regular requirements for admission, as described under Admission.

A student who is a candidate for a degree cannot become a special student without the permission of the faculty.

VETERANS

Veterans who have special admission problems are invited to write to the Assistant Dean for advice.

COUNSELING SERVICES

Counseling services of many types are available at the University. Students who are uncertain concerning procedures, or who have special problems, may seek advice from the Assistant Dean's Office, 259 West Engineering Building.

All new students, both freshmen and those transferring from other colleges, are placed in groups and are guided through the various steps of the Orientation period. These details include the testing for freshmen, a call at the Health Service, preparation of the student's identification card, the adjustment of transfer credit from other colleges, consultation with advisers, selection of courses, and payment of fees.

The **Committee on Classification** is responsible for assisting each entering freshman to determine his schedule of courses for his first semester. The necessary counseling takes into account his entrance credits, level of high school achievements, orientation test results, and other information made available to the Committee. Entering freshmen are encouraged to come to the campus during the summer for a two-day appointment during which time they may be guided through the same orientation procedures that are offered during the Orientation period in September.

As soon as possible after the opening of a semester, all freshmen are placed in groups of approximately fifteen students, each group under a **freshman counselor** who is a member of the faculty. Insofar as possible, groups are formed of those students living in a single unit of the residence halls. Freshmen are urged to call on their counselors at their offices; counselors are encouraged to visit their groups in the residence halls so that they may become personally acquainted and so that each student may feel that there is a particular person to whom he may go for discussion of his problems.

At the beginning of each of the discussions (later in the *Announcement*) on the fourteen undergraduate programs is the name of a member of the faculty designated as **Program Adviser.** This person is available primarily to counsel students above the freshman level on their academic programs 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 help in this respect may, in addition to his freshman counselor, consult with the several program advisers. To enjoy a more leisurely discussion, the student should arrange such interviews at a time other than the busy registration week.

The **counselor** with whom a student beyond freshman level meets during registration week is a delegate of the program adviser and assumes responsibility, along with the program adviser, of counseling a student on course changes after the term is underway.

Transfer students are instructed by the Assistant Dean's Office on procedures for appraisal of their records from other colleges necessary for determining the amount of advanced credit and schedule of courses in the programs selected.

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 engineering field necessitates considerable flexibility in arranging schedules and programs.

TESTS AND PLACEMENT

All entering freshmen are required to take placement tests in English, chemistry, and mathematics during the orientation period. Each individual student has the benefit of counseling that takes into account his achievement on these tests as well as his past record. His particular courses are planned with the objective of placing him in subjects at a level which will enable him to continue his education without repeating subject matter in which he has already demonstrated adequate proficiency. At the same time, his schedule should not include subjects or levels of work which he is unable to handle successfully.

DEFICIENCIES

Students are required to remove all admission deficiencies during their first year, unless granted an extension of time. A student who does not present 3½ units in the mathematics group (see Admission as a Freshman) will find it to his advantage to take the lacking subject or subjects during the summer preceding the first semester of the freshman year.

Mathematics Courses Lacking From High School	*Mathematics Courses to be Elected*
Solid Geometry	Mathematics 6......2 hrs. (no credit)
Trigonometry	Mathematics 8......2 hrs. (2 hrs. credit)
Algebra and Trigonometry	Mathematics 7......4 hrs. (2 hrs. credit)

FRESHMAN PROGRAM

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.

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 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 years that are permitted in the schedule of requirements of the respective departments (under B — Professional Subjects and Electives).

Studies of The First Year. 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 SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 11 and 21	4	English 12	2
Mathematics 33	4	Mathematics 34	4
Chemistry	4 or 5	Physics 45	5
Eng. Graphics	3	Chemistry 4	2 to 6*
Physical Education *or*	0	Eng. Graphics 2 or 3	
ROTC	2 or 3	Other 2 to 6	
		Physical Education *or*	0
		ROTC	2 or 3

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

Usual combinations of the subjects listed above will result in a semester 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, extra curricular activities, and need for partial self-support through outside work.

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 during the first semester. He should consult with his freshman counselor, with program advisers, and others for assistance and counsel in planning his career. Near the close of the second semester, he should be ready 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.

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 11, Composition, and English 21, Speech, are generally prescribed for the first semester. A student who is considered to be unprepared for English 11 will be assigned to English 10, Preparatory Composition, but may be advanced to English 11 if the instructor finds him able to meet the requirements of that course. Generally students will take English 12 during the second semester and prior to electing courses from Group II.

If students have met the English 12 requirement during the first semester, or have been excused from the course on the basis of proficiency, they may elect a course from Group II during the second semester. Courses in Group I-A are also available to freshmen to satisfy part of the requirements for non-technical electives.

Mathematics. Mathematics 33 and 34 shown in the schedule above are followed by Mathematics 55 and 56 (each 4 hours credit). This series of four courses unifies analytic geometry and calculus throughout.

Students who lack trigonometry preparation and in addition have an algebra deficiency must take Mathematics 7 preceding Mathematics 33. When only trigonometry preparation is lacking, Mathematics 8 must be taken, and may either accompany or precede Mathematics 33.

Transfer students can be accommodated by Mathematics 13, 14, 53, and 54 (each 4 hours credit), when their mathematical training has begun in a similar sequence. If the transfer student has had a course in plane and solid analytic geometry which had no introduction to the calculus, as offered in Mathematics 14, he will elect Mathematics 52 for 5 hours credit instead of Mathematics 53.

Qualified students who have shown high proficiency in mathematics in both high school and their orientation mathematics test may be able to accelerate their mathematics requirements by a three-semester series in analytic geometry and calculus, Mathematics 35, 36, and 37 (each 4 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	HOURS
I. Have not had chemistry in high school (*a*) and who definitely plan to take succeeding chemistry courses for programs such as Chemical, Metallurgical, Materials, or Science Engineering;	Chemistry 1 and 4	8
(*b*) others	Chemistry 1 and 6	8
II. Have had chemistry in high school but do not qualify for Chemistry 5E or Physics 53 (*a*) and who definitely plan to take succeeding chemistry courses for programs such as Chemical, Metallurgical, Materials, or Science Engineering;	Chemistry 3 and 4* ...	8
(*b*) others	Chemistry 3 and 6* ...	8
III. †Have shown proficiency in chemistry in high school and on the orientation chemistry test	Chemistry 5E	5
IV. †Qualify for Physics 53 (see Physics below)	Chemistry 14 and 15..	8

*A student with a high record in Chemistry 3 may be invited to elect Chemistry 8, 5 hours, instead of Chemistry 4 or 6. This combination provides the student with additional background in chemistry and permits him to take succeeding courses at a saving of credit hours.

†III and IV are acceptable to any program in the College.

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; e.g., a preferred sequence following Chemistry 5E is Chemistry 23, 182, 183; one alternate is Chemistry 20, 41, 182, 183.

Engineering Graphics. The freshman schedule includes a 3-hour engineering drawing course in the first semester, Engineering Graphics 1 or 21. Students who expect to enter mathematics, physics, or science programs usually elect Graphics 21. All others normally elect Graphics 1.

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 for electing further graphics courses. Those who have completed Graphics 21 will normally elect Graphics 22. Graphics 1 is usually followed by Graphics 2. Students planning to enter Mechanical Engineering or Electrical Engineering, however, may meet the program requirements by electing Graphics 4.

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

The freshman schedule includes Physics 45 in the second semester. This course assumes knowledge of calculus and follows Mathematics 33. Transfer students placed in Mathematics 53 may elect Physics 45 concurrently. Physics 45 is followed by Physics 46, making a total of 10 hours.

Upon recommendation of a faculty committee, qualified students who have demonstrated high proficiency in physics and mathematics may be able to complete their physics requirements by two four-hour courses, Physics 53 and 54. Physics 53 should be elected during the first semester in place of chemistry and accompanied by Mathematics 33 or Mathematics 35. It is followed by Chemistry 14 and 15, and Physics 54 in that order, making a total of 16 hours for an integrated science sequence that provides a superior coverage of the material. This combination also permits students to take succeeding courses in chemistry at a saving of credit hours.

Other Possibilities for First-Year Schedule. A student who satisfies his chemistry requirements with Chemistry 5E during his first semester has an opportunity to select two to six hours from a number of subjects during his second semester.

For students planning to select the chemical or metallurgical engineering program, Chemical and Metallurgical Engineering 3 may be elected in the second semester.

Engineering Mechanics 11 is recommended for students planning to elect science engineering and may be elected the second semester if preceded by Physics 53 and accompanied by Mathematics 34 or equivalent.

Acceptable nontechnical subjects may be elected as part of the requirements for nontechnical electives in Group B. See English, page 32.

Rules and Procedures

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 smallpox 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 chest X-ray examination 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 rendered is in conformity with the rules and regulations of the Health Service.

Foreign students should see regulation regarding health insurance under Fees and Expenses, page 13.

PHYSICAL EDUCATION

Each student entering the University from a secondary school is required to complete satisfactorily a one-year course in physical education suited to his health condition.* Students who enroll in a Reserve Officers Training Corps also fulfill the requirements of physical education.

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.*

*By Regents' action on December 29, 1944, all veterans of World War II who have had basic training or its equivalent are excused from the regular 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.

ELECTION OF STUDIES

1. Each counselor has the responsibility for the proper election of courses by the student. The counselor should carefully consider the student's preparation, his demonstrated ability, his other activities and desires, and particularly any special recommendations of the Committee on Scholastic Standing. In general, no student is permitted to elect fewer than twelve hours, or more than eighteen hours unless his grade average for the preceding semester is at least 3.0. No credit will be allowed a student for work in any course unless the election of that course is formally entered on his office classification card.

2. The counselor shall see that a student entering this College with a deficiency remove this deficiency, so far as possible, during the first semester of residence and, in all cases, before the beginning of the second year of residence.

3. Credit is not given for a course in which the grade of E is received. Such a course must be repeated if it constitutes a requirement for graduation and unless a substitution is permitted. Courses in which D grades are earned must be, or may be, repeated in accordance with paragraphs 14, 15, and 16 in the section on Grades and Scholarship.

4. All requests for changes in classification must be made on a printed form which may be secured at the Office of the Recorder, 263 West Engineering Building. A course may be dropped without record during the first eight weeks of the semester with the consent of the counselor after conference with the instructor in the course. After the first eight weeks of the semester, except under extraordinary circumstances and with the consent of the program adviser or the head freshman counselor for freshmen, a course dropped will carry the grade of E. A student enrolled in an ROTC program must have the 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.

5. A student who has been absent from studies any time in the semester for more than a week, because of illness or other emergency, should consult his counselor concerning a revision of his elections. The Assistant Dean's Office may be consulted for recommendation.

6. 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 sufficiently employed. A student who supports himself wholly or in part should so inform his counselor and should elect a limited number of courses. It is very difficult for a student supporting himself to carry

a full schedule and retain his health. It is even more difficult under such conditions to carry a full schedule and to earn grades sufficiently high to qualify for graduation.

7. 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's Office. After consultation with the Department of English and the program adviser, the student may be required to elect further work in English as may be deemed necessary.

8. All regular students are required to complete a group of nontechnical electives in order that they may explore areas other than engineering. The choice of subjects is defined as follows:

a) English beyond the required courses is acceptable as a nontechnical elective as, also, are courses in the College of Architecture and Design whose major emphasis is on the fine arts.

b) Nontechnical electives may also be selected from the offerings of any instructional department or unit of this University except the following:

1. A department already represented by a required course in the student's degree program
2. The departments of Air, Military, or Naval Science
3. The College of Engineering (see *a*, above)
4. The School of Business Administration
5. The College of Architecture and Design (see *a*, above)

9. Substitution of a course for one which is a requirement for graduation must be approved by the student's program adviser of his degree program, and is subject to review of the Curriculum Committee.

10. After admission, a student will not be allowed, without special permission of the faculty, to take quizzes, tests, or examinations in any of the courses given unless he is regularly enrolled in such courses.

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

EXAMINATIONS

The regular examination at the end of the semester is an essential part of the work of the course. Classes may be examined at any time, with or without notice, on any part of the work.

GRADES AND SCHOLARSHIP

1. The semester average grade and the over-all average grade are computed for each student at the end of each semester and become part of his permanent record.

2. The average grade is determined on the basis of A (excellent) equals 4 points, B (good) equals 3 points, C (satisfactory) equals 2 points, D (passed) equals 1 point, and E (not passed) equals 0.

3. The average grade is computed by multiplying the number corresponding to the grade in each course by the hours of credit for the course and dividing the sum of these products by the total number of hours represented by all the courses elected. A supplementary grade removing an incomplete shall be used in computing averages when that grade is different from the original semester grade qualifying the report of incomplete.

4. No student who has earned an over-all average grade below 2.0 in the courses elected in this College may be graduated. A student whose over-all average or semester average falls below 2.0 should consult with his freshman counselor or program adviser immediately.

5. A student whose average grade for a semester or summer session is from 1.7 to less than 2.0 shall be automatically placed on the warned list.

6. A student on the warned list who fulfills the requirements of paragraph 10 and whose average for the following semester or summer session is 2.0 or better shall be restored to good standing, provided his over-all average grade is 2.0 or better; if not, he shall be continued on the warned list.

7. A student on the warned list whose average for the following semester or summer session is from 1.7 to less than 2.0 shall be automatically placed on probation.

8. When the average semester or summer session grade of a student falls below 1.7, he is automatically placed on probation.

9. A student on probation who fulfills the requirements of paragraph 10 and obtains an average semester or summer session grade of 2.0 or more is automatically removed from probation, provided his over-all average is 2.0 or better; if not, he shall be placed on the warned list.

10. A student on probation or under warning shall not be removed from the probation or warned list unless he elects and carries at least twelve hours of work in a semester or six hours in a summer session.

11. For any one of the following reasons a student will be placed on the home list and will not be permitted to register or classify in the College of Engineering unless authorized by the Committee on Scholastic Standing after a thorough review of his case:

a) If his average semester or summer session grade falls below 1.1.

b) If he is on probation and fails to obtain an average grade of 2.0, or C, during the semester or summer session next enrolled.

c) If he is on the warned list and obtains a semester or summer session average below 1.7.

d) If he has been on probation during any two semesters and subsequently fails to obtain an average semester or summer session grade of 1.7.

12. In cases of extenuating circumstances, at the discretion of the Committee on Scholastic Standing, students on the warned list or probation may be removed from these lists, and students who have been required to withdraw may be reinstated on probation.

13. A student who has been asked to withdraw but is reinstated on probation by the Committee on Scholastic Standing for the purpose of electing a transitional program in another school or college of the University will be permitted to continue his enrollment in the College of Engineering for one semester. If at the end of the semester the student has demonstrated ability to pursue his revised objectives successfully, by meeting the conditions for admission to the new unit, his transfer will be made effective; if he fails to meet the requirements for admission to the new unit, he will be requested to withdraw from the College of Engineering.

A student on warning or probation who enters upon a transitional program and fails to meet the requirements for admission to the new unit will be requested to withdraw from the College of Engineering.

14. A student who is placed on probation or under warning at the end of a semester or summer session must repeat as soon as possible all courses in which he received a grade of D. In exceptional cases this requirement may be waived by the student's program adviser (for freshmen, the Assistant Dean).

15. Any student may at his own option repeat a course in which he has a D grade, provided he does so during the next two semesters and summer session he is in residence.

16. Except as provided above, a student may not repeat a course which he has already passed. In exceptional cases this rule may be annulled by the student's program adviser (for freshmen, the Assistant Dean) upon recommendation of the department of instruction concerned.

17. All grades received in legally repeated courses shall be included in computing the student's average grade.

INCOMPLETES

When a student is prevented by illness or by any other cause beyond his control from taking an examination or from completing any other part of a course, or if credit in a course is temporarily withheld for any reason, 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 a temporary grade average. Should an I be incorrectly reported without a qualifying grade, it is used as a D grade in the temporary average. A permanent average is recorded when a final grade is filed by the instructor.

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. In order that credit for a course may be given, it must be completed before the end of the eighth week of the semester of residence next succeeding that in which it was elected unless an extension is granted by the Assistant Dean.

The final grade in a course which has been completed during the semester of residence following that in which it was elected 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. At the time of completing such a course, students must obtain from the Recorder a blank form for presentation to the instructor. The blank when filled out is to be sent at once by campus mail, or delivered by the instructor, directly to the Recorder's office, 263 W. Engineering Building.

CLASS STANDING

The following classification of a student in terms of credit hours applicable to his program has been approved by the faculty: *sophomores* should have from thirty to thirty-three hours; *juniors,* sixty-seven to seventy hours; and *seniors,* 100 to 104 hours or a reasonable chance to graduate within a year. The Assistant Dean will make decisions in unusual cases. The faculty recognizes as *upperclassmen*: (*a*) those students in good standing, i.e., not under scholastic discipline, who have obtained at least sixty-seven hours of credit, with an average grade of at least C for all work taken at the University; (*b*) all new students who have completed a four-year program at approved colleges and other like institutions; and (*c*) other new students with good previous records who, in the opinion of the program adviser, may qualify for graduation within one year.

EXCUSES FOR ABSENCES

Underclassmen in the College of Engineering must take the initiative in securing from the Assistant Dean excuses for absences from classes, which excuses must be applied for within five days after the return to class.

Upperclassmen are not required to obtain excuses for irregularities of attendance from the Assistant Dean but should explain them to their instructors.

WITHDRAWAL FROM THE COLLEGE

A student should not withdraw from class even temporarily without obtaining permission from the Assistant Dean's Office.

Withdrawal from the college requires the approval of the Assistant Dean's Office.

Honorable dismissal will be granted to those who wish to transfer to another college of the University and to those going elsewhere, provided in either case they are in good standing.

REQUIREMENTS FOR GRADUATION

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 English, engineering graphics, mathematics, chemistry, and physics, which is common to all degree programs; (*b*) he must complete the remaining specified professional subjects and electives in the program of his choice.
2. His grade average for all courses taken at the University must be 2.0 or more.
3. He must spend at least one year in residence and complete at the University a minimum of thirty credit hours. Attendance at four summer sessions will be accepted as the equivalent of one year in satisfying the present residence requirements.
4. He must be in residence during the term in which he completes the requirements for the degree.
5. To obtain a second bachelor's degree, the student must complete such subject requirements as are acceptable to the program advisers in both departments and must have completed not less than eight credit hours more than would be required for one degree.

A credit hour represents as a rule one hour of recitation or lecture a week for one semester, preparation for which should require two hours of study; or in the case of laboratory work, the credit hours are one-half to one-third of the actual hours spent in session, the time required depending on the necessary outside preparation.

An explanation of the number of credit hours and time requirement for graduation will be found under Undergraduate Degree Programs and Requirements.

All students who complete the requirements for graduation and who are entitled to receive degrees are expected to be present at the Commencement exercises.

Undergraduate Degree Programs and Requirements

The graduation requirements of the College of Engineering are expressed in terms of attainment rather than in terms of a fixed number of credit hours. The basic level of attainment required of all students in every degree program is demonstrated ability in English, mathematics, chemistry, engineering graphics, and physics equivalent, respectively, to the satisfactory completion of the following courses: English 12 and 21, Mathematics 56 or 37, Chemistry 5E or 15, Engineering Graphics 1 or 21, Physics 46 or 54. In addition, the student must complete the specific program of courses, or their equivalent, required in his elected degree program with an average of C (2.0) or more in all courses taken while enrolled in the College.

On the basis that the scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student, a superior student may materially decrease the time required to graduate from the University by carefully planning his high school program. Depending upon his preparation and ability, as indicated by high school standing and orientation period examinations, he may save as much as six credit hours in mathematics, three hours in chemistry, and two in physics. These savings may represent an amount equivalent to a summer session or a semester of one-half time work. In addition, a student who has attained a sufficiently high degree of proficiency in English composition and speech, in engineering graphics, and in other subjects in which attainment levels are indicated in the several degree programs, may be able to graduate with fewer hours and thereby save additional time for the completion of degree requirements.

GROUP A AND B SUBJECTS

Each degree program is composed of two groups of subjects.

Group A. Group A includes subjects in those basic areas common to all programs. These must be elected and passed or equivalent proficiencies must be demonstrated.

SUBJECT	HOURS
English	6
Mathematics	12 to 18
Chemistry	5 to 8
Engineering Graphics	3
Physics	8 to 10

Group B. Group B is composed basically of professional subjects and varies in the 14 degree programs. Group B requirements, a total of 95 credit hours, will be found under the heading Professional Subjects and Electives for each of the programs.

Courses taken at other recognized colleges or universities, if passed with a grade equivalent in the College of Engineering to C or better, will be accepted for appropriate credit (see Admission with Advanced Standing).

CREDIT HOURS AND TIME REQUIREMENT

For those students admitted with trigonometry, the total number of credit hours necessary to meet the level of attainment in Groups A and B varies around an average of 138. Usually the time requirement for such students completing their programs on schedule will be eight semesters plus a summer session, or nine semesters.

Students making up deficiencies or increasing their electives will enroll in more than 138 credit hours. Students who are admitted with advanced preparation or with demonstrated ability to achieve at high levels may graduate with less than 138 credit hours, thereby materially accelerating their progress as indicated above.

GROUP OPTIONS AND ELECTIVE STUDIES

The system of group options and electives allows the student to follow his particular interests and aptitudes by electing certain optional studies within the degree program in which he is enrolled or to elect work for which he is qualified in other departments of engineering or in other colleges or schools of the University, subject to the approval of his counselor or program adviser. In this way the student may receive instruction from specialists and plan in advance for possible graduate studies in some special field, in cognate sciences, in economics, or in business administration. The plan permits the greatest freedom of choice of subjects consistent with the acquisition of a sound background and a desirable breadth of education in the chosen fields.

A student's interests and objectives will normally determine his choice of subjects to meet the requirement of nontechnical electives. Definitions of acceptable courses may be found under Election of Studies. The student's counselor or program adviser is in a position to make recommendations. 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.

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

Program Adviser: Professor Schetzer, 1511 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 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 the design of wings and bodies. A sequence of courses in propulsion treats the theory and design of power plants, with special emphasis on the turboprop, turbojet, ramjet, and rocket motors. The stress analysis and design of elastic bodies is offered in a series of structures courses. Studies in the field of instrumentation include principles of measurement, data transmission, automatic control, and systems of analysis.

In the senior year, the engineering sciences described above are brought together in a sequence of courses that present the mechanics of flight. The performance and design of all types of flight vehicles are treated from the dynamics point of view.

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

Electives are provided with which the student may emphasize aerodynamics, propulsion, structures, aeroelasticity, mechanics of flight, or instrumentation as applied to various flight vehicle systems.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Aeronautical Engineering) are required to complete the following program:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (See page 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Groups II and III	4
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Mech. Eng. 2, Engineering Materials and Manufacturing Processes	2
Eng. Graphics 2, Descriptive Geometry	3
Econ. 53, 54*, General Economics	6
Math. 104, Differential Equations for Systems Analysis	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 123, Structural Mechanics	3
Mech. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, Direct and Alternating Current Apparatus and Circuits	4

*Econ. 153 and Bus.Ad. Accounting 100, or Econ. 153 and three hours additional of non-technical electives also will satisfy this requirement.

	HOURS
Aero. Eng. 1, General Aeronautics	1
Aero. Eng. 101, Airplane Design	3
Aero. Eng. 110, Aerodynamics I	4
Aero. Eng. 114, Aerodynamics II	4
Aero. Eng. 130, Flight Structures I	3
Aero. Eng. 131, Flight Structures II	4
Aero. Eng. 141, Mechanics of Flight I	2
Aero. Eng. 142, Mechanics of Flight II	3
Aero. Eng. 143, Control Systems	3
Aero. Eng. 163, Propulsion I	3
Aero. Eng. 164, Propulsion II	4
Nontechnical electives	9
Group options and electives*	10
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Physics 46	5	Chem.-Met. Eng. 18	3
Aero. Eng. 1	1	Mech. Eng. 2	2
Eng. Mech. 1	3	Eng. Mech. 2	4
Elective	3	Eng. Mech. 2*a*	1
		Mech. Eng. 105	3
	16		17

SUMMER SESSION	
Elective	3
Elec. Eng. 5	4
	7

FIFTH SEMESTER		SIXTH SEMESTER	
Math. 104	3	Aero. Eng. 130	3
Aero. Eng. 110	4	Aero. Eng. 114	4
Eng. Mech. 3	3	Econ. 54	3
Eng. Mech. 123	3	Aero. Eng. 163	3
Econ. 53	3	Aero. Eng. 141	2
		English, Group II	2
	16		17

SEVENTH SEMESTER		EIGHTH SEMESTER	
Aero. Eng. 131	4	Aero. Eng. 143	3
Aero. Eng. 164	4	Aero. Eng. 101	3
Aero. Eng. 142	3	Electives	8
Electives	5	English, Group III	2
	16		16

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

CHEMICAL ENGINEERING

Program Adviser: Professor Williams, 3213 East Engineering

Chemical Engineering is defined by the American Institute of Chemical Engineers as "the application of the principles of the physical sciences, together with the principles of economics and human relations, to fields that pertain to processes and process equipment in which matter is treated to effect a change in state, energy content, or composition." Quite apparently the work of the chemical engineer encompasses many industries, from space technology and nuclear energy to petroleum refining and chemical manufacturing; and a variety of functions including research, development, design, production, and management in these industries.

The education of the chemical engineer emphasizes the need for courses in basic physical sciences and is organized on functional concepts — that is, upon operations which are similar regardless of the industry or process in which they are used. For example, the transfer of heat, flow of fluids, combustion, whether applied to missiles or to design of chemical plants, have common principles.

The program leading to the degree begins with a foundation in mathematics and basic science, including a concentration in chemistry; and the communication aids of engineering graphics and English. Only the level of attainment is specified; the route to this level will depend upon the preparation and ability of the student. These requirements combined with the fairly large proportion of elective courses permit the student who wishes to do so to enter chemical engineering through the honors program of the College of Literature, Science, and the Arts or the integrated science program. The electives in advanced science may be equivalent to those required for the master's degree in other programs. This program, then, provides an excellent opportunity to prepare for postgraduate work.

REQUIREMENTS

Candidates for the degree of 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.

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 32)

B. PROFESSIONAL OR ADVANCED SUBJECTS AND ELECTIVES

Basic Science	HOURS
Advanced chemistry through Chem. 61 and 183	16
(In addition to the chemistry required of all students in Group A, these 16 hours will satisfy the need for advanced chemistry based upon the permissible sequence: Chem. 23, 182, 183, and 61)	
Introduction to Engineering Calculations, Chem.-Met. Eng. 3	3
Chemical and Metallurgical Engineering Science	
Thermodynamics, Chem.-Met. Eng. 110 and 111	7
Rate Processes, Chem.-Met. Eng. 112	4
Measurements Laboratory, Chem.-Met. Eng. 16	3
Structure of Solids, Chem.-Met. Eng. 118	3
Electives*	
Electives in humanities, social science, languages and literature, fine arts, etc.	14
Electives in law, business, and economics	6
Electives in engineering science and analysis: mechanics of solids and fluids, network analysis, electronics and systems, electromagnetics and energy conversion, etc.	14
Electives in advanced mathematics and science	12
Electives in chemical engineering, professional, such as materials, laboratory, and design	13
	95

Professional courses are those in which the physical and engineering sciences are used in engineering synthesis and design. Typical courses in this group are Chem.-Met. Eng. 117, 121, 129, and 130.

Electives may be grouped in special areas as shown below. The student should plan his elective units for several semesters in advance with the approval of his program adviser.

Bio-engineering: Bact. 109, 160; Chem.-Met. Eng. 238, 239
Combustion: Chem.-Met. Eng. 105, Aero. Eng. 262, Mech. Eng. 164, 165
Electrochemistry: Chem.-Met. Eng. 258, Chem. 277
Electronic materials: Elec. Eng. 108, 112; Math. 103; Phys. 196, 173
Graduate preparation: Math. 150 and language preparation
Instrumentation: Math. 104, 148; Instr. Eng. 174, 175
Machine computation: Math. 114, 173, 174; Instr. Eng. 175
Materials: Chem.-Met. Eng. 122, 124, 125, 126, 136; Eng. Mech. 126
Nuclear: Nucl. Eng. 190, 191
Polymers: Chem.-Met. Eng. 125, 232; Phys. 179
Petroleum: Geol. 98, 237; Chem.-Met. Eng. 235

*Courses that satisfy the requirements of the ROTC units will also be considered for use as electives where appropriate.

SUGGESTED SCHEDULE

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 11	3	English 12, 21	3
Eng. Graphics	3	Physics 45	5
Chemistry 5E	5	Math. 34	4
Math. 33	4	Chem.-Met. Eng. 3	3
	15		15

THIRD SEMESTER		FOURTH SEMESTER	
Physics 46	5	Math. 56	4
Math. 55	4	Chemistry 182	3
Chemistry 23	4	Chem.-Met. Eng. 110	3
Eng. Science	4	Eng. Science	4
		Nontechnical electives	3
	17		17

FIFTH SEMESTER		SIXTH SEMESTER	
Chemistry 183	3	Chemistry 61	6
Chem.-Met. Eng. 111	4	Chem.-Met. Eng. 112	4
Eng. Science	3	Math. or Science	3
Math. or Science	3	Eng. Science	3
Nontechnical electives	5	Chem.-Met. Eng. 118	3
	18		18

SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem.-Met. Eng. 16	3	Math. or Science	3
Professional Eng.	6	Professional Eng.	7
Math. or Science	3	Nontechnical electives	6
Nontechnical electives	6		
	18		17

If a summer session is contemplated, Chemisty 61 (Organic), 6 hours, is suggested following the sophomore year.

COMBINED PROGRAMS

CHEMICAL ENGINEERING AND METALLURGICAL ENGINEERING

Degrees in both chemical and metallurgical engineering may be earned by taking fourteen additional hours. Students in the chemical engineering program who desire to earn a degree in metallurgy as well will take fourteen hours in courses in metallurgical engineering in the field of process, physical, and mechanical metallurgy. Students in the metallurgical program will take Chem. 61 and eight hours in professional chemical engineering courses, to include laboratory and engineering synthesis for a total of fourteen additional hours. These programs should be formulated in consultation with program advisers.

CHEMICAL ENGINEERING AND CHEMISTRY

Advisers: Associate Professor Taylor, College of Literature, Science, and the Arts; Professor Schneidewind, College of Engineering.

Combined degrees are offered in chemistry (B.S.[Chem.], College of Literature, Science, and the Arts) and in chemical engineering (B.S.E.[Ch.E.], College of Engineering).

This program aims to supply the demands of students and of industry for a strong curriculum in chemistry and in chemical engineering. It is also excellent preparation for further graduate study and for research or development.

During the first four semesters the student is under the complete jurisdiction of the College of Literature, Science, and the Arts. After completing the work of the first four semesters the student is under the complete jurisdiction of the College of Engineering. After satisfactorily completing all the course requirements listed below, the student will be granted the two degrees, B.S. (Chem.) and B.S.E. (Ch.E.).

Candidates for the degrees of Bachelor of Science in Chemistry in the College of Literature, Science, and the Arts and Bachelor of Science in Engineering (Chemical Engineering) in the College of Engineering are required to complete the following program:

	HOURS	HOURS
HUMANITIES GROUP		26
English 23, 24 (L.S.&A.)	6	
Groups II and III (Engineering)	4	
German 1, 2, 31, 32	16	
MATHEMATICS AND SCIENCE GROUP		66 to 74
Chem. 3, 8 (or 3, 4, 20), 41, 61, 107, 141, 161, 182, 183, 185, 186, 191	41 to 43	
Math. 8, 33, 34, 55, 56 (or 35, 36, 37) and 103 or 104	15 to 21	
Physics 45, 46	10	
SOCIAL SCIENCES GROUP		9
Econ. 53, 54	6	
Bus.Ad., Accounting 100	3	
ENGINEERING COURSES		46
Eng. Mech. 3, 5	7	
Elec. Eng. 5	4	
Eng. Graphics 1 or 21	3	
Chem.-Met. Eng. 3, 110, 111, 112, 117, 118, 121, 130	29	
Elective in engineering materials	3	
ELECTIVES IN HUMANITIES		6
Total		153 to 161

CIVIL ENGINEERING

Program Adviser: Professor Boyce, 304 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. 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.

Geodesy and Surveying. Theory and practical applications 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. Location, design, construction, and maintenance of various types of roads and streets, including materials, surveys, plans, specifications, economics, financing, and administration.

Hydraulic. 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.

Meteorology. Courses in meteorology offered under the sponsorship of the Department of Civil Engineering are of general interest to, and may be elected by, qualified students from all branches of engineering and physical science. For courses in meteorology, see Description of Courses.

Railroad. 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. 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 sanitation; air sanitation; principles and standards of ventilation.

Soils. Soil mechanics: evaluation of soil properties and environmental conditions in foundations of earth-supported structures; mass stability in excavations and subsurface construction. Soil engineering: use of soil characteristics and properties and soil classification in design and construction of highways, railways, airports, and other surface facilities.

Structural. 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.

Traffic. 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.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Civ. Eng. 1, 2, 3, Surveying	10
English, Groups II and III	4
Eng. Graphics 2, Descriptive Geometry	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Adv. Math.	3
Elec. Eng. 5, Electrical Apparatus and Circuits	4
Mech. Eng. 13, Thermodynamics and Heat Transfer	4
Civ. Eng. 22, Theory of Structures	3
Civ. Eng. 23, Elementary Design of Structures	3
Civ. Eng. 30, Concrete Mixtures	1
Civ. Eng. 52, Water Supply and Treatment	3
Civ. Eng. 53, Sewerage and Sewage Treatment	2
Civ. Eng. 65, Transportation Engineering	3
Civ. Eng. 121, Reinforced Concrete	3
Civ. Eng. 135, Engineering Properties of Soil	3

	HOURS
Civ. Eng. 140, Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 180, Specifications and Contracts	2
Geol. 98	4
Economics, elective	3
Humanities and social sciences (see below)	8
Technical option group* (see below)	10
Total, professional subjects and electives	95

The electives in humanities and social sciences are to be approved courses in such fields as economics, fine arts, history, law, literature, 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—Adviser: Associate Professor Alt
2. Geodesy and Surveying—Adviser: Professor Berry
3. Highway—Adviser: Assistant Professor Cortright
4. Hydraulic—Adviser: Professor Brater
5. Meteorology—Adviser: Professor Hewson
6. Railroad—Adviser: Assistant Professor Heimbach
7. Sanitary—Adviser: Associate Professor Borchardt
8. Soils—Adviser: Professor Housel
9. Structures—Adviser: Professor Maugh
10. Traffic—Adviser: Professor Kohl

Other combinations of technical courses for special fields of professional interest can be formulated and approved by the program adviser to meet the needs of individual students.

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

SUMMER SESSION (at Camp Davis)

	HOURS
Civ. Eng. 1	4
Geol. 98	4
	8

THIRD SEMESTER		FOURTH SEMESTER	HOURS
Math. 55	4	Math. 56	4
Physics 45†	5	Physics 46†	5
Civ. Eng. 2	3	Eng. Mech. 2	4
Civ. Eng. 30	1	Eng. Mech. 2*a*	1
Eng. Mech. 1	3	Civ. Eng. 3	3
	16		17

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

†If Physics 45 was elected second semester, then Physics 46 should be elected third semester.

FIFTH SEMESTER	HOURS
Civ. Eng. 140	3
Eng. Mech. 4	3
Civ. Eng. 22	3
Civ. Eng. 65	3
Adv. Math.	3
*Electives	2
	17

SIXTH SEMESTER	HOURS
Civ. Eng. 121	3
Civ. Eng. 141	2
Civ. Eng. 52	3
Civ. Eng. 135	3
Eng. Mech. 3	3
English, Group II	2
*Electives	3
	19

SEVENTH SEMESTER	
Civ. Eng. 180	2
Civ. Eng. 23	3
Elec. Eng. 5	4
Civ. Eng. 53	2
English, Group III	3
Technical Electives	3
	16

EIGHTH SEMESTER	
Mech. Eng. 13	4
Technical Electives	7
Econ. 153	3
*Electives	3
	17

COMBINED PROGRAM WITH COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS

Advisers: Assistant Professor John A. Dorr, College of Literature, Science, and the Arts; Associate Professor Robert B. Harris, College of Engineering.

As one of the combined programs referred to on pages 9-10, the College of Engineering and the College of Literature, Science, and the Arts offer a combined program which leads to the degrees of Bachelor of Science in Engineering (Civil Engineering) and Bachelor of Arts.

This program is designed to meet the desires of those who wish to have a broader background in the humanities and liberal arts than can be offered in the regular four-year civil engineering curriculum. Many civil engineers find a need for a humanistic and liberal arts background in their professional work, particularly as they relate their designs and constructions to the economic and social demands of society.

The program includes those courses in languages, literature, fine arts, philosophy, and history which would normally be taken by a student receiving a Bachelor of Arts degree with science as his major. At the same time, his science elections are planned in such a manner as to satisfy the requirements for both degrees. Upon completion of the five-year program, the student will have fulfilled all of the requirements for the Bachelor of Science in Engineering (Civil Engineering) degree and for the Bachelor of Arts degree. The degrees will be granted on completion of the prescribed program, with the understanding that if military science is elected it must be carried in addition to the full requirements of the regular curriculum.

A student electing the five-year combined program will enroll in the College of Literature, Science, and the Arts for the first four semesters.

*Electives in the humanities and social science group.

He will then enroll in the College of Engineering for the remaining six semesters and summer session. The complete program is as follows:

	HOURS	HOURS
HUMANITIES GROUP		37
English 23, 24, 45	9	
Fine Arts 3	4	
Foreign language or social sciences*	16	
Speech 61	2	
Philosophy 31 or 34, 33	6	
MATHEMATICS AND SCIENCE GROUP		37 (to 42)
Math. 33, 34, 55, 56 or 35, 36, 37	16 (or 12)	
Advanced Math.	3	
Chem. 3, 4, or 5E and Psych. 31	8 (or 9)	
Geology 98 (at Camp Davis)	4	
Physics 45, 46	10	
SOCIAL SCIENCE GROUP		9
Bus. Ad. Accounting 100	3	
Economics 53, 54	6	
ENGINEERING GROUP		79
Eng. Graphics 1, 2	6	
Chem.-Met. Eng. 18	3	
Eng. Mech. 1, 2, 2*a*, 3, 4	14	
Elec. Eng. 5	4	
Mech. Eng. 2, 13	6	
Civil Eng. 1 (at Camp Davis), 2, 3, 22, 23, 30, 52, 53, 65 121, 135, 140, 141, 180, group options	46	
ELECTIVES IN COLLEGE OF L.S.&A.		5
Total		167–172

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, electric streetcars, and communication systems. The modern automobile, and still more the modern passenger or military airplane, carries a bewildering array of electric controls, gages, and instruments without which our present automobile and airplane transportation would be impossible. Radar, electrically controlled gun batteries, guided missiles, robot

*The College of Literature, Science, and the Arts requires that during his fourth semester the student demonstrate, by examination, proficiency in a foreign language. If a student satisfies this requirement prior to the completion of 16 hours of language course work, he will take the remaining hours in foreign language literature or the social sciences.

airplanes, and scores of other such developments are all in the realm 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.

The facilities of the Electrical Engineering Department include the following research laboratories: Digital Computer Engineering, Electron Physics, Electronic Defense Group, Plasma Engineering, Radiation, Radio-Astronomy, Feedback Control Systems, Solid-State Devices, and Space Physics Research.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
Eng. Graphics 4, Introduction to Descriptive Geometry	2
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Math. 103 or 104, Differential Equations	3
English, Groups II and III	4
Econ. 53, 54*, Principles of Economics	6
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 2, Engineering Materials and Manufacturing Processes	2
Mech. Eng. 13, Thermodynamics and Heat Transfer	4
Mech. Eng. 83, Machine Design	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 10, Principles of Electricity and Magnetism	3
Elec. Eng. 100, Circuits II	4
Elec. Eng. 101, Circuits III	3
Elec. Eng. 110, Electromagnetic Fields and Waves	3
Elec. Eng. 120, Electronics and Communications I	4
Elec. Eng. 130, Electrical Measurements	3
Elec. Eng. 141, Economic Applications in Electrical Engineering	2
Elec. Eng. 153, Energy Conversion and Control I	3
Elec. Eng. 154, Energy Conversion and Control II	4
Elec. Eng. 160, Electrical Design	4
Elec. Eng. 180, Physical Electronics of Electron Devices I	4
Nontechnical electives	6
Electives†	11
Total, professional subjects and electives	95

*Econ. 153 and Bus.Ad., Accounting 100, or Econ. 153 and three additional hours of nontechnical electives also will satisfy this requirement.

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

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS
Math. 55	4
Physics 46	5
Elec. Eng. 3	4
Elective (nontechnical)	3
	—
	16

FOURTH SEMESTER	HOURS
Math. 56	4
Elec. Eng. 10	3
Chem.-Met. Eng. 18	3
Mech. Eng. 2	2
Eng. Graphics 4	2
Elective (nontechnical)	3
	—
	17

SUMMER SESSION	
Elec. Eng. 100	4
Mech. Eng. 13	4
	—
	8

FIFTH SEMESTER	
Elec. Eng. 130	3
Elec. Eng. 180	4
Eng. Mech. 5	4
Math. 103 or 104	3
Econ. 53	3
	—
	17

SIXTH SEMESTER	
Elec. Eng. 120	4
Elec. Eng. 141	2
Elec. Eng. 153	3
Eng. Mech. 3	3
English, Group II	2
Econ. 54	3
	—
	17

SEVENTH SEMESTER	
Elec. Eng. 101	3
Elec. Eng. 154	4
Eng. Mech. 4	3
Electives	7
	—
	17

EIGHTH SEMESTER	
Elec. Eng. 110	3
Elec. Eng. 160	4
English, Group III	2
Mech. Eng. 83	3
Electives	4
	—
	16

ENGINEERING MECHANICS

Program Adviser: Professor Clark, 201 West Engineering

Rapid technological developments have brought about an increasing need for engineers exceptionally well-trained in the basic sciences. The need is acute throughout industry and government as well as in institutions of research 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 companies and institutions 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 without loss of time after one or two years of college work. The later years are filled mainly by 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 bachelors program are strength of materials, elasticity, plasticity, dynamics, vibrations, fluid mechanics, and thermodynamics. The department has modern laboratories and adequate computer and research facilities. The association of theory with the physical aspects of the work is very close. To help maintain the professional outlook the program contains a group option in a professional or technical area chosen by the student. In addition there are seven to nine hours of free electives.

Graduate work toward a masters degree is a natural sequence for those mechanics graduates who qualify. It is also open to graduates in other areas of engineering.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Group II and III	4
Math. 103, Differential Equations	3
Math. 147, Modern Operational Mathematics, *or* Math. 176, Vector Analysis	2
Math. 150, Advanced Mathematics for Engineers	4
Civil Eng. 21, Theory of Structures	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 105, Thermodynamics	3
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Eng. Graphics 2, Descriptive Geometry	3
Eng. Mech. 1, Statics *or* Eng. Mech. 11	3
Eng. Mech. 2, Mechanics of Materials *or* Eng. Mech. 102	4
Eng. Mech. 2*a*, Strength of Materials Laboratory *or* Eng. Mech. 12	1
Eng. Mech. 3, Dynamics *or* Eng. Mech. 13	3
Eng. Mech. 4, Fluid Mechanics *or* Eng. Mech. 14	3
Eng. Mech. 103, Experimental Mechanics, *or* Inst. Eng. 172, Instrument Dynamics	2
Eng. Mech. 112, Intermediate Mechanics of Materials	3
Eng. Mech. 113, Intermediate Mechanics of Vibrations	3
Eng. Mech. 114, Intermediate Mechanics of Fluids	3
Eng. Mech., approved advanced courses	7
Economics 153	3
Nontechnical electives	9
Group options and electives* (see below)	22
Total, professional subjects and electives	95

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

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, 7 to 9 hours, selected in conference with the adviser will complete this group of requirements.

Suggested group options are:

Aerodynamics	Mechanics of Solids
Aeromechanics	Metallurgy
Chemical Engineering	Meteorology
Dynamics	Naval Architecture
Electrical Engineering	Nuclear Engineering
Hydraulics	Physics
Instrumentation	Propulsion
Machine Design	Structural Engineering
Mechanics of Fluids	Others arranged

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

INDUSTRIAL ENGINEERING

Program Adviser: Professor Gage, 235 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; and 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, and human effort and energy. The industrial engineer should combine the aptitudes of an engineer, an accountant, and a business executive. 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 analysis work and compensation, evaluation, operations research, engineering economy, production engineering, probability and statistics, and organization and management, including the use of new mathematical techniques for solving industrial problems. As an aid to education the department has well-equipped demonstration facilities.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Groups II and III	4
Econ. 153*	3
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Chem.-Met. Eng. 107, Metals and Alloys	3
Eng. Graphics 2, Descriptive Geometry	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 13, Thermodynamics and Heat Transfer	4
Mech. Eng. 14, Heat-Power Laboratory	1
Mech. Eng. 31, Manufacturing Processes I	3
Mech. Eng. 33, Manufacturing Processes II	3
Mech. Eng. 83, Machine Design	3
Mech. Eng. 86, Machine Design II	3
Ind. Eng. 100, Industrial Management	3
Ind. Eng. 110, Plant Layout and Materials Handling	3
Ind. Eng. 120, Work Measurement	3
Ind. Eng. 130, Wage Incentives and Job Evaluation	2
Ind. Eng. 135, Management Control	3
Ind. Eng. 140, Production Control	2
Ind. Eng. 150, Engineering Economy	2
Ind. Eng. 160, Operations Research	3
Ind. Eng. 165, Data Processing	3
Bus.Ad., Accounting 100	3
Bus.Ad., General 154, Industrial Cost Accounting†	3
Math. 161, 162, Statistical Methods for Engineers	6
Nontechnical electives	7
Technical electives	8
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Chem.-Met. Eng. 18	3	Chem-Met. Eng. 107	3
Physics 46	5	Mech. Eng. 13	4
Bus. Ad., Accounting 100	3	Eng. Graphics 2	3
English, Group II	2	Bus. Ad. General 154	3
	17		17

*Econ. 53 and 54 may be substituted for Econ. 153 and three hours technical electives.
†Bus.Ad., Accounting 101 and 105 may be substituted for Bus.Ad., General 154 and three hours of technical electives.

SUMMER SESSION	HOURS
Eng. Mech. 5	4
Elective	3
	7

FIFTH SEMESTER	HOURS	SIXTH SEMESTER	HOURS
Math. 161	3	Math. 162	3
Eng. Mech. 3	3	Ind. Eng. 110	3
Elec. Eng. 5	4	Mech. Eng. 83	3
Mech. Eng. 31	3	Mech. Eng. 33	3
Ind. Eng. 100	3	Ind. Eng. 120	3
Mech. Eng. 14	1	Elective	2
	17		17

SEVENTH SEMESTER	HOURS	EIGHTH SEMESTER	HOURS
Ind. Eng. 160	3	English, Group III	2
Ind. Eng. 130	2	Ind. Eng. 135	3
Economics 153	3	Ind. Eng. 140	2
Mech. Eng. 86	3	Ind. Eng. 150	2
Elective	6	Ind. Eng. 165	3
	17	Elective	4
			16

MATERIALS ENGINEERING

Program Adviser: Professor Van Vlack, 4215 East Engineering

With the rapid development of new and better materials to meet the more exacting demands of industry and government agencies, there has developed a demand for engineers with a sound understanding of materials and the factors that determine their various properties. Materials engineers must have a sound foundation in physics and chemistry, as well as in engineering and in the materials used and manufactured by industry. They must also understand the utility, properties, and applications of materials such as metals, alloys, cements, plastics, ceramics, and protective coatings. They are particularly valuable in manufacturing plants where it frequently is desirable to replace present materials for the purpose of improving the product, reducing costs, reducing service failures, or because of shortages of specific raw materials. They find opportunities in the development of new products, specification of new materials, or combinations of these for existing products, development of new applications, or in the sales field. This program as designed also offers work in specifications, methods of fabrication, corrosion, high temperature properties of metals, and stress analysis.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Materials Engineering) are required to complete the following program:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (See page 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
Eng. Graphics 22	3
Math. 103, Differential Equations, or Math. 161	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics *or* Chem.-Met. Eng. 114, Unit Operations	3
Chem. 23, Analytical	4
Chem. 61, Organic	6
Chem. 182, 183, Physical	6
Science Eng. 110, Chem.-Met. Eng. 111, Thermodynamics or equivalent	3
Elec. Eng. 5,* D.C. and A.C. Apparatus and Circuits and Electronics	4
Chem.-Met. Eng. 16, Measurements, or Elec. Eng. 136, Methods of Instrumentation	3
Chem.-Met. Eng. 118, Structure of Solids	3
Chem.-Met. Eng. 122, Ceramic Materials	4
Chem.-Met. Eng. 124, X-ray Structure	3
Chem.-Met. Eng. 125, Introduction to High Polymers	4
Chem.-Met. Eng. 127, 128, Physical Metallurgy	7
Humanities and social sciences (see below)	16
Technical group options (see below)	9
Free electives†	4
Total, professional subjects and electives	95

Under the humanities and social science group requirement, at least one course must be in English and the others must include selections in at least two of the following fields: anthropology, classical studies, economics, geography, fine arts, history, journalism, music, languages, political science, philosophy, psychology, sociology, and speech.

In satisfying the technical group option requirement, subjects are to be elected within one engineering area with the advance approval of the program adviser.

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Chem. 23	4	Physics 46	5

*If the technical group options are chosen in the electrical area, Elec. Eng. 9 (*3*) should be elected in place of Elec. Eng. 5 (*4*) and followed by 10 hours of technical options.

†Advanced courses in air, military, or naval science (300 and 400 series) may be used for these electives.

THIRD SEMESTER (CONT.)	HOURS
Physics 46	5
Eng. Mech. 1	3
	—
	16

FOURTH SEMESTER (CONT.)	HOURS
Eng. Mech. 2	4
Electives	2
	—
	16

SUMMER SESSION	
Eng. Mech. 3	3
Elec. Eng. 5	4
	—
	7

FIFTH SEMESTER	
Math. 103 (or 161)	3
Chem. 182	3
Sci. Eng. 110 *or* Chem.-Met. Eng. 111	3
Elective	7
	—
	16

SIXTH SEMESTER	
Chem. 183	3
Chem.-Met. Eng. 16 *or* Elec. Eng. 136	3
Chem.-Met. Eng. 118	3
Eng. Mech. 4	3
Electives and options	4
	—
	16

SEVENTH SEMESTER	
Chem.-Met. Eng. 124	3
Chem.-Met. Eng. 125	4
Chem.-Met. Eng. 127	4
Electives and options	6
	—
	17

EIGHTH SEMESTER	
Chem.-Met. Eng. 122	4
Chem.-Met. Eng. 128	3
Electives and options	10
	—
	17

MATHEMATICS

Program Co-advisers: Professor Ullman, 270 West Engineering; Professor J. J. Martin, 3217 East 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).

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Eng. Graphics 2 or 22	3
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Mech Eng. 2, Engineering Materials and Manufacturing Processes	2
Math. 103 or 104, Differential Equations	3
Math. 150, Advanced Calculus for Engineers	4
Electives in the humanities, social sciences, and philosophy (see the *Announcement* of the College of L.S. & A. for the basic courses in these fields of knowledge)	12
Eng. Mech. 1 or 11, Statics	3
Eng. Mech. 2 or 12, Mechanics of Materials	4
Eng. Mech. 3 or 13, Dynamics	3
Eng. Mech. 4 or 14, Fluid Mechanics	3 or 4
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 105, Chem.-Met. 111, or Sci. Eng. 110, Thermodynamics	3
Electives in mathematics, to include work in approved advanced mathematics having applications to problems in the physical sciences, such as: operational mathematics, Fourier series, complex variables, statistics, numerical analysis and application of the computer	8
Electives in engineering analysis and design	15
Electives in science and engineering science	11 or 12
Electives*	9
Total, professional subjects and electives	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 are:

- Aerodynamics
- Mechanics of Flight
- Aircraft Propulsion
- Automotive Engineering
- Chemical Engineering
- Computer Engineering
- Electrical Power
- Electronics
- Fluid Machinery
- Geodesy and Surveying
- Heat–Power
- Hydraulics
- Instrumentation
- Machine Design
- Marine Engineering
- Meteorology
- Metallurgy
- Naval Architecture
- Nuclear Engineering
- Solid Mechanics
- Structures

Details of these can be obtained from the program advisers and options in other areas can be arranged by conference with the Program Advisory Committee.

All electives must be approved by a program adviser.

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

MECHANICAL ENGINEERING

Program Adviser: Professor Pearson, 230A West Engineering

The mechanical engineer is concerned with the generation and control of power and heat transfer systems, the design and development of a wide variety of products and machinery, and the operations and methods of manufacture. As such he engages in the design, operation, and control of conventional and nuclear power plants. He designs and develops automobiles, engines, turbines, fluid machinery, production machinery, and equipment; heating, ventilating, air conditioning, refrigeration systems and equipment, appliances and other consumer goods. He is responsible for the development, operation, and control of manufacturing processes.

The mechanical engineer is employed in many industries. Automotive, machine tool, and general machinery firms are obvious examples. Less obvious, but no less important, are the aircraft, chemical, electrical, public utilities, and materials industries.

The varied nature of mechanical engineering demands a strong foundation in the basic sciences of mathematics, physics, and chemistry. To this the program adds study in the engineering sciences: thermodynamics and heat transfer, solid and fluid mechanics, electricity and electronics, and materials. These fundamentals are then applied to the design, heat and power, and manufacturing aspects of mechanical engineering through a group of lecture, laboratory, and design courses required of all mechanical engineering students. In addition, as indicated below, the student undertakes study in an area of particular interest to himself through the selection of a sequence of electives.

The particular interest of a mechanical engineering student may make it desirable for him to work toward a second bachelor's degree in another engineering program, simultaneously with his work toward the degree in mechanical engineering. The requirements governing work toward two degrees are presented under Requirements for Graduation. The mechanical engineering program is readily adaptable to these requirements; interested students should consult the program adviser.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Econ. 53 and 54, or Econ. 153 and three hours nontechnical elective	6
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Eng. Graphics 4	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Math. 103 or 104, Differential Equations	3
Mech. Eng. 17, Mechanical Engineering Laboratory	2
Mech. Eng. 31, Manufacturing Processes I*	3
Mech. Eng. 33, Manufacturing Processes II	3
Mech. Eng. 80, Dynamics of Machinery	3
Mech. Eng. 82, Machine Design I	3
Mech. Eng. 86, Machine Design II	3
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 105, Thermodynamics I	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 111, Heat Transfer I	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 7, Motor Control and Electronics	4
Chem.-Met. Eng. 107, Metals and Alloys	3
Nontechnical electives	6
Technical electives†	17
Total, professional subjects and electives	95

The technical electives requirement permits the student to pursue a sequence of courses reflecting his interest in a particular field such as automotive, air conditioning, design, fluids machinery, heat power (automotive and stationary power plants, including turbines, rockets, nuclear energy, etc.), instrumentation and control, manufacturing, mathematics and science, refrigeration, etc. The student who does not wish to emphasize any particular field may distribute his selections.

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. A student interested in the automotive area, for example, may wish to emphasize body and chassis work or engine and transmission aspects, or he may elect courses in each. As another example, a student interested in the mechanical engineering aspects of the chemical industry may wish to select some electives in the chemical engineering area.

*Freshmen who have not taken Mech. Eng. 2 should take Mech. Eng. 31., Manufacturing Processes I. (*3*).

†This group of electives should include 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.

SUGGESTED SCHEDULE*

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56	4
Eng. Mech. 1	3	Eng. Mech. 2	4
Physics 46	5	Eng. Mech. 2*a*	1
Chem.-Met. Eng. 18	3	Chem.-Met. Eng. 107	3
English, Group II	2	Mech. Eng. 31	3
		Eng. Graphics 4	2
	17		17

SUMMER SESSION	
Eng. Mech. 3	3
Mech. Eng. 105	3
	6

FIFTH SEMESTER		SIXTH SEMESTER	
Math. 103	3	Mech. Eng. 104	3
Eng. Mech. 4	3	Mech. Eng. 111	3
Mech. Eng. 106	3	Mech. Eng. 17	2
Nontechnical elective	3	Elec. Eng. 5	4
Mech. Eng. 33	3	Mech. Eng. 82	3
Mech. Eng. 80	3		15
	18		

SEVENTH SEMESTER		EIGHTH SEMESTER	
English, Group III	2	Nontechnical elective	6
Technical electives	8	Econ. 153	3
Elec. Eng. 7	4	Technical electives	9
Mech. Eng. 86	3		
	17		18

METALLURGICAL ENGINEERING

Program Adviser: Professor Flinn, 4305 East Engineering

Metals and alloys possessing carefully defined properties are required by manufacturers of electronic equipment, aircraft, and reactors as well as in structures. In many cases the discoveries of science cannot be usefully applied until metals of the required characteristics are developed.

The metallurgical engineer is concerned, therefore, with the conversion of ores into metals and combinations of metals which possess specified qualities such as higher strength, increased resistance to extreme

*The most appropriate schedule for any student will depend upon his area of group options and electives interest. The student should develop the desired modifications to the above basic schedule with the advice and approval of his counselor.

temperatures, and greater hardness or ductility. In common with other engineers he is required to have a thorough background of the physical and engineering sciences, as well as a knowledge of casting and of other metallurgical operations. The nature and control of metal structures are studied by modern methods, such as X-ray diffraction and the use of the electron and light microscopes, as also are the structural transformations resulting from heat treatment.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Metallurgical Engineering) are required to complete the following program:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (See page 32)

B. PROFESSIONAL OR ADVANCED SUBJECTS AND ELECTIVES

	HOURS
BASIC SCIENCE	
Advanced chemistry through Chem. 183	10
(In addition to the chemistry required of all students in Group A, these 10 hours will satisfy the need for advanced chemistry based upon the permissible sequence: Chem. 23, 182, and 183.	
Introduction to Engineering Calculations, Chem.-Met. 3	3
CHEMICAL-METALLURGICAL ENGINEERING SCIENCE	
Thermodynamics, Chem.-Met. Eng. 110 and 111	7
Rate Processes, Chem.-Met. Eng. 112	4
Measurements Laboratory, Chem.-Met. Eng. 16	3
Structure of Solids, Chem.-Met. Eng. 118	3
ELECTIVES*	
Electives in humanities, social sciences, and language	14
Electives in law, business, accounting (limit of one course) and economics	6
Electives in cognate engineering science and analysis in the College of Engineering (to include mechanics and electrical theory)	14
Electives in advanced mathematics, advanced science, and advanced engineering	12
Electives in metallurgical engineering in each of the fields of process, physical, and mechanical metallurgy	19
	95

*Courses that satisfy the requirements of the ROTC units will also be considered for use as electives where appropriate.

SUGGESTED SCHEDULE

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 11	3	English 12, 21	3
Eng. Graphics	3	Physics 45	5
Chemistry 5E	5	Math. 34	4
Math. 33	4	Chem.-Met. Eng. 3	3
	15		15
THIRD SEMESTER		FOURTH SEMESTER	
Physics 46	5	Math. 56	4
Math. 55	4	Chemistry 182	3
Chemistry 23	4	Chem.-Met. Eng. 110	3
Nontechnical electives	5	Chem.-Met. Eng. 16	3
		Nontechnical electives	5
	18		18
FIFTH SEMESTER		SIXTH SEMESTER	
Eng. Mech 5	4	Chem.-Met. Eng. 118	3
Chemistry 183	3	Eng. Mech. 3	3
Chem.-Met. Eng. 111	4	Chem.-Met. Eng. 112	4
Math. 104	4	Chem.-Met. Eng. 13	2
Bus. Ad. 100	3	Elec. Eng. 5	4
	18		16
SEVENTH SEMESTER		EIGHTH SEMESTER	
Nontechnical electives	4	Mech. Eng. 83	3
Chem.-Met. Eng. 127	4	Chem.-Met. Eng. 128	3
Sci. or Math. elective	2	Chem.-Met. Eng. 210	2
Econ. 153	3	Chem.-Met. Eng. 122	4
Chem.-Met. Eng. 114	4	Chem.-Met. Eng. 148	3
Chem.-Met. Eng. 210	1	Chem.-Met. Eng. 129	3
	18		18

METEOROLOGY

Program Adviser: Associate Professor Dingle, 5062 East Engineering

The increasing recognition of the importance of weather and climate in a wide range of engineering problems has created a demand for engineers with a knowledge of meteorology and the ability to apply it to specific problems. There is a need for qualified engineering meteorologists, both men and women, in industry, government, teaching, research, and private practice — a need which gives every evidence of continuing for years to come.

Weather forecasting has traditionally been the main occupation of meteorologists, but modern meteorology encompasses a much wider range of activities and interests. In the planning of a large industrial plant the engineering meteorologist may be called upon to evaluate the proposed location, plant processes, stack characteristics, etc., in order to avoid or minimize air pollution problems. In the design of towers or suspension bridges, the dynamic wind loadings on the structure for that region and terrain must be studied and estimated. In transportation, whether by land, water, or air, weather is often the determining factor in maintaining efficient operation. Engineering meteorology has important application in many other areas, such as vehicle design; electrical power and natural gas dispatching; air conditioning; nuclear power plant design, location, and operation; cooling tower design; evaluation and prevention of weathering of materials; design of snow clearance heating systems; hydroelectric power development; solar energy use; and analysis of planetary atmospheres.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Meteorology) are required to complete the following program:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (see page 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
English, Groups II and III	4
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Eng. Graphics 2, Descriptive Geometry	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics I	3
Sci. Eng. 110, Thermodynamics	3
Sci. Eng. 112, Rate Processes	3
Elec. Eng. 9, Network Analysis	3
Elec. Eng. 11, Electromagnetics and Energy Conversion	4
Ind. Eng. 160, Operations Research	3
Math. 103 or 104, Differential Equations	3
Meteor. 122, Atmospheric Thermodynamics and Radiation	3
Meteor. 126, Dynamic Meteorology	3
Meteor. 132, Synoptic Meteorology	3
Meteor. 135, Laboratory in Synoptic Meteorology I	3
Meteor. 144, Physical Meteorology	3
Meteor. 153, Physical Climatology	3
Meteor. 162, Meteorological Instrumentation	3
Meteor. 182, Hydrology and Hydrometeorological Design	4
Meteor. 186, Meteorological Analysis and Design Criteria	4
Electives in mathematics, engineering science, physical science, and biological science*	11
Electives in humanities and social science	13
Total, professional subjects and electives	95

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

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 meteorology 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.

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Physics 46	5	Eng. Graphics 2	3
Eng. Mech. I	4	Eng. Mech. 2	4
English, Group II	2	Eng. Mech. 3	3
Chem.-Met. Eng. 18 *or* elective	3	Elective	4
	18		18
FIFTH SEMESTER		SIXTH SEMESTER	
Sci. Eng. 110	3	Math. 103 or 104	3
Eng. Mech. 4	3	Elec. Eng. 9	3
Meteor. 122	3	Meteor. 126	3
Meteor. 132	3	Meteor. 144	3
Meteor. 135	3	English, Group III	2
Elective	3	Elective	3
	18		17
SEVENTH SEMESTER		EIGHTH SEMESTER	
Elec. Eng. 11	4	Ind. Eng. 160	3
Sci. Eng. 112	3	Meteor. 186	4
Meteor. 153	3	Electives	11
Meteor. 162	3		18
Meteor. 182	4		
	17		

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Adams, 448B West Engineering

This program has for its object the training of students in the design and construction of ships, their propelling machinery, and auxiliaries. The program ultimately is directed to the following two divisions:

Naval Architecture. Option 1 relates to the design and construction of ship hulls and includes such topics as form, strength, structural details, resistance, powering, stability, weight and cost estimating, and the methods available for solving the general problems of preliminary and final ship design.

Marine Engineering. Option 2 includes those subjects dealing more particularly with the design and construction of the various types of propelling machinery, such as steam turbine, gas turbine, and oil engines; boilers of different types; auxiliaries; propellers; and the general problem of heat transference.

In addition to these two fields of activity, graduates frequently become connected with the operating divisions of transportation companies. Others have entered the Coast Guard service or other governmental maritime agencies. Some prefer to work with and specialize in the design, construction, and brokerage of both power and sail yachts. The prescribed courses are therefore designed to give a student a thorough training in the fundamental problems relating to naval architecture and marine engineering with certain of them open to elective work in any group which may give him a more specific training in the particular line of work he may wish to follow.

In planning the program, it has been recognized that the basic work is similar to that in mechanical engineering, with the differentiation largely in the third and, particularly, the fourth years. As a ship represents a floating power plant, fundamental courses in electrical and chemical engineering also are included. Although it is true, in the shipbuilding and shipping industry, that men are eventually segregated into the divisions mentioned above, it has been thought advisable to devote more time to the essentials of the subject rather than to undue specialization in any one, and to give the student as broad a background as possible. If, however, further specialization is desired, it is recommended that the student return for a fifth year for graduate study. Facilities for research work are provided in the experimental ship model basin. The University also has an operating nuclear reactor and an extensive nuclear engineering graduate program. Thus upon completion of the requirements for a B.S.E. (Naval Architecture and Marine Engineering) the student may continue with a nuclear engineering graduate program.

The department is in constant touch with all the shipbuilding and shipping establishments, not only in this district but throughout the country, and is able to aid its graduates in obtaining positions in the various lines mentioned.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES

	HOURS
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Eng. Graphics 2, Descriptive Geometry	3
Math. 103, Differential Equations	3
English, Groups II and III	4
Econ. 153	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 123, Structural Mechanics	3
Eng. Mech. 136, Theory of Vibrations	3
Mech. Eng. 2, Engineering Materials and Manufacturing Processes	2
Mech. Eng. 17, Heat-Power Laboratory	2
Mech. Eng. 80, Dynamics of Machinery	2
Mech. Eng. 82, Machine Design I	3
Mech. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Nav. Arch. 11, Introduction to Practice	2
Nav. Arch. 12, Form Calculations I	3
Nav. Arch. 21, Structural Design I	3
Nav. Arch. 147, Marine Auxiliary Machinery	3
Nav. Arch. 151, Resistance, Propulsion, and Propellers	5
Nontechnical electives	9
Group options and electives	18
Total, professional subjects and electives	95

One of the following groups should be selected by the student before the beginning of his junior year:

1. NAVAL ARCHITECTURE. Adviser: Professor Adams

For those principally interested in ship design and hull construction.

Nav. Arch. 13, Form Calculations II	2
Nav. Arch. 127, Stress Analysis in Ship Structures	2
Nav. Arch. 131, Ship Dynamics	2
Nav. Arch. 132, Ship Design I	3
Nav. Arch. 133, Ship Design II	2
Nav. Arch. 134, Structural Design II	2
Nav. Arch. 137, Specifications and Contracts	2
Nav. Arch. 141, Marine Propulsion Machinery	3
	18

2. MARINE ENGINEERING. Adviser: Associate Professor West

For those principally interested in the design of propelling and other ship machinery.

Elec. Eng. 7, Motor Control and Electronics	4
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 111, Heat Transfer	3
Nuc. Eng. 190, Elements of Nuclear Engineering	3
Nav. Arch. 146, Design of Marine Power Plants I	2
Nav. Arch. 144, Design of Marine Power Plants II	3
	18

SUGGESTED SCHEDULE

For studies of the first year, see page 22.

THIRD SEMESTER	HOURS
Math. 55	4
Physics 46	5
Eng. Mech. 1	3
Nav. Arch. 11	2
Eng. Graphics 2	3
	17

FOURTH SEMESTER	HOURS
Math. 56	4
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nav. Arch. 12	3
Chem.-Met. Eng. 18	3
Mech. Eng. 2	2
	17

SUMMER SESSION	
Mech. Eng. 105	3
Math. 103	3
English, Group II	2
	8

FIFTH SEMESTER	*Option 1*	*Option 2*
Nav. Arch. 21	3	3
Eng. Mech. 3	3	3
Eng. Mech. 4	3	3
Elec. Eng. 5	4	4
Nav. Arch. 13	2	–
Nav. Arch. 141	3	–
Mech. Eng. 106	–	3
	18	16

SIXTH SEMESTER	*Option 1*	*Option 2*
Mech. Eng. 80	2	2
Mech. Eng. 82	3	3
Eng. Mech. 123	3	3
Nav. Arch. 147	3	3
Nav. Arch. 131	2	–
Nontechnical elective	3	–
Elec. Eng. 7	–	4
Mech. Eng. 111	–	3
	16	18

SEVENTH SEMESTER	*Option 1*	*Option 2*
Eng. Mech. 136	3	3
Mech. Eng. 17	2	2
Econ. 153	3	3
Nav. Arch. 127	2	–
Nav. Arch. 132	3	–
Nav. Arch. 137	2	–
Nontechnical elective	3	3
Nav. Arch. 146	–	2
Nav. Arch. 151	–	5
	18	18

EIGHTH SEMESTER	*Option 1*	*Option 2*
English, Group III	2	2
Nav. Arch. 133	2	–
Nav. Arch. 134	2	–
Nav. Arch. 151	5	–
Nuc. Eng. 190	–	3
Nav. Arch. 144	–	3
Nontechnical elective	3	6
	14	14

PHYSICS

Program Co-advisers: Professor Wolfe, 4063 Randall; Professor Kerr, 3028 Phoenix Memorial Laboratory

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 is this program and qualify for graduation with a degree in physics as well. See Requirements for Graduation.

REQUIREMENTS

Candidates for the degree of 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 32)

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Groups II and III	4
Modern language	8
Chem.-Met. Eng. 18, Principles of Engineering Materials	3
Chem. 23, General and Analytical	4
Chem. 188, Physical	4
Math. 103. Differential Equations	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 3, Dynamics, *or* Physics 171, Intermediate Mechanics	3
Eng. Mech. 4, Fluid Mechanics, *or* Physics 172, Mechanics of Fluids	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 100, Circuits II	4
Mech. Eng. 2, Engineering Materials and Manufacturing Processes	2
Physics 165, Electron Tubes	4
Physics 180, Intermediate Electricity and Magnetism	3
Physics 181, Heat and Thermodynamics, *or* a course in engineering thermodynamics	3
Physics 196, Atomic and Molecular Structure	3
Group options and electives	33
Total, professional subjects and electives	95

Group options and electives are to be selected with the advice and consent of the advisory committee 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.

	HOURS
Physics	7
Mathematics	3
Engineering electives	12
From economics, geography, history, philosophy, political science, psychology, or sociology	6
Electives*	5
	33

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

SCIENCE ENGINEERING

Program Adviser: Professor Churchill, 3036 East Engineering

Modern trends in engineering are characterized by increasing emphasis upon science. In recent years engineering has expanded in spectacular fashion into many new fields such as nuclear energy, instrumentation, control, operations analysis, and space technology. Also many revolutionary advances have been made in the scientific bases of the older fields of engineering.

The science engineering program is excellent preparation for postgraduate work in most fields of engineering and applied science as well as for immediate employment in engineering, particularly in fields of endeavor, old and new, which overlap several of the traditional divisions of engineering.

A student completing the science engineering program has a background in physical, chemical, and engineering science equivalent to that required in many of the programs leading to the master's degree, but is not required to complete all of the specialized engineering courses required for the bachelor's degree in the traditional engineering programs.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Science Engineering) are required to complete the program outlined below. The student is encouraged to formulate his own sequence of subjects, including a number of integrated courses in an area of particular interest to him, with the advice and approval of the program adviser.

The accelerated and integrated sequence of preparatory courses beginning with Mathematics 35, Physics 53, Chemistry 14, Engineering Mechanics 11, and Engineering Graphics 21 are strongly recommended for those students who are qualified. The suggested schedule below is expressed in terms of these accelerated sequences. The many alternative sequences of preparatory courses with the same terminal level of accomplishment are, of course, acceptable but add hours to the preparatory portion of the illustrated schedule. The mathematics sequence beginning with Mathematics 33 adds 4 hours, the physics sequence beginning with Physics 45 adds 2 hours, the chemistry sequence beginning with Chemistry 5E adds 1 hour and the chemistry sequence beginning with Chemistry 3 adds 4 hours.

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED (See page 32)

B. PROFESSIONAL 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 15 or equivalent and at least 3 hours of advanced mathematics	16
Electives in English, literature, fine arts, or philosophy	6–10
Electives in anthropology, economics, geography, history, journalism, political science, psychology, or sociology	14–10
Electives*	6
Total, professional subjects and electives	95

SUGGESTED SCHEDULE

(In terms of accelerated sequences)

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Math. 35	4	Math. 36	4
Physics 53	4	Chemistry 14	4
Eng. Graphics 21	3	Eng. Mech. 11	3
English 11	3	English 12	2
English 21	1	Elective (humanities, soc. sci.)	3
	15		16

THIRD SEMESTER		FOURTH SEMESTER	
Math. 37	4	Elective (math.)	3
Chemistry 15	4	Physics 54	4
Eng. Mech. 12	4	Eng. Mech. 13	3
Electives (humanities, soc. sci.)	6	Elec. Eng. 9	3
		Electives (humanities, soc. sci.)	5
	18		18

FIFTH SEMESTER		SIXTH SEMESTER	
Sci. Eng. 110	4	Sci. Eng. 112	4
Elec. Eng. 11	4	Elec. Eng. 87	4
Eng. Mech. 14	4	Chem.-Met. Eng. 118	3
Elective (math., chem., physics)	3	Elective (math., chem., physics)	3
Elective (humanities, soc. sci.)	3	Elective (engineering)	4
	18		18

SEVENTH SEMESTER		EIGHTH SEMESTER	
Electives (engineering)	6	Electives (engineering)	7
Elective (math., chem., physics)	3		
Elective (humanities, soc. sci.)	3		7
Electives	6		
	18		

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

Special Fields

New development 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.

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. 174, Principles of Automatic Control (*3*); Instr. Eng. 174*a*, Automatic Control Laboratory (*1*); Instr. Eng. 177, Probability in Instrumentation (*2*); Elec. Eng. 108, Networks and Electron Tube Circuits (*4*) or 128, Electronics and Radio Communication (*4*); Math. 148, Operational Methods for Systems Analysis (*4*).

MANAGEMENT SCIENCES

The last decade has developed new and complex tools for management in the form of high-speed computational, display, and communication techniques as well as of powerful analytical methods such as information theory, linear programing, and queueing theory. These tools are being applied to continuing industrial problems, such as production and labor force scheduling, inventory control, sales forecast, and data processing (flow of information), as well as to special problems arising in connection with planning, market analysis, and organization. There is a rapidly growing demand for those well trained in the management sciences. Special graduate training in this field may be based on undergraduate study leading to a bachelor's degree in such fields as business administration, engineering, mathematics or the physical sciences, economics, and psychology. Undergraduate training should stress mathematics, regardless of field of origin, at least through a course beyond differential equations.

Undergraduate students may start the special studies by electing one or more of the following courses: Math. 117, Introduction to Linear Algebra and its Application (*3*); Math. 163, Theory of Statistics I (*4*); Math. 173, Methods of High-Speed Computation I (*3*); Math. 147, Modern Operational Mathematics (*2*).

NUCLEAR ENGINEERING

The new developments in nuclear energy have required engineers to design, construct, and operate the essential facilities. The implications and effects of nuclear energy demand the attention of engineers with backgrounds from all fields; and a special undergraduate or B.S.E. degree program in this field is not considered desirable at this time. Specialization in nuclear engineering is offered at the graduate level (see page 82). Undergraduates desiring only a one-semester course of nuclear engineering should elect Nuclear Eng. 190, Elements of Nuclear Engineering. Seniors who wish to start on the advanced program should elect Nuclear Eng. 191, Introduction to Nuclear Engineering.

RESERVE OFFICERS' TRAINING CORPS

The objective of the ROTC is to train well-qualified officers for the armed forces. Each male student attending The University of Michigan has the opportunity to enroll in the Army ROTC, the Navy ROTC, or the Air Force ROTC if he meets the specific requirements of the respective unit. Enrollment is voluntary but the University and the Armed Forces expect each student who enrolls in ROTC to meet the full obligations assumed by that enrollment unless excused by the regulations of the Army, Navy, or Air Force:

1. The student agrees to add to his own degree requirements the completion of the ROTC program in which he is enrolled as follows:

Unit	ROTC Program in which student is enrolled	Student agrees to add to his degree requirements for graduation	Credit allowed toward degree requirement as electives
Army or Air Force	2 year basic	Completion of 2 years (Fr.-Soph.)	None
	2 year advanced (upon application and selection)	Completion of 2 years (Jr.-Sr.)	See degree requirements of professional program elected
Navy	NROTC Contract and Regular	Completion of 4 years	See degree requirements of professional program elected for (300 and 400 series courses only)

2. The student completing four years of ROTC agrees to accept his commission as a condition of receiving his diploma.

Since there are variations among the three services, interested students are requested to write to Professor of Military Science and Tactics for further information about the Army; Professor of Naval Science for further information about the Navy; and Professor of Air Science for information about the Air Force.

AIR SCIENCE

Professor Belsma; Assistant Professors Archibald C. Smith, W. Smith, and White; Instructors Brown, Buist, Friedwald, Kieffer, and Lowery. Department office, North Hall.

The Department of Air Science offers a four-year generalized course of study designed to develop in selected male students those attributes of character, personality, and leadership essential to a commissioned officer of the United States Air Force. The course provides students with a broad knowledge and understanding of national and international defense requirements and the global mission of the United States Air Force. Students are accepted into the advanced program under a quota system established by the Department of Defense. Priority will be given to students who qualify and desire flying training upon graduation. A qualified student who is selected for the AFROTC and successfully completes a four-year program with an academic major acceptable to the United States Air Force will, upon graduation from the University, be considered for a commission as a second lieutenant in the United States Air Force Reserve. No specific academic major is required for students desiring flying training. Throughout the program both the theoretical and the practical phases of modern air power are emphasized. Students enrolling in the basic course add to their degree requirements the completion of the basic course as a prerequisite for graduation.

Flying activities. The Department of Air Science sponsors numerous local orientation flights as well as flights to various Air Force bases throughout the United States. These flights are made in Air Force aircraft and are available to all students desiring to participate. A program of light plane instruction at no cost to the student is sponsored at the local airfield for all qualified students desiring flying training.

Requirements for registration. Students enrolled in the University who are physically qualified male citizens of the United States and who meet the age requirements may apply for enrollment in the Air Force ROTC program. Women students may apply for enrollment in a non-commission seeking status.

Course substitutions. University courses have been substituted for parts of all four years of the AFROTC curriculum. The net effect is less time spent in the AFROTC program and proportionately more credit participation in AFROTC in meeting degree requirements. For details contact the Professor of Air Science, North Hall.

Pay and allowances. Pay and allowances are offered to students who are formally enrolled in the advanced course (third and fourth years), approximately $275 for each of these two years. An additional amount of approximately $75, plus all expenses and life insurance, is earned while in four weeks' summer training, which is mandatory for each cadet between his junior and senior years.

Uniforms and books. All students formally enrolled will be issued the Air Force blue uniform and the necessary textbooks.

Credit for previous military training or service. Students with satisfactory records of previous military training or service at the time of enrollment who wish to apply for advanced standing should consult the Department of Air Science, North Hall.

Commissions in the Regular Air Force. Any Air Force ROTC student designated as a distinguished AFROTC student who graduates from the University as a distinguished AFROTC graduate may apply for a commission in the Regular Air Force.

Selective Service Act. A student accepting deferment under authority of Public Law 759 of the Eightieth Congress must certify in writing that upon completion of his college training he will serve as an officer for three years on active duty with the Air Force, if ordered to do so by the Secretary of the Air Force.

Extracurricular activities. The Department of Air Science sponsors a rifle team, drill team, and an Air Force band. There is also on campus a chapter of the National Arnold Air Society, which is sponsored by the Department of Air Science. Qualified members of the unit may participate in Scabbard and Blade and the Pershing Rifles.

COURSES OFFERED IN AIR SCIENCE

101, 102. Foundations of Air Power I. *(1 and 2).*
101. *(1).* Introduction to Air Force doctrine. Familiarization with concepts and principles of "fellowship" and "leadership". Lecture and laboratory.
102. *(2).* Introduction to aircraft industry, basic aeronautical science and organization, and operation of the military air arm of the Federal government. Familiarization with group activities. Lecture and laboratory.
201, 202. Foundations of Air Power II. *(2 and 1).*
201. *(2).* More advanced consideration of the elements of aerial warfare and their employment, including space operations. Lecture and laboratory.
202. *(1).* Practice in leadership activities involving small groups. Introduction to leadership methods and organization at group level. Lecture and laboratory.
301, 302. Air Force Officer Development. *(2 and 3).*
301. *(2).* Staff organization and functions. Techniques of problem solving.
302. *(3).* Principles and practices of leadership. Includes psychology of leadership, the military justice system, and application of problem-solving techniques and leadership theory to Air Force problems. Lecture and laboratory.
401, 402. Global Relations. *(2 and 1).*
401. *(2).* Study of weather and navigational aspects of airmanship.
402. *(1).* Problems of adjustment to duty as an officer of the United States Air Force.

MILITARY SCIENCE AND TACTICS

Professor Woodman; Assistant Professors E. Hicks, R. Hicks, Pulver, and Trost; Instructors Jones, Jahnke, Penrose, and Davis. Department office, 212 Temporary Classroom Building.

The Department of the Army offers a four-year program designed 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, if otherwise qualified, are commissioned as second lieutenants in the Army Reserve on attainment of a baccalaureate degree. Distinguished military graduates may apply for direct commissions in the Regular Army. Each student, by voluntarily enrolling in the Army ROTC for the basic course (freshman and sophomore years) or the advanced course (junior and senior years), makes the completion of that course a degree prerequisite, unless excused by Army regulations. Students in the basic course are not required to sign draft deferment agreements. Each student in the basic course who signs a draft deferment agreement accepts the obligations of (1) continuing his studies in ROTC, unless excused by Army regulations, until graduation; (2) accepting a commission on graduation, if tendered, and serving his military obligation in accordance with the law. The military obligation may be served, in accordance with the needs of Department of the Army, in one of two ways: (1) active duty as an officer for two years, followed by three years as an officer in an Army Reserve or a National Guard unit, and one year on inactive reserve duty, for a total of six years; or (2) active duty as an officer for six months, followed by seven and one-half years as an officer in an Army Reserve or National Guard unit, a total of eight years. The method of serving the military obligation of officers is determined by the needs of the Department of the Army for officers on active duty.

At the end of the sophomore year, students who successfully complete the basic ROTC course are screened for entrance into the advanced course in the junior year. Selection for the advanced course is made on demonstrated leadership potential and inherent qualities, proficiency in the ROTC and academic curriculums, and desires of students for entrance into the advanced course. Those students selected and enrolled in the advanced ROTC course make completion of the course, attendance at summer camp, and acceptance of a Reserve commission, if tendered, a degree prerequisite, unless excused in accordance with Army regulations.

Army ROTC students who maintain prescribed standards will be deferred from military service until the ROTC curriculum has been completed.

Duration of the complete course of instruction comprises four years with not fewer than ninety hours of instruction in each year of the basic course and one hundred and fifty hours of instruction in each year of the advanced course. Attendance at a six-week ROTC summer camp is mandatory, normally during the summer between the junior and senior years. The complete course of instruction is organized into four major subcourses: American Military History; Operations, Tactics and Techniques; Logistics and Materiel; School of the Soldier and Exercise of Command. These four subcourses are concerned with four broad and distinct areas of military knowledge and skill. The instructional objective of the Department of Military Science and Tactics 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 among ROTC students.

BASIC COURSE	HOURS
Military Science I	
Organization of the Army and ROTC	5
American Military History	30
Individual Weapons and Marksmanship	25
School of the Soldier	30
Military Science II	
Crew-Served Weapons and Gunnery	30
Map and Aerial Photograph Reading	20
School of the Soldier	30
U. S. Army and National Security	10

ADVANCED COURSE	HOURS
Military Science III	
Small Unit Tactics and Communications	55
Organization, Function, and Mission of Arms and Services	30
Military Teaching Methods	20
Leadership	10
Pre-Camp Orientation	5
Exercise of Command	30
Military Science IV	
Logistics	20
Operations	50
Military Administration and Personnel Management	30
Service Orientation	20
Exercise of Command	30

Branch assignments. During the senior year cadets will be classified for assignment as officers on graduation to one of the following branches in accordance with their leadership, aptitude, University curriculum, interest, and the needs of the Army: *Arms:* Armor, Artillery, Infantry; *Technical and Administrative Services:* Adjutant General Corps, Army Security, Chemical, Corps of Engineers, Finance Corps, Medical Service Corps, Army Intelligence, Military Police Corps, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. Completion of the ROTC course does not lead to commission in Medical Corps, Dental Corps, Chaplains' Corps, Judge Advocate General's Corps, or Veterinary Corps.

Pay and allowances. These begin with the enrollment in the third year of the military science course and amount to approximately $265 for each of the last two years. In addition, the student receives approximately $117, plus travel expenses to and from camp for the six-week summer camp held between the third and fourth years of the military science course. All ROTC students are furnished uniforms without charge.

Prior servicemen. Credit for prior active duty enlisted service is allowable. Satisfactory ROTC participation for men with prior active service can be substituted for the Ready Reserve obligation. On graduation and commissioning prior servicemen assume a second military obligation.

The new four-year obligation requires six months on active duty, unless urgent necessity requires more, and the remainder as a member of a Ready Reserve unit. Interested students should consult the Department of Military Science and Tactics.

The Department of Military Science and Tactics sponsors a rifle team and the ROTC Marching Band. The two national honorary military societies — Scabbard and Blade and Pershing Rifles — have active chapters on the campus.

NAVAL SCIENCE

Professor Mothersill; Associate Professor Banfield; Assistant Professors Arkland, DeMartini, Graves, Palmer, Riley, and Samuelson; Instructors Alexander, Browning, Durham, Girten, McMurray, and Turner. 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. Officer candidates in the NROTC are of two types:

a) Regular NROTC students. These students, after selection by nationwide competitive examinations, are appointed midshipmen, USNR, and are granted a retainer pay at the rate of $600 a year, with tuition, nonrefundable fees, and books provided by the Navy for a maximum period of four years while under instruction at the NROTC institution or during summer training cruises. Regular students are obligated to serve four years on active duty after being commissioned as ensigns, United States Navy, or as second lieutenants, United States Marine Corps, unless released sooner by the Secretary of the Navy. They may apply for retention as career officers in the Regular Navy or Marine Corps.

b) Contract NROTC students. The Contract NROTC students have the status of civilians who have entered into a mutual contract with the Navy. They are not entitled to the compensation or benefits paid regular NROTC students except that they are entitled to the uniform issue, naval science textbooks and equipment, and payment of commutation of subsistence (currently about $30 a month) during their last two years of NROTC training. Under this plan students must agree to accept a commission in the Naval or Marine Corps Reserve on graduation and, while undergraduates, to engage in one summer practice cruise of approximately six weeks duration between the junior and senior years. After graduation, they are commissioned as ensigns, USNR, or second lieutenants, USMCR, and called to active duty for a period of obligated service. They may then apply, if they desire, for retention in the service.

Candidates must be between seventeen and twenty-one years of age. In special cases Contract 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 uncorrected by glasses and in all cases must be correctible to 20/20.

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

Regular NROTC students participate in three summer cruises of six to eight weeks' duration; Contract NROTC students participate in one six-week summer cruise. Marine candidates spend the third cruise period at the Marine Corps Schools, Quantico, Virginia.

All candidates must have completed a sequence in mathematics through trigonometry in high school or by the end of their sophomore year in college. Regular NROTC students must also complete one year of college physics by the end of their sophomore college year.

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 History and Sea Power. I. (*3*).

Study of various components of the United States Navy; shipboard organization and duties. Develops the psychology and techniques of leadership by means of practical problems and the study of the history of sea power.

102. Naval History and Sea Power. II. (*3*).

A study of history of sea power and its influence in shaping world affairs socially, economically, and politically.

200. Naval Weapons. I or 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, antisubmarine warfare, and space technology.

301. Naval Machinery. I. (*3*).

Provides a broad general concept of the fundamentals of naval engineering installation including steam, diesel, nuclear power, gas turbines, and auxiliary plants, and ship stability.

301S. Navy Supply. I. (*3*).

For Navy Supply Corps candidates only. Naval finance, organization, logistics, and naval accounting methods.

301M. Study of Evolution of Art of War. I. (*3*).
For Marine Corps candidates only. Analysis of decisive battles of history according to Principles of War and evolution of weapons.

302. Navigation. II. (*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.

302S. Navy Supply. II. (*3*).
For Navy Supply Corps candidates only. Supply organization and administration afloat.

302M. Modern Strategy and Tactics. II. (*3*).
For Marine Corps candidates only. Study of European and U. S. military policies and strategies and fundamental infantry tactics.

401. Naval Operations. I. (*3*).
Provides a broad understanding of basic naval tactics, tactical communications, relative motion, and the rules of the nautical road.

401S. Naval Administration. I. (*3*).
For Navy Supply Corps candidates only. Supply problems with emphasis on ship's store, clothing, and basic commissary management and operation.

401M. Amphibious Warfare. I. (*3*).
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare.

402, 402S. Principles and Problems of Leadership. 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.

402N. Amphibious Warfare. 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 offers excellent facilities in many fields.

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

MASTER OF SCIENCE IN ENGINEERING

A student who has received a bachelor's degree from the College of Engineering of this University, or has completed an equivalent program of studies elsewhere with sufficient evidence that he can meet the requirement of an average grade of B in his graduate studies, may enroll in the Graduate School for the degree of Master of Science in Engineering. The general requirements include the completion of at least thirty credit hours of graduate work approved by the program adviser or advisory committee with an average grade of at least B covering all courses elected as a graduate student.

A superior student who is well prepared may complete the requirements for a master's degree in two semesters. If his preparation is not adequate, the student will be required to take the necessary preparatory courses without graduate credit. A grade below B will not be accepted for graduate credit, unless, after review of the circumstances, the acceptance of the credit is recommended by the program adviser or the advisory committee.

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

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

Advisory Committee: Professors Isakson, Kuethe, and Nichols; Associate Professor Adamson

A program is offered leading to the degree of Master of Science in Engineering in aeronautical and astronautical engineering. A candidate for this degree may, through suitable selection of courses, put emphasis on any of the following fields of aeronautics and astronautics: aerodynamics, structures, aeroelasticity, propulsion, mechanics of flight, guidance and control, and instrumentation. Ordinarily the candidate may include three to four hours of non-technical studies but should not include more than five hours of laboratory research courses.

Students undertaking graduate work with a bachelor's degree in engineering but no previous work in aeronautical engineering will be required to complete the equivalent of the undergraduate aeronautical courses and the graduate requirements.

CHEMICAL ENGINEERING

Advisory Committee: Professors Van Vlack, York, and Young; Associate Professors Ragone and Gordon

The requirements for this degree include Chemical and Metallurgical Engineering 211, 213, 215, and such other courses as are approved by the advisory committee. Each student is encouraged to develop a program to fit his professional objectives and should consult with the advisory committee in this matter.

A full range of courses is available for those interested in many special fields, particularly: food processing, materials, petroleum refining or production, plastics and elastomers, process and equipment design, protective coatings.

CIVIL ENGINEERING

Program Adviser: Professor Boyce

All applicants for the degree of Master of Science in Engineering in civil engineering must present the equivalent of the undergraduate civil engineering program as preparation and in addition must complete a minimum of fifteen hours of graduate work in civil engineering courses and such other courses as are approved by the adviser. Graduate study programs leading to this degree may be arranged in the special fields as follows: construction, geodesy and surveying, highway and traffic, hydraulics, municipal, railway, sanitary, structures, and soil mechanics.

CONSTRUCTION ENGINEERING

Program Adviser: Associate Professor Alt

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 include Civil Engineering 131, 132, 181, and 235 and such other courses in engineering, economics, business administration, and other fields as may be approved by the program adviser.

ELECTRICAL ENGINEERING

Program Advisers: Professors Holland and Macnee

A candidate for this degree must have satisfactorily completed the undergraduate electrical engineering program of the University or its equivalent. Normally, a minimum of thirty credit hours of advanced graduate work is required for this degree, which must include Electrical Engineering 210 and two courses in advanced mathematics. At least fifteen credit hours must be in electrical engineering. By suitable selection of his remaining courses he 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, feed-back control systems, illumination engineering, energy conversion machinery, microwave engineering, physical electronics, solid-state engineering.

ENGINEERING MATERIALS

Advisory Committee: Professors Van Vlack, York, and Young; Associate Professors Ragone and Gordon

A candidate for this degree is required to have a background essentially equivalent to that represented by the program leading to the degree of Bachelor of Science in Engineering (Materials Engineering) at the University. This includes chemistry, through organic and physical, structure of materials, mechanics of materials, and thermodynamics. Thirty semester hours of additional work are required, which are to be selected with the approval of the advisory committee of the program and which will include Chemical and Metallurgical Engineering 208 or 218.

ENGINEERING MECHANICS

Advisory Committee: Professors Ormondroyd, Clark, Dodge, Haythornthwaite, Masur, and Yih

Candidates may be admitted to the 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 Engineering Mechanics 112, 113, and 114 and Mathematics 152 and 155, 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, Mathematics 157 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.

GEODESY AND SURVEYING

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 surveying, geodesy, or astronomy. A minimum of thirty credit hours of graduate work, approved by the Civil Engineering Department, is required for this degree, including Civil Engineering 101 and 113, and other courses in engineering, mathematics, astronomy, city planning, or other closely allied fields related to the professional practice of geodesy and surveying in government or in private practice.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Wyeth Allen

A candidate for this degree must have completed satisfactorily the undergraduate industrial engineering program of this College, or its equivalent, and must complete in residence a minimum of thirty hours of recognized graduate work approved by the adviser. The course selections necessary for this degree are rather flexible but it is expected that approximately twelve hours of course study will be in the industrial engineering area.

INSTRUMENTATION ENGINEERING

Adviser: Professor Rauch

Candidates may be admitted to the degree program from any of the undergraduate engineering curriculums. The requirements for the degree include Mathematics 148; Electrical Engineering 108 or 128; Instrumentation Engineering 174, 174*a*, 177 and a 200-level Instrumentation Engineering course; and other courses approved by the Committee on Instrumentation. The systems-engineering concept is emphasized throughout the program. See under Special Fields and course listings.

MANAGEMENT SCIENCES

Advisory Committee: Professors Goode, Dwyer, Fitts, Flood, and Rauch; Associate Professor Gardner

Candidates may be admitted to the degree program from any of the undergraduate engineering curriculums if accepted by the advisory committee. See Special Fields.

MECHANICAL ENGINEERING

Program Adviser: Associate Professor H. H. Alvord

An applicant for the degree of Master of Science in Engineering in mechanical engineering must complete at least fifteen hours in the department of specialization and at least two cognate subjects totaling five or more credit hours in 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. In general a student must have maintained a B average in his undergraduate work to be accepted into the master's degree program.

METALLURGICAL ENGINEERING

Advisory Committee: Professors Van Vlack, York, and Young; Associate Professors Ragone and Gordon

The requirements for this degree include Chemical-Metallurgical Engineering 211, 218, and 210 (4 hours) and a minimum of one course from each of the following groups of courses: Chemical-Metallurgical Engineering 207, 217, 241, 244, 251; Chemical-Metallurgical Engineering 216, 219, 240, 243; and Chemical-Metallurgical Engineering 224, 228, 242, 328.

Other courses are to be selected as approved by the graduate committee. Each student is encouraged to design his program to satisfy his special interests.

MUNICIPAL ENGINEERING ADMINISTRATION

Program Adviser: Professor Boyce

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

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Adams

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 for a Master of Science in Engineering in naval architecture and marine engineering degree usually include Mathematics 150, Naval Architecture 145 or 154, Engineering Mechanics 114, and electives in mathematics, engineering mechanics, and naval architecture.

It is also possible to obtain a combined degree Master of Science in Engineering in marine and nuclear engineering. 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.

NUCLEAR ENGINEERING

Advisory Committee: Professors Gomberg, Kerr, and Osborn

Candidates may be admitted to the program from any of the undergraduate engineering curriculums if accepted by the department. The requirements for the degree include twenty hours of course work in the nuclear engineering field, plus electives which meet with the approval of the graduate advisers.

Opportunities for thesis work may be found in theoretical problems or in experimental areas, making use of the extensive radiation source and tracer laboratory facilities now available or the 1000 kw Ford Nuclear Reactor.

SANITARY ENGINEERING

Program Adviser: Associate Professor Borchardt

The program leading to the degree Master of Science in Engineering in sanitary engineering is generally open to graduates in civil, chemical, and mechanical engineering. A student is expected to elect at least fifteen hours in the field of sanitary engineering and a number of courses in environmental health and public health statistics offered by the School of Public Health.

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 Graduate School 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 German and French is required. 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, Dr. Leta Lewis, 3028 Rackham Building, at his earliest convenience after becoming an applicant. A student who completes French 12, German 12, Spanish 12, or Russian 12 with a grade of B or better will be recorded as having met the language requirement in the respective language. Substitutions for the French or German request 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.

Courses numbered below 100 are for undergraduate credit only; those numbered 100 to 199 may be elected for undergraduate or graduate credit; courses numbered 200 and above are primarily for graduate credit.

The semester in which the course is offered is indicated as follows: the first semester — I, the second semester — II, summer session — S.S. The italic numeral or other information enclosed in parentheses indicates the hours of credit for the course: (*3*) denotes three hours credit or (*To be arranged*) denotes credit to be arranged.

AERONAUTICAL AND ASTRONAUTICAL ENGINEERING

1. **General Aeronautics.** *Prerequisite: completion of freshman year in College of Engineering, or equivalent.* I and II. (*1*).

An introduction to aeronautical 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.

72. **Instrument and Control Systems.** *Prerequisite: Math. 54 or 56, and Eng. Mech. 3, or equivalent.* I and II. (*3*).

Static sensitivity of instrument systems, null principle of measurement, random and systematic errors, dynamic errors, dynamics of instrument systems, such as accelerometers and vibrometers, elements of feedback control. Statistical properties of random errors, propagation of errors in instrument systems, least squares analysis of data. The laboratory includes measurement of temperature, pressure, strain, vibration, and parameters of physical systems, as well as the use of the electronic differential analyzer for study and simulation of dynamic instrument and control systems. Lecture and laboratory.

101. **Airplane Design I.** *Prerequisite: preceded or accompanied by Aero. Eng. 141 and 130.* I and II. (*3*).

Design procedure, including layouts and preliminary structural design; preliminary performance, stability and control; subsonic and supersonic designs. Emphasis on design techniques and systems approach. Lecture and laboratory.

103. **Airplane Design II.** *Prerequisite: Aero. Eng. 101.* (*2*).

Design procedure, including layouts and preliminary structural design; stress analysis and detail design. Lectures and drawing.

110. **Aerodynamics I.** *Prerequisite: preceded or accompanied by Eng. Mech. 3 and Math. 104.* 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 compressible inviscid flow and comparison with experiment.

114. Aerodynamics II. *Prerequisite: Aero. Eng. 110, and preceded or accompanied by Aero. Eng. 163.* 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.

116. Principles of Aerodynamics. *Prerequisite: Eng. Mech. 4 or equivalent. (3)*.
An accelerated coverage of the material in Aero. Eng. 110 and 114 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 110 or 114.

117. Theory of Propellers and Fans. *Prerequisite: Aero. Eng. 110 and Mech. Eng. 105. (2)*.
Critical study of the fundamental aerodynamic 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.

118. Experimental Aerodynamics. *Prerequisite: Aero. Eng. 119. (2)*.
Covers the work presented in the experiments in Aero. Eng. 114 but with more attention to detail and more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

119. Intermediate Aerodynamics. *Prerequisite: Aero. Eng. 114 or 116 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.

121. Turbulence and Diffusion. *Prerequisite: a course in advanced calculus and Aero. Eng. 114 or Eng. Mech. 4. (To be arranged)*.
A physical picture of turbulence in boundary layers, wakes, jets, and behind a grid. The basic equations are derived, isotropic and locally isotropic turbulent fields are described, and applications to practical problems such as transfer and diffusion of heat and mass are treated.

123. Aerodynamics of High Speed Flight. *Prerequisite: Aero. Eng. 114 or 116 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.

130. Flight Structures I. *Prerequisite: Eng. Mech. 123. (3)*.
Application of the basic equations of strength of materials and elasticity to elements of light-weight structures. Among the topics included are thin-walled beams, rings and frames, plates in bending, and an introduction to thermal stress.

131. Flight Structures II. *Prerequisite: preceded or accompanied by Aero. Eng. 130 and 142. (4)*.
Stability of structural elements in compression and shear; beam columns; deflection analysis, influence coefficients and functions, matrix algebra; introduction to structural dynamics. Lectures and laboratory.

133. Flight Structures III. *Prerequisite: Aero. Eng. 131. (3)*.
Strength and deformation analysis of light-weight structures, with emphasis on secondary stress, stress concentration and fatigue, inelastic deformation, and other selected topics.

134. **Structures at Elevated Temperatures.** *Prerequisite: Aero. Eng. 131 or 135. (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.

135. **Principles of Flight Structures.** *Prerequisite: Eng. Mech. 2. (3).*
An accelerated coverage of the material in Aero. Eng. 130 and 131 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 130 or 131.

141. **Mechanics of Flight I.** *Prerequisite: preceded by Aero. Eng. 110. (2).*
Longitudinal and lateral static stability of aircraft, control power, steady state maneuvers, hinge moments, and control forces. Power-required and power-available characteristics of aircraft on a comparative basis, calculation of performance characteristics.

142. **Mechanics of Flight II.** *Prerequisite: preceded by Math. 104 and preceded or accompanied by Aero. Eng. 141. (3).*
Dynamic analysis of systems with many degrees of freedom, dynamic stability and response of the rigid aircraft, use of servo controls, influence of structural elasticity in airplane dynamics, aeroelastic stability problems.

143. **Aircraft Control Systems.** *Prerequisite: preceded by Aero. Eng. 142. (3).*
Analysis of linear control systems; Routh-Hurwitz and Nyquist stability criteria; static and dynamic characteristics of aircraft instruments; airplane transfer functions; analysis and introduction to synthesis of autopilot and powerplant control systems; use of the analog computer in the laboratory for simulation. Two lectures and one laboratory.

144. **Aeroelasticity I.** *Prerequisite: Aero. Eng. 131. (3).*
Description of the deformation characteristics of aircraft structures. Deformations of aircraft structures under dynamic loads; differential equation, integral equation, energy methods of analysis. Wing divergence, control surface effectiveness, aeroelastic effects on load distribution, flutter.

145. **Principles of Mechanics of Flight.** *Prerequisite: a course in differential equations. (3).*
An accelerated coverage of the material in Aero. Eng. 141 and 142 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 141 or 142.

146. **Performance of High-Speed Vehicles.** *Prerequisite: Aero. 145 and 165 or equivalent. (3).*
Properties of the atmosphere, regimes of flow, analysis and optimization of thrust programing, performance of high-speed vehicles, including coasting and glide trajectories, optimum flight paths, orbital vehicles and re-entry problems.

150. **Principles of Vertical Take-off and Landing Aircraft.** *Prerequisite: Aero. Eng. 141. (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.

163. **Propulsion I.** *Prerequisite: Mech. Eng. 105, Aero. Eng. 110, or Mech. Eng. 106. (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.

164. Propulsion II. *Prerequisite: Aero. Eng. 163 or equivalent. (4).*
Performance and analysis of flight propulsion systems including the reciprocating engine-propeller, turboprop, turbojet, ramjet, pulse-jet, and rocket. Lectures and laboratory.

165. Principles of Propulsion. *Prerequisite: Mech. Eng. 105 or equivalent. (3).*
An accelerated coverage of the material in Aero. Eng. 163 and 164 designed primarily for graduate students. Not open to students who have elected Aero. Eng. 163 or 164.

166. Aircraft Propulsion Laboratory. *Prerequisite: preceded by Aero. Eng. 163. (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 pulse-jet, turbojet, ramjet, and rocket motors.

167. Propulsion III. *Prerequisite: Aero. Eng. 164 or equivalent. (3).*
Continuation of Aero. Eng. 164. Further treatment of aircraft engine performance, including off-design operation, and study of selected problems in the field of propulsion.

168. Topics in Gas Dynamics. *Prerequisite: Aero. Eng. 114 or permission of instructor. (3).*
The role of transport phenomena in gas dynamics problems is stressed. The subjects covered include simplified gas kinetics, definition of transport properties, general conservation equations, laminar boundary layer and mixing problems with heat transfer and diffusion.

169. Rocket Propulsion. *Prerequisite: Aero. Eng. 164 or 165 or equivalent. (3).*
Analysis and performance of liquid and solid propellant rocket powerplants; propellant thermochemistry, heat transfer, system considerations, advanced rocket propulsion techniques.

173. Wind Tunnel Instrumentation. *Prerequisite: Instr. Eng. 172 or equivalent. (2).*
Study of the role of schlieren, shadow, and interferometric techniques in aerodynamic research and a comparison of their relative accuracy and effect in data reduction; pressure and temperature measurements. Lectures and laboratory.

176. Flight Testing. *Prerequisite: Aero. Eng. 141 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.

179. Flight Mechanics of Space Vehicles I. *Prerequisite: a course in differential equations. (3).*
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.

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

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

185. **High-Altitude Studies.** *Prerequisite: a course in differential equations. (3).*
Upper atmosphere pressure, density, temperature, winds, composition. Rarified gas dynamics; solar constant and spectrum; the ionosphere; techniques and results of rocket research; characteristics of research vehicles; the earth satellite.

201. **Dynamics of Viscous Fluids.** *Prerequisite: Aero. Eng. 119 or permission of instructor. (3).*
Effect of viscosity in fluid flows. Flow in laminar and turbulent, compressible and incompressible boundary layers, boundary layer stability, real gas effects at low densities.

202. **Dynamics of Compressible Fluids.** *Prerequisite: Aero. Eng. 119. (3).*
Emphasis on transonic and hypersonic flow, and on real gas effects at high temperature. Heat transfer near the stagnation point.

205. **Introduction of Magnetohydrodynamics.** *Prerequisite: permission of instructor. (3).*
Review of electrodynamics. The basic equations of magnetohydrodynamics and magnetogasdynamics, simple solutions of these equations, stability theory in laminar flow, magnetohydrodynamic shock waves, theory of characteristics, applications to aerodynamics.

212. **Control and Guidance of Missiles.** *Prerequisite: Instr. Eng. 248 or Elec. Eng. 256, Math. 148. (2).*
Analysis and synthesis of missile autopilot systems. Navigational homing systems; inertial and celestial navigation systems. Trajectories of ballistic missiles.

212a. **Missile Guidance and Control Laboratory.** *Prerequisite: to be taken concurrently with or following Aero. Eng. 212. (1).*
Simulation of missile control and guidance systems on the electronic differential analyzer.

220. **Theory of Thin Airfoils.** *Prerequisite: Aero. Eng. 110 or equivalent and preceded or accompanied by Math. 155. (3).*
Application of complex variables and mapping theory to the thin airfoil in arbitrary motion; quasi-steady theory of cambered airfoils; apparent mass and wake effects, nonstationary flow equations. Aerodynamic forces and moments are developed in a form suitable for use in the gust and flutter problems.

222. **Theory of Supersonic Wings and Bodies.** *Prerequisite: preceded or accompanied by Aero. Eng. 119. (3).*
The linearized theory of finite wings of arbitrary planform and cross section in supersonic flow. Linearized body theory, flow field around wings and bodies, interference effects. A companion course to Aero. Eng. 119 that is directed toward aerodynamic aspects of the design of supersonic aircraft and missiles.

230. **Advanced Structural Analysis.** *Prerequisite: Aero. Eng. 131 or equivalent, Math. 150. (3).*
Application of the theorems of minimum potential and complementary energy, Galerkin's method, finite difference approximations, and relaxation procedures to the deformation and stress analysis of light-weight structures.

244. **Aeroelasticity II.** *Prerequisite: Aero. Eng. 144. (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.

245. **Flight Mechanics of Space Vehicles II.** *Prerequisite: Aero. Eng. 179 and preceded or accompanied by Aero. Eng. 119 or 123. (3).*
Dynamic performance of hypervelocity vehicles within the atmosphere. Problems associated with departure from and re-entry to the atmosphere.

246. Flight Mechanics of Space Vehicles III. *Prerequisite: Math. 150, Physics 171, 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.

262. Combustion and Flame Propagation. *Prerequisite: permission of instructor. (3).*
The fluid dynamic and thermodynamic relationships governing the propagation of combustion waves are derived and applied to deflagrations and detonations. Emphasis is placed on the close connection that exists between the hydrodynamics of burning mixtures and the heat release of chemical reactions.

274. Control of Nonrigid Space Vehicles. *Prerequisite: Aero. 135 or equivalent; Instr. Eng. 174 or equivalent. (3).*
Description of structures by influence functions. Determination of normal modes and dynamic representation by normal co-ordinates. Transfer functions of elastic structures as part of closed-loop control systems. Autopilot design using thrust vector, jet reaction, and inertial wheel control systems; effect on control of structural dynamics. Analysis of nonlinearities using describing-function theory.

310. Seminar in Aerodynamics. *(To be arranged).*

330. Seminar in Structures. *(To be arranged).*

340. Seminar in Mechanics of Flight. *(To be arranged).*

341. Seminar in Space Technology. *Prerequisite: permission of instructor. (2).*
Selected topics in space vehicle systems. Primarily for military officers.

360. Seminar in Propulsion. *(To be arranged).*

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

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

395. 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 infra-red data from meteorological satellites. Research in attitude control of multistage sounding rockets.

BACTERIOLOGY*

Professors Kempe, Gerhardt, and Nungester; Associate Professors Merchant and Wheeler; Assistant Professors Blumenthal, Heath, Johnson, Murphy, Preston, and Rajam; Instructors Callahan, Garrison, and Whitehouse.

109. Bacteriology for Engineers. I. *(3).*
Lectures and laboratory. Principles and techniques of microbiology with an introduction of their application to the several fields of engineering.

*Medical School

151. Bacterial Physiology. *Prerequisite: Bact. 101 or Bact. 109.* II. *(4–2).*
Lectures and laboratory. Study of the structure and function of bacterial cells.

156. Bacterial Metabolism. *Prerequisite: Bact. 101 or Bact. 109 and Biochem. 115.* I. *(4–2).*
Lectures and laboratory. Presentation of principles and methods for study of bacterial metabolism.

160. Industrial Bacteriology. *Prerequisite: Bact. 109 or equivalent.* II. *(3).*
Lectures and laboratory to illustrate the application of microbiology in industry.

BUSINESS ADMINISTRATION*

Professors Dixon, Dykstra, Hayes, and Moore; Associate Professors Brummet, Jones, Leabo, and Rewoldt.

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 100 and 101, which are listed as sophomore-level courses in the economics department.
2. Juniors may elect courses numbered 100 to 149, inclusive, and seniors may elect any course numbered 100 to 199, inclusive, provided they have satisfied particular course prerequisites.
3. Courses numbered above 200 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 semester. The following are courses of particular interest to engineering students:

BUSINESS ADMINISTRATION—GENERAL

154. Industrial Cost Accounting. *(3).*
180. Business Law. *(3).*
181. Business Law. *(3).*

ACCOUNTING

100. Principles of Accounting. *(3).*
101. Principles of Accounting. *(4).*

FINANCE

100. Money and Banking. *(3).*
101. Financial Principles. *(3).*

INDUSTRIAL RELATIONS

100. Personnel Administration. *(3).*

MANAGEMENT

111. Production Management. *(3).*

MARKETING

100. Marketing Principles and Policies. *(3).*

STATISTICS

100. Statistical Method. *(3).*

*School of Business Administration

CHEMICAL AND METALLURGICAL ENGINEERING

1. **Engineering Materials and Processes.** *Prerequisite: Chem. 3 or one year of high school chemistry validated by a satisfactory grade on the chemistry placement test given during orientation period, or Chem. 4. Preceded or accompanied by Math. 13 or 33.* (*3*).
An introductory course of study of materials used by the engineer. Attention is given to the factors such as structure and service conditions which govern the properties and behavior of metallic, ceramic, and plastic materials. Two lectures and two recitations.

2. **Engineering Calculations.** *Prerequisite: general chemistry and Physics 45.* (*3*).
Material and energy balances and their application to chemical and metallurgical problems.

3. **Introduction to Engineering Calculations.** *Prerequisite: a University course in chemistry or physics.* (*3*).
Material and energy balances, the equilibrium concept, rate operations, properties of fluids and solids, engineering systems.

10. **Fuels.** (*1*).
Laboratory testing of fuels, gases, oils, and water and interpretation of results.

11. **Cast Metals.** *Prerequisite: preceded or accompanied by Math. 54.* (*2*).
For mechanical and industrial engineering students. Melting and refining of cast metals including charge calculations and cost analysis; development of proper mold design based upon heat transfer calculations. Quality control exercises using magnaflux and radiographic inspection. Precision casting methods, foundry layout, and operation are also investigated. One lecture and one three-hour laboratory.

13. **Processing of Cast Metals.** *Prerequisite: preceded or accompanied by Math. 54.* (*2*).
For metallurgical engineering students. Quantitative study of the operations of smelting, molding, pouring, cleaning, and inspection as well as exercises in quality control. Melting experiments emphasize the application of physical chemistry to liquid metals. Operation and critical evaluation of cupola, induction, and arc furnaces are included. Molding experiments correlate the principles of gating and risering with heat transfer from liquid metal. Radiographic, magnaflux, metallographic, and rapid chemical control procedures are surveyed. One lecture and one three-hour laboratory.

16. **Measurements Laboratory.** *Prerequisite: Chem. 23, preceded or accompanied by Chem. 182.* (*3*).
Physicochemical measurements and determination of properties. Laboratory, computation, and reports.

18. **Principles of Engineering Materials.** *Prerequisite: Chem. 6 or equivalent; preceded or accompanied by Phys. 46* (Phys. 53 and Chem. 14 are equivalent to this prerequisite.) (*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.

100. **Plant Work.** (*1*).
Credit is given for a satisfactory report on some phase of work done in a plant. The nature of a problem must be approved before entering upon the work.

101. Chemical Plant Design Problem.
The American Institute of Chemical Engineers holds an annual competition for the solution of a problem, open to all undergraduate students. A credit of one hour will be granted to any student who submits a solution of this problem which is satisfactory to the staff of the department.

102. Structure of Metals. *Prerequisite: Chem.-Met. Eng. 107.* (*2*).
Survey of fundamental mechanisms controlling the properties of metallic solids; their crystallography; elastic and plastic properties; electrical, thermal, and mechanical properties.

105. Fuels and Chemical Equilibrium in Combustion. *Prerequisite: Mech. Eng. 105 or Chem.-Met. Eng. 2.* (*3*).
Chemical properties of jet fuels, rocket fuels, and oxidizers, computation of propulsive performance under equilibrium conditions, kinetics of reactions.

107. Metals and Alloys. *Prerequisite: Chem.-Met. Eng. 1 and Mech. Eng. 2.* (*3*).
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.

107a. Metals and Alloys Laboratory. (*1*).
May be elected only in conjunction with Chem.-Met. Eng. 107. One three-hour laboratory.

110. Thermodynamics I. *Prerequisite: Chem.-Met. Eng. 3 and Math 55.* I and II. (*3*).
Introduction to thermodynamics; mass and energy balances; use of elementary thermodynamic properties in thermochemical calculations. Generalized gas relations, charts and tables of thermodynamic properties.

111. Thermodynamics II. *Prerequisite: Chem.-Met Eng. 110 or Sci. Eng. 110.* I and II. (*4*).
Basic relations among thermodynamic properties; entropy balance and concept of availability. Physical and chemical equilibrium, solutions and equilibrium stage calculations. Elementary treatment of statistical mechanics and irreversible thermodynamics.

112. Rate Processes. *Prerequisite: Chem.-Met. Eng. 111.* I and II. (*4*).
A unified study of heat, mass, and momentum transfer, and chemical kinetics with emphasis upon identification of rate processes, measurement, correlation, and the application of rate data and theories to process design.

113. Unit Operations I. *Prerequisite: preceded or accompanied by Chem-Met. Eng. 111.* (*4*).
Equipment and theory of unit operations and their applications.

114. Unit Operations. *Prerequisite: preceded or accompanied by Chem-Met. Eng. 111.* (*4*).
Unit operations in the field of metallurgical engineering.

115. Unit Operations II. *Prerequisite: Chem.-Met. Eng. 113.* (*3*).
Theories of heat and mass transfer operations and their application in calculations for equipment design.

116. Measurements and Instrumentation for Pollution Control. *Prerequisite: enrollment in Air Pollution Curriculum or permission of program adviser.* II. (*3*).
A study of methods of sampling, identification, and measurement of the constituents of air pollution.

117. Metals and Alloys. *Prerequisite: Chem.-Met. Eng. 118.* (*3*).
Structures of metals as affected by composition and thermal and mechanical treatment; their resultant physical properties and behavior in service. Lectures, recitations, and laboratory.

118. Structure of Solids. *Prerequisite: Chem. 182. (3).*
Atomic structure; amorphous and crystalline solids covering fundamental crystallographic concepts, types of solids, ionic crystals, free electron theory of metals and semiconductors, specific heats, electric, magnetic, and optical properties, cohesive forces, crystal growth, work hardening and recrystallization, and surface properties of solids.

119. Metallurgical Process Design. *Prerequisite: Chem.-Met. Eng. 113 or 114. (4).*
Application of principles involved in the extraction of metals from ores and scrap, the production of alloys and their commercial shapes or forms.

121. Design of Process Equipment. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 115 or 119. (3).*
The student designs and estimates cost of selected equipment.

122. Ceramic Materials. *Prerequisite: physical chemistry or permission of instructor. (4).*
The nature, preparation, and properties of ceramic materials. Lectures, recitations, and laboratory.

123. Survey of the Unit Operations. *Prerequisite: calculus, senior or graduate standing. (2).*
A survey of the unit operations of chemical engineering, including fluid flow filtration, distillation, heat transfer, and mass transfer. Not open to students in chemical or metallurgical engineering.

124. X-ray Studies of Engineering Material. *Prerequisite: Chem.-Met. Eng. 16 and 118.* I. *(3).*
Radiography, investigation of welds and castings; diffraction studies of metals and alloys. Lectures, recitations, and laboratory.

125. Introduction to High Polymers. *Prerequisite: organic chemistry, physical chemistry, or permission of instructor. (4).*
Preparation, properties, and utilization of polymeric materials. Lectures, recitations, and laboratory.

126. Electron Microscopy. *Prerequisite: Chem.-Met. Eng. 16 or senior or graduate standing in engineering or science. (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.

127. Physical Metallurgy I. *Prerequisite: Chem.-Met. Eng. 118.* I. *(4).*
Structures and properties of metals as related to composition and thermal and mechanical treatment. Lectures, recitations, and laboratory.

128. Physical Metallurgy II. *Prerequisite: Chem.-Met. Eng. 127.* II. *(3).*
Surface hardening, hardenability, hardening, tempering, isothermal transformation, related properties of iron and steel.

129. Engineering Operations Laboratory. *Prerequisite: Chem.-Met. Eng. 16 and 115 or 119. (3).*
Laboratory determination of factual operating data of equipment for chemical and metallurgical operations. Laboratory, conferences, and reports.

130. Chemical Process Design. *Prerequisite: Chem.-Met. Eng. 115 and 117. (3).*
Application of chemistry and the unit operations to the design of chemical processes.

131. Industrial Processes and Wastes. *Prerequisite: enrollment in Air Pollution Curriculum (School of Public Health) or permission of program adviser. (3).*
Discussion and problems concerning industrial process variables which influence the emission of air contaminants, including combustions, chemical processing, and physical processing. Emphasis on the modification of waste products and byproducts by changes in process conditions, improved process control, and changes in equipment.

147. Metals for Process Equipment. *Prerequisite: physical chemistry. (3).*
Structures and properties as affected by composition and mechanical or thermal treatment; their resultant mechanical properties and behavior in service.

148. Metallurgy of Joining. *Prerequisite: Chem.-Met. Eng. 117 or 127 or 147. (3).*
The effects of the joining of metals on the mechanical, physical, and chemical properties of the structures. Special emphasis on the roles of solid phase transformations, liquid state reactions, properties of metallic surfaces, and residual stresses in joining processes.

202. Advanced Chemical Engineering Calculations. *Prerequisite: Chem.-Met. Eng. 115 and a course in differential equations. (3).*
Chemical engineering calculations on unsteady-state heat and mass transfer, stagewise or column-plate operations, chemical reactions, fluid flow, and thermodynamics.

204. High Polymer Processes and Materials. *Prerequisite: course in physical and organic chemistry or permission of instructor. (3).*
Nature and types of polymers and copolymers. Polymerisation processes and their mechanism. Condensation, addition, cationic, anionic, polymerisation, stereospecific polymerisation. Amorphous and crystalline polymers; structure of polymeric materials. Relation between structure and mechanical properties, plastics, fibers, elastometers.

205. Combustion. *Prerequisite: Chem.-Met. Eng. 105 or 115 or Mech. Eng. 112. (3).*
Fundamentals of deflagration and detonation, with emphasis on the chemical aspects. Applications of combustion to industrial processes and propulsive devices.

207. Metals at High Temperatures. *Prerequisite: Chem.-Met. Eng. 107, 117, or 127. (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.

209. Thermodynamics of Metallurgical Processes. *Prerequisite: Chem.-Met. Eng. 111. (3).*
Laws of thermodynamics and statistical mechanics applied to metallurgical systems. Emphasis on nonideal solid solutions, order-disorder transformations, and multicomponent systems.

210. Special Research and Design. (*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 semester 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, paint, varnish, 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.

211. Engineering Thermodynamics. *Prerequisite: Chem.-Met. Eng. 111. (3).*
Principles of the laws of energy as applied to chemical and metallurgical engineering problems.

212. Equilibrium Stage Operations. *Prerequisite: Chem.-Met. Eng. 115, preceded or accompanied by Chem.-Met Eng. 121. (3).*
Design of multicomponent separation systems, including liquid-liquid extraction, distillation, and gas absorption, with primary emphasis on the equilibrium stage concept.

213. Rate Operations. *Prerequisite: Chem.-Met. Eng. 115. (4).*
Chemical reactions, transport of material, heat transfer, mass transfer, and momentum transfer.

215. Rate Operations Design. *Prerequisite: Chem.-Met. Eng. 213. (3).*
Simultaneous rate operations and process design.

216. Engineering Experiments and Their Design. *Prerequisite: senior or graduate standing in engineering or science. (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-Squared" and "t" tests in analyzing and comparing data from simple experiments, the analysis of variance, and the design of complex experiments. Lecture, recitation, and laboratory.

217. Corrosion and High-Temperature Resistance of Metals. *Prerequisite: Chem-Met. Eng. 107 or 117. (3).*
Fundamentals involved in choosing a metal for use in oxidizing or corroding media or at elevated temperatures.

218. Theoretical Metallurgy. *Prerequisite: Chem.-Met. Eng. 124. (3).*
Electron theory of metals, zone theory of metals, theory of alloying, rate processes, dislocation and imperfection theories, diffusion, polygonization and recrystallization, grain boundaries, nucleation and growth.

219. Metallurgical Operations. *Prerequsite: Chem.-Met. Eng. 107 or 127. (3).*
Rolling, forging, extrusion, piercing, drawing, and straightening.

220. Chemical Plant Process Design. *Prerequisite: Chem.-Met. Eng. 130 or equivalent. (3).*
Selection and design of processes, equipment, and control systems for chemical plants. Utilization and extension of minimum available information to produce workable schemes. Economic studies and comparisons to determine optimum situations.

221. Equipment Design for Advanced Engineering Students. *Prerequisite: Chem.-Met. Eng. 115. (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.

222. Solid State Kinetics. *Prerequisite: a course in solid state science. (3).*
The study of the rates and mechanisms of solid state reactions. The thermodynamic and structural aspects of point defects, phase transformations, chemical reactions in nonstoichiometric compounds, chemical compounds, spinels, ceramics, and polymers. Lectures and recitations.

223. Solid State Chemical Principles of Semiconductors and Catalysts. *Prerequisite: Chem.-Met. Eng. 118 or Elec. Eng. 180 or permission of instructor. (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.

224. X-ray Studies of Engineering Materials. *Prerequisite: Chem.-Met. Eng. 124.* II. *(3).*
Application of X-ray methods to the study of age hardening, cold working, and phase changes.

227. Nuclear Metallurgy. *Prerequisite: Chem.-Met. Eng. 117 or 127 or 147. (3).*
The physical process and mechanical metallurgy of the primary metals used in nuclear reactors: uranium, plutonium, thorium, and their fission products. Container metals, fuel elements, moderators, control elements, liquid metals.

228. Nonferrous Metals. *Prerequisite: Chem.-Met. Eng. 128. (3).*
Ternary systems, solution and precipitation, plastic deformation, recrystallization, grain growth. Lectures, recitations, and laboratory.

232. Process Engineering of Polymer Plants. *Prerequisite: Chem.-Met. Eng. 125 or 124, or permission of instructor. (3).*
Processing methods for production of polymers from raw materials. Design of plants for manufacture of materials such as polystyrene, cellulose plastics, nylon, and rubbers.

235. Petroleum Engineering. *Prerequisite: Chem.-Met. Eng. 115.* I. *(3).*
Properties of petroleum gases and liquid under pressure, process design in the production and processing of natural gas and crude oil.

238. Fermentation Processes. *Prerequisite: organic chemistry and Chem.-Met. Eng. 115 or permission of instructor. (3).*
Detailed study of the processes, operations, and equipment involved in selected industrial fermentation processes directed towards the production of pharmaceuticals and industrial chemicals, and industrial waste disposal. Lectures, seminars, and field trips.

239. Food Processing. *Prerequisite: organic chemistry and Chem.-Met. Eng. 115 or permission of instructor. (3).*
Chemistry of food and food processing methods. Lectures, seminar, and field trips.

240. Metal Reactions in Melting and Refining. *Prerequisite: Chem. 183, Chem.-Met. Eng. 119. (4).*
Experiments concerning reactions during melting, refining, and solidification of ferrous and nonferrous metals. Experiments include gas-metal and refractory slag-metal reactions in a variety of furnaces including cupola, direct arc electric, vacuum induction, as well as vacuum fusion analyses. Lectures, calculations, and laboratory.

241. Cast Iron and Steel. *Prerequisite: Chem.-Met. Eng. 107, 117, or 127. (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.

242. Steels. *Prerequisite: Chem.-Met. Eng. 128. (3).*
Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel.

243. Powder Metallurgy. *Prerequisite: Chem.-Met. Eng. 107, 117, or 127.* (*3*).
Characteristics and properties of metal powders, principles of compacting, physical metallurgy, and theories of sintering. Lectures, recitation, and laboratory.

244. Cast Metals in Engineering Design. *Prerequisite: Chem.-Met. Eng. 117, 127, or permission of instructor.* (*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. The application of these properties in the design of critical parts in the aircraft, automotive, chemical, mining, and railroad industries is presented by case histories and examination of castings. One lecture and one three-hour laboratory.

247. Nuclear Metallurgy Laboratory. *Prerequisite: Chem.-Met. Eng. 227.* (*3*).
The metallurgical examination and testing of radioactive materials by specialized remote techniques. Metallography, X-ray diffraction, mechanical, thermal, and electrical properties investigations.

251. Furnace Design and Construction. *Prerequisite: Chem.-Met. Eng. 114 or 115.* (*3*).
Furnace atmosphere, refractory materials, and their application in the design of furnaces.

254. Heavy Chemicals. *Prerequisite: Chem.-Met. Eng. 129 and 130.* I. (*3*).
Design study of selected heavy chemical manufacturing processes and the design of major equipment.

255. Petrochemical and Refining Processes. *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 211.* (*4*).
Designs and economic studies of selected petrochemical and refining processes.

256. Mechanics of Multiphase Flow. *Prerequisite: Chem.-Met. Eng. 113 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.

257. Chemical Process Dynamics and Control. *Prerequisite: a course in La Place transforms or permission of instructor.* (*3*).
The concepts of automatic control and process dynamics will be applied to typical rate processes encountered in chemical engineering practice such as the control of temperature, fluid flow, mass transfer, and chemical reaction systems.

258. Electrochemical Operations. *Prerequisite: Chem. 183 and Chem.-Met. Eng. 111.* I. (*4*).
The principles and industrial applications of electrochemistry. Lectures, recitation, and laboratory.

267. Nuclear Fuels and Fuel Processing. *Prerequisite: Nuclear Eng. 191 or permission of instructor.* (*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 projects.

311. Applied Thermodynamics. *Prerequisite: Chem.-Met. Eng. 211.* (*3*).
Advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics.

315. Advanced Distillation Calculations. *Prerequisite: Chem.-Met. Eng. 211.* (*3*).
Design of distillation equipment for multicomponent and nonideal separation processes.

328. **Physical Metallurgy Seminar.** *Prerequisite: Chem.-Met. Eng. 228.* (*2*).

342. **Applied Physical Metallurgy.** *Prerequisite: Chem.-Met. Eng. 242.* I. (*3*).
Processing and service failures.

355. **Petroleum Seminar.** *Prerequisite: Chem.-Met. Eng. 235 or 255.* (*2*).
Individual study of advanced topics in production, commercial natural gas, refining and petrochemical processes. Seminar and reports.

363. **Heat Transfer Seminar.** *Prerequisite: Chem.-Met. Eng. 213.* (*2*).

365. **Mass Transfer Seminar.** *Prerequisite: Chem.-Met. Eng. 213.* (*2*).

CHEMISTRY*

Professor Anderson; Professors Brockway, Elderfield, Elving, Halford, Parry, Smith, Vaughan, and Westrum; Associate Professors Bernstein, Case, Meinke, Rulfs, Tamres and Taylor; Assistant Professors Eisch, Ireland, Jaselskis, Nordman, Schilt, Stiles, and Weatherill; Instructors Atkinson, Berry, Cooke, De Rocco, Gordus, Longone, and Martin.

1. **General and Inorganic Chemistry.** I. (*4*)
Elementary course for students who have not studied chemistry in high school. Two lectures, three recitations, and one three-hour laboratory.

3. **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. Two lectures, two recitations, and four hours of laboratory.

4. **General and Inorganic Chemistry.** *Prerequisite: Chem. 1 or 3.* I and II. (*4*).
Continuation of Chem. 1 or 3 designed for students who are planning to take additional work in chemistry. Students in engineering who are not planning to enter the curriculum in chemical, metallurgical, or materials engineering should elect Chem. 6 rather than Chem. 4. In Chem. 1 or 3 and Chem. 4, the fundamental principles of chemistry are studied, accompanied by the descriptive chemistry of most of the nonmetallic elements (Chem. 1 or 3) and of the important metallic elements (Chem. 4). Two lectures, two recitations, and four hours of laboratory.

5E. **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. 1 or 3, followed by Chem. 4 or 6.* I and II. (*5*).
Fundamental principles of chemistry and a study of the more important elements and compounds, omitting the common nonmetallic elements. Two lectures, three recitations, and four hours of laboratory.

6. **General Chemistry.** *Prerequisite: Chem. 1 or 3.* II. (*4*).
Continuation of Chem. 1 or 3 for students who are planning to take no 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. 4. *Chem 6 will not be accepted as a prerequisite for more advanced courses in chemistry.* Two lectures, two recitations, and four hours of laboratory.

*College of Literature, Science, and the Arts

8. Inorganic Chemistry and Qualitative Analysis. *Prerequisite: Chem. 3 with a grade of A or high B.* II. (*5*).
Ionic equilibrium, descriptive chemistry of the metallic elements, and qualitative analysis of the metallic ions. Three lecture-recitation periods and eight hours of laboratory.

14. Unified Chemistry. *Prerequisite: Physics 53.* 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.

15. Unified Chemistry. *Prerequisite: Chem. 14 and Physics 54.* I. (*4*).
Properties of matter from the viewpoint of atomic structure, including periodic relationships; organic and inorganic chemistry. Lectures, recitations, and laboratory.

20. Qualitative Analysis. *Prerequisite: Chem. 4 or 5E.* I and II. (*3*).
The physicochemical treatment of ionic equilibria with applications to the identification of inorganic substances. Recitation and laboratory.

23. Introductory Analytical Chemistry. *Prerequisite: Chem. 4.* I and II. (*4*).
Ionic equilibria; an introduction to analytical chemistry. Approximately half the laboratory work deals with qualitative analysis and half with quantitative, the latter covering introductory work in both gravimetric and volumetric techniques.

41. Quantitative Analysis. *Prerequisite: Chem. 8 or 20.* I and II. (*4 required*).
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.

61. Organic Chemistry. *Prerequisite: Chem. 8 or 20.* I and II. (*6*).
Survey of the whole field of organic chemistry. Four lectures, one recitation, and seven hours of laboratory.

161. Organic Chemistry. *Prerequisite: Chem. 61.* I and II. (*4*).
Special topics in organic chemistry not taken up in detail in Chem. 61. Two lectures, one discussion, and seven hours of laboratory.

161R. Organic Chemistry. *Prerequisite: Chem. 61.* I and II. (*2*).
Same as Chem. 161, but without laboratory work.

171. Electrochemistry. *Prerequisite: Chem 183.* I. (*2*).
Elementary treatment of the fundamentals of the subject. Two lectures.

182. Physical Chemistry. *Prerequisite: Chem. 41, Physics 26, and Math. 54 or 56.* I and II. (*3*).
Nature of the gaseous and liquid states, solution theory, homogeneous and heterogeneous equilibria, thermochemistry and thermodynamics.

183. Physical Chemistry. *Prerequisite: Chem. 182.* I and II. (*3*).
Electrochemistry, atomic concepts of matter and energy, molecular and crystal structures, chemical kinetics.

188. Physical Chemistry. *Prerequisite: calculus, and Chem. 20 or permission of instructor.* I and II. (*4*).
Fundamentals of physical chemistry, particularly for students enrolled in the curriculum in physics; others by special permission. Four lectures.

235. Nuclear Chemical Techniques. *Prerequisite: permission of instructor.* II. (*2*).
A laboratory course illustrating measurement, manipulatory, and safety techniques and equipment used with radioactive isotopes at the microcurie, millicurie, and multicurie levels; includes radiochemical separations, weak beta emitter (C^{14}) work, typical tracer experiments, and use of high-level handling facilities.

256. Organic Chemistry of Synthetic Polymers. *Prerequisite: Chem. 161.* II. (2).
Chemistry of synthetic polymers, including the preparation of the intermediates for resins and rubber substitutes of commercial importance. Two lectures and reading.

CIVIL ENGINEERING

1. Basic Surveying. *Prerequisite: Math. 33.* Camp Davis. S.S. (4).
Care, adjustment, and use of basic surveying instruments; leveling, taping, horizontal angle measurement, traverse surveys; circular curve theory and applications, co-ordinate computation, use of calculating machines.

2. Route Surveying. *Prerequisite: Civ. Eng. 1 or 4 and preceded or accompanied by Math. 34.* I and II. (3).
Vertical and horizontal alignment, including parabolic curves and spiral easement curves, sight distances, etc., developed from basic mathematical principles and applied to specific problems in modern practice; earthwork principles and practice; study of topographic mapping, including applications of photogrammetry to route location.

3. Advanced Surveying. *Prerequisite: Civ. Eng. 1 (or Civ. Eng. 4 and 5), or preceded or accompanied by Math. 55.* I and II. (3).
Triangulation, local control surveys, astronomical observations, Public Land surveys. Computation and adjustment, field observations.

4. Basic Surveying. *Prerequisite: Math. 33 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.

5. Surveying Computations. *Prerequisite: Civ. Eng. 4 or equivalent and Math. 33 or equivalent.* I and II. (2).
A short course in surveying computations based on the concept of plane rectangular co-ordinate position. The use of the calculating machine is emphasized. The course is designed primarily for transfer students who have had no elementary course in surveying, but lack one or two hours of having the equivalent of Civil Engineering 1.

12. Surveying. *Prerequisite: Math 13.* (3).
Similar to Civ. Eng. 1. Designed for forestry students.

20. Structural Drafting. *Prerequisite: Eng. Graphics 2.* I and II. (2).
Standard civil engineering drafting-room practice, including conventional signs and symbols, preparation of civil engineering computations and graphs, detailing of structural elements, and use of standard structural handbooks.

21. Theory of Structures. *Prerequisite: Eng. Mech. 2.* I and II. (3).
Not open to civil engineering students. Analysis of stresses in simple and continuous structures; calculation of reactions, shear, and bending moment due to fixed and moving loads; design of steel, reinforced concrete, and wood structures. Discussion of framing plans.

22. Theory of Structures. *Prerequisite: Eng. Mech. 2.* I and II. (3).
Analysis of stresses in simple structures; calculation of reaction, shear, and bending moment in simple, restrained, and continuous beams due to fixed and moving loads; analysis of stresses in simple trusses due to fixed and moving loads.

23. Elementary Design of Structures. *Prerequisite: Civ. Eng. 20 and 22.* I and II. (*3*).
Design and details of simple beams, girders, columns, and trusses. Computations, drawing work, and laboratory experiments.

30. 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.

52. Water Supply and Treatment. *Prerequisite: Eng. Mech. 4.* (*3*).
Sources of water supply, quality and quantity requirements, design fundamentals of works for development, collection, purification, and distribution of water.

53. Sewerage and Sewage Treatment. *Prerequisite: Civ. Eng. 52.* (*2*).
Requirements of residential and municipal sewerage systems, procedures for the design and construction of sewerage and sewage treatment works.

65. Transportation Engineering. *Prerequisite: Civ. Eng. 2.* I and II. (*3*).
Planning, location, design, construction, and maintenance of inland transportation facilities. Introduction to transportation economics.

101. Geodesy. *Prerequisite: Civ. Eng. 3.* 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.

[**102. Geodetic Methods.** *Prerequisite: Civ. Eng. 101.* II. (*2*). Omitted in 1960–61.]

105. Geodetic Measurements and Electronic Computers. *Prerequisite: Math 56.* (*2*).
Adjustment of observations, theory of least squares, application to geodetic computations; introduction to electronic digital computers, arrangement of surveying and geodetic problems for solution by electronic computer, elementary principles of programing. Each student will individually program and solve one assigned problem. Lectures, reference work, and laboratory.

106. Special Problems in Advanced Surveying. I, II. S.S. (*To be arranged*).
Special advanced work can be provided for those who have received credit in Civ. Eng. 3.

107. Municipal Surveying. *Prerequisite: Civ. Eng. 3.* (*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.

113. Aerial Photogrammetry and Mapping. *Prerequisite: preparation in trigonometry and physics.* II. (*2*).
Map projections and map making from aerial photographs.

115. Boundary Surveys. *Prerequisite: Civ. Eng. 1 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.

120. Fundamentals of Experimental Research. I. (*2*).
Scientific method, its elements and procedures. Research project; outline, bibliography, design of experiments, selecting materials, instrumentation, analysis of data, inferences, and conclusions; preparation for publication. Seminar, problems, and laboratory.

121. Reinforced Concrete. *Prerequisite: Civ. Eng. 22.* I and II. (*3*).
Properties of materials; stress analysis and design of reinforced concrete structures; introduction to prestressed concrete and ultimate strength analysis. Lectures, problems, and laboratory.

122. Advanced Theory of Structures. *Prerequisite: Civ. Eng. 22.* (*3*).
Continuation of Civ. Eng. 22. Analysis of stresses in advanced types of trusses; statically indeterminate structures; arches.

123. Design of Structures. *Prerequisite: Civ. Eng. 23, 121.* I and II. (*3*).
Design of reinforced concrete and steel structures. Computations and drawing.

124. Rigid Frame Structures. *Prerequisite: preceded or accompanied by Civ. Eng. 121.* I and II. (*3*).
Analysis of rigid frames by methods of successive approximations and slope deflections; special problems in the design of continuous frames.

125. Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 23 and 121.* I and II. (*2*).
Fundamental principles of prestressing; prestress losses due to shrinkage, elastic action, plastic flow, creep, etc.; stress analysis and design of prestressed concrete structures.

127. Timber Construction. *Prerequisite: Civ. Eng. 23.* I. (*1*).
Physical characteristics of structural woods; grading rules; design of timber structures.

128. Matrix Analysis of Structures. *Prerequisite: Civ. Eng. 122 and preceded or accompanied by Civ. Eng. 124 or permission of instructor.* II. (*2*).
Systems of linear equations in structural analysis; matrix notation for linear systems; elementary matrix algebra; stiffness and flexibility matrices; general matrix formulation of the force and displacement methods of structural analysis for solution by the electronic digital computer.

130. Physical Properties of Concrete Masonry. (*2*).
Design of concrete mixtures to obtain specified physical properties, including strength, elasticity, plasticity, impermeability, durability, and economy. Seminar, problems, and laboratory.

131. 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.

132. Construction Methods and Equipment. II. (*3*).
Open to seniors and graduates. Contractors' organizations; plant selection and layout; equipment studies; methods of construction.

133. Estimating Practice. *Prerequisite: preceded or accompanied by Civ. Eng. 131.* I. (*1*).
Laboratory practice in the estimating and pricing of construction work. Quantity surveys, unit costs of labor and material, indirect costs.

135. Engineering Properties of Soil. *Prerequisite: Eng. Mech. 2 and 4.* I and II. (*3*).
Origin, evolution, and classification of soil; characteristics and properties of soil; soil moisture, ground water, capillarity, and frost action; theories of soil resistance and an introduction to practical applications including pressure distribution, bearing capacity of spread footings and pile substructures; excavations and embankment stability; highway and airport construction.

136. Soil Mechanics Laboratory. *Prerequisite: preceded or accompanied by Civ. Eng. 135.* 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.

140. Hydrology. *Prerequisite: Eng. Mech. 4.* I and II. (*3*).

The hydrograph and the various factors that affect and determine its characteristics; precipitation, evaporation, transpiration, infiltration; the unit hydrograph; the distribution graph; maximum flood flows and frequency of occurrence; normal flow and low flow; effect of forests, cultivation, and drainage; yield of wells; stream flow records. Lectures and laboratory.

141. Hydraulics. *Prerequisite: Eng. Mech. 4.* I and II. (*2*).

Hydrostatic stability; orifices and weirs; Venturi meters; cavitation; pump characteristics; flow in pipes and fittings; unsteady-uniform flow; steady-nonuniform flow. Lecture, laboratory, and computation.

142. Water-Power Engineering. *Prerequisite: Eng. Mech. 4.* II. (*2*).

Design factors in turbines; fundamental principles of water-power development; selection of turbines; storage and pondage; surge in pipe lines; water hammer.

143. Flow in Open Channels. *Prerequisite: Civ. Eng. 141 or equivalent.* I and II. (*3*).

Laminar and turbulent flow; rapidly varied flow; subcritical and supercritical flow; transitions; channel controls; gradually varied flow; translatory waves.

144. Advanced Hydraulics. *Prerequisite: Civ. Eng. 141, preceded or accompanied by Civ. Eng. 143.* I. (*3*).

Two-dimensional potential flow; the flow net; percolation and hydrostatic uplift; side-channel spillways; boundary-layer; hydraulic similitude; hydraulic models; stilling pools.

145. Seminar in Hydraulic Engineering. *Prerequisite: Civ. Eng. 140 and 143.*

Lectures, assigned reading, and student reports on problems selected from the field of hydraulic engineering.

146. Hydraulic Engineering Design. *Prerequisite: Civ. Eng. 121 and 140; preceded or accompanied by Civ. Eng. 143.* II. (*3*).

Design of hydraulic structures such as diversion dams, head gates, control works, silt traps, siphon spillways, side-channel spillways, earth canals, and other structures involving accelerated flow, backwater, hydraulic jump, sedimentation, and erosion.

152. Water Purification and Treatment. *Prerequisite: Civ. Eng. 52 and 156 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.

153. Sewerage and Sewage Disposal. *Prerequisite: Civ. Eng. 53 and 156 or permission of instructor.* I. (*3*).

Engineering, public health, legal, and economic problems involved in the design and construction of sewers and in the disposal of city sewage and industrial wastes. Lectures, library reading, and visits to nearby disposal plants.

154. **Sanitary Engineering Design.** *Prerequisite: Civ. Eng. 52, 53, and 121.* II. (*3*).
Computations and drawing-board design of typical structures related to water supply, water purification, sewerage, and sewage disposal. Drawing room and visits to plants and work under construction.

155. **Municipal and Industrial Sanitation.** I. (*3*).
Scientific foundations of public sanitation, in particular relation to closely built-up areas and to industrial environments.

156. **Sanitary Engineering Laboratory.** *Prerequisite: Civ. Eng. 52, 53, and Bact. 109 or other acceptable laboratory preparation.* I. (*2 or 3*).
Fundamental principles of chemistry as applied to sanitary design of water, sewage, and industrial waste treatment facilities.

157. **Industrial Waste Treatment.** *Prerequisite: Civ. Eng. 153 and 156, Environmental Health 260, 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.

160. **Advanced Highway Engineering.** *Prerequisite: Civ. Eng. 65.* I. (*2*).
Seminar course dealing with special phases of highway design and construction. Assigned reading and reports.

161. **Highway Materials.** *Prerequisite: preceded or accompanied by Civ. Eng. 65.* I. (*3*).
Sources, production, and testing of highway materials; specifications; minor research problems.

162. **Bituminous Materials and Pavements.** *Prerequisite: Civ. Eng. 65.* II. (*2*).
Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods.

163. **Soils in Highway Engineering.** *Prerequisite: Civ. Eng. 135 and 136.* 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.

164. **Highway Transport.** II. (*2*).
Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers, management of transportation companies.

165. **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.

166. **Traffic Engineering.** *Prerequisite: Civ. Eng. 65, or permission of instructor.* II. (*3*).
Principles of highway traffic flow, traffic surveys and planning, analysis and presentation of data, traffic design.

167. **Highway Economics.** *Prerequisite: Civ. Eng. 65.* II. (*2*).
Principles of engineering economics applied to highway planning, location, and design; highway finance, taxation, and administration.

169. **Highway Design.** *Prerequisite: Civ. Eng. 65.* I and II. (*3*).
Studies of highway capacity, alignment, profiles, intersections, interchanges, and grade separations.

172. **Railroad Maintenance.** *Prerequisite: Civ. Eng. 65.* II. (*3*).
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.

173. Terminal Design. *Prerequisite: Civ. Eng. 65.* (*3*).
Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities.

174. Airport Design and Construction. *Prerequisite: Civ. Eng. 135 and 136.* 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.

176. Economics of Railroad Construction and Operation. *Prerequisite: Civ. Eng. 65.* 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.

178. Transportation. *Prerequisite: principles of economics.* I. (*3*).
Transportation facilities, services, and policies, with emphasis on comparative performance of the various agencies of transport.

180. Specifications, Contracts, and Professional Conduct. I and II. (*2*).
Engineering relations; ethics; war and civil contracts, and specifications. Lectures, reading, and discussion.

181. 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.

182. Patent Law for Engineers. (*3*).
Monopoly as an advancement of the arts and sciences; patentability; statutory provisions; rights of inventors generally; patent royalty contracts and assignments; procedure in preparation of patents. Texts, cases, and discussion.

183. Public Utility Problems. II. (*2*).
Nature of public service corporations; organization; ownership; valuation; depreciation; accounting; regulations; taxation; rates.

210. Geodesy and Surveying Research. *Prerequisite: Civ. Eng. 101.* (*To be arranged*).
Assigned work in geodesy, or other special field in surveying of interest to the student and approved by the professor of geodesy and surveying.

220. 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.

221. Analysis and Design of Folded Plates, Domes, and Shells. *Prerequisite: Civ. Eng. 122 and 124 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.

222. Structural Members. I. (*3*).
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.

223. Advanced Design of Structures. *Prerequisite: Civ. Eng. 123.* (*3*).
Functional design of structures, including also the selection and analysis of structural elements, usually reinforced concrete. Lectures, computations, and drafting.

224. Advanced Problems in Statically Indeterminate Structures. *Prerequisite: Civ. Eng. 124.* II. (*3*).
Continuous truss bents; hinged and fixed arches; rings; frames with curved members; flexible members including suspension bridges; frames with semirigid connections.

225. Structural Engineering Seminar. I and II. (*1*).
Preparation and presentation of reports covering assigned subjects.

226. 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.

227. Bridge Engineering and Design. *Prerequisite: Civ. Eng. 123 or 169.* 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, computations, and drafting.

229. Mechanical Methods of Stress Analysis. *Prerequisite: preceded or accompanied by Civ. Eng. 124.* II. (*1*).
Mechanical analysis of stresses in statically indeterminate structures by means of models. Use of the Begg's apparatus in analyzing complicated structures is given particular attention. Students are required to make the models and the necessary observations and calculations.

231. Analysis and Design of Shock-Loaded Structures. (*3*).
Response of bridges, buildings, towers, and other structures to dynamic loading by earthquake or explosive blast; vibration of structures; inelastic strength of structures exposed to atomic blast.

233. 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.

235. Foundation and Underground Construction. *Prerequisite: Civ. Eng. 135; preceded or accompanied by Civ. Eng. 136.* I and II. (*3*).
Analysis and evaluation of field borings, soil test data, and field loading tests; bearing capacity for spread footings, piles, and pile groups; earth pressure and mass stability; surface excavation and embankments; tunnel construction and design; subsidence and control of damage due to subsurface excavation; investigation of overloaded foundations. Lectures, references, and design problems.

236. 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.

240. Hydrological Research. *Prerequisite: Civ. Eng. 140.* (*To be arranged*).
Assigned work on some special problem in the field of hydrology; an enormous amount of data is available for such studies.

241. Hydraulic Engineering Research. *Prerequisite: Civ. Eng. 143. (To be arranged).*

Assigned work in hydraulic research; a wide range of matter and method permissible.

243. Applied Hydromechanics. *Prerequisite: Civ. Eng. 143 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.

250. 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, experimentation in the laboratory, searches in the library and among public records, and drafting room designing.

251. Public Water Supply. 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.

254. Advanced Sanitary Engineering Design. *Prerequisite: Civ. Eng. 152 and preceded or accompanied by Civ. Eng. 153.* II. (*3*).

Functional design of sanitary engineering structures and typical plant layouts; drafting room and field studies; preparation of design reports.

255. Sanitary Engineering Seminar. I and II. (*1*).

Preparation and presentation of reports covering assigned topics.

260. Highway Engineering Research. *Prerequisite: permission of instructor.* I and II. (*To be arranged*).

Individually assigned work in the field of highway engineering.

262. Advanced Bituminous Materials and Flexible Pavement Design. *Prerequisite: Civ. Eng. 162. (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.

264. Industrial Transport Management. *Prerequisite: Civ. Eng. 178 or Econ. 133, 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.

265. Transportation Planning. *Prerequisite: Civ. Eng. 165 and 173, 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.

270. 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.

280. 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.

ECONOMICS*

Professor Ackley; Professors Boulding, Ford, Haber, Hayes, Katona, Levinson, Morgan, Peterson, Smith, Stolper, and Suits; Associate Professors Brazer, Lansing, and Palmer; Assistant Professors Bornstein, Demsetz, Shearer, and Mueller; Lecturers Anderson and Patrick. Department office, 106 Economics Building.

Economics 53 and 54 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. Upperclassmen, however, may take Economics 71, 173, and 175 without having had Economics 53 and 54. 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.

53, 54. General Economics. *Prerequisite: Econ. 53 is prerequisite to Econ. 54.* 53, I and II; 54, 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 during the second semester.

71, 72. Accounting. *Prerequisite: Econ. 71 is prerequisite to Econ. 72.* 71, I and II. *(3)*; 72, I and II. *(4).*
Not open to freshmen. Concepts and procedures of accounting from the standpoint of investors and business management.

91. Economic and Financial Problems of the Family. *Open to juniors and seniors.* I and II. *(2).*
An introduction to problems and methods in budgeting and spending the consumer's money and effort. Among other topics are consumer co-operation, insurance, and other security measures.

101, 102. Money and Banking. *Prerequisite: Econ. 53 and 54. Econ. 101 is prerequisite to Econ. 102.* 101, I and II; 102, I and II. *(3 each).*
Nature and function of money and banking and contemporary monetary problems.

121, 122. Labor. *Prerequisite: Econ. 53 and 54. Econ. 121 is prerequisite to Econ. 122.* 121, I and II; 122, I and II. *(3 each).*
Economics 121 considers the labor force, its employment and unemployment, wages, hours, social security, and an introduction to trade unions. Economics 122 deals with union history, union structure and organization, the development of

*College of Literature, Science, and the Arts

collective bargaining, labor disputes, labor law, and the significant issues in labor relations.

123. Social Security. *Prerequisite: Econ. 121 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.

130. Industrial Organization and Price Policy. *Prerequisite: Econ. 53 and 54.* I. (*3*).
A theoretical and empirical analysis of the operation of American industrial markets. Attention is focused on the occurrence and economic significance of various market practices in relation to the structure and organization of markets.

131. Corporations. *Prerequisite: Econ. 53 and 54.* 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.

133. Transportation. *Prerequisite: Econ. 53 and 54.* II. (*3*).
An economic analysis of the transportation industries and the application of this analysis to public policy problems.

134. Public Utilities. *Prerequisite: Econ. 53 and 54.* II. (*3*).
Nature and problems of the public utility industries from the standpoint of government regulation.

153. Modern Economics Society. I and II. (*3*).
For juniors, seniors, and graduates who have had no course in economics and who desire one semester 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.

175. Elementary Economic Statistics. *Prerequisite: Econ. 53 or 54. Juniors and seniors may elect this course concurrently with Econ. 53 or 54.* I and II. (*3*).
Introduction to the principal methods of statistical analysis as applied to economic problems.

181. Public Finance. *Prerequisite: Econ. 53 and 54.* I. (*3*).
Principles and problems of government finance — federal, state, and local.

197. Comparative Economic Systems. *Prerequisite: Econ. 53 and 54.* 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.

ELECTRICAL ENGINEERING

3. Circuits I. *Prerequisite: preceded or accompanied by Math. 53 or preceded by Math. 34.* (*4*).
Direct-current and alternating current circuits. Kirchoff's laws, loop and node equations, network theorems. Alternating-current wave forms, effective and average 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.

5. **Direct- and Alternating-Current Apparatus and Circuits and Electronics.** *Prerequisite: Math. 54 or 56 and Physics 46. (4).*
Electric circuits; direct- and alternating-current motors and generators; electron ballistics, tubes, and R.C. coupled amplifiers. Three lectures and one three-hour laboratory.

7. **Motor Control and Electronics.** *Prerequisite: Elec. Eng. 5. (4).*
Direct- and alternating-current motors and control equipment; electronic tubes and circuits including industrial types. Not open to electrical engineering students. Three lectures and one four-hour laboratory.

9. **Network Analysis.** *Prerequisite: preceded or accompanied by Math. 56. (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.

10. **Principles of Electricity and Magnetism.** *Prerequisite: preceded or accompanied by Physics 45 and either preceded by Math. 34 or preceded or accompanied by Math. 54. (3).*
Mathematical and physical treatment of force actions and energy relations in electrostatic and electromagnetic fields; capacitance and inductance of systems of conductors; ferromagnetism, permanent magnets. Two lectures and one three-hour computing period.

11. **Electromagnetics and Energy Conversion.** *Prerequisite: preceded by Math. 56, Elec. Eng. 9, and Physics 54. (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 of materials, definition of circuit elements, transient and nonlinear phenomena; magnetic circuits and principles of energy conversion. Three lectures and one three-hour laboratory.

79. **Directed Research Problems.** *Prerequisite: Elec. Eng. 3. (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. 279 in that the instructor is in close touch with the work of the student. Elec. Eng. 279 is for graduates.

87. **Electronic Circuits and Systems.** *Prerequisite: Elec. Eng. 11. (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 close-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.

100. **Circuits II.** *Prerequisite: Elec. Eng. 3. (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 zeros; admittance and impedance; network theorems; graphical analysis methods; energy and power effects; polyphase circuits; electromechanical systems.

101. **Circuits III.** *Prerequisite: Elec. Eng. 100. (3).*
Analysis of distributed parameter systems; transmission of eletromagnetic waves in lines and waveguides; reflections; measurements; equivalent circuits; image wave filter analysis.

102. Circuit Analysis by Symmetrical Components. *Prerequisite: Elec. Eng. 100.* (*3*).
Representation of unbalanced polyphase currents and voltages by component symmetrical sets; solution of unbalanced circuit problems by use of symmetrical components; faults in power systems.

103. Electroacoustics and Ultrasonics. *Prerequisite: Math. 103 or 104 and Elec. Eng. 100, 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.

105. Network Analysis and Synthesis. *Prerequisite: Elec. Eng. 100.* (*2*).
Matrix analysis of multi-terminal networks; network function properties; two-port networks; synthesis of driving-point and transfer functions; cascaded networks; image filter synthesis.

108. Networks and Electronic and Transistor Circuits. *Prerequisite: Elec. Eng. 5 or equivalent.* (*4*).
Network analysis; vacuum tube and transistor circuits; amplifiers, mixers, modulators, and detectors. Not open to electrical engineering students. Lectures and laboratory.

109. Transistor Circuits. *Prerequisite: Elec. Eng. 5 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.

110. Electromagnetic Fields and Waves. *Prerequisite: Elec. Eng. 10 or equivalent.* (*3*).
Solutions of field problems. Elementary vector analysis — gradient, divergence, and curl, Poisson and Laplace equations. Maxwell's equations. Poynting's vector and energy relations. Plane waves in perfect and semiconducting dielectrics. Polarization of waves.

112. Electric and Magnetic Properties of Solids I. *Prerequisite: Elec. Eng. 180 or permission of instructor.* (*3*).
The roles of solids in determining electric and magnetic parameters of circuit elements and in wave propagation. The origin, frequency, and field dependence of the permittivity and the permeability. The thermodynamics of electric and magnetic processes. Metallic conduction, superconductivity and superconducting devices. Semiconductors, the relationships between the physical phenomena and the circuit representations, phosphors, light amplifiers.

120. Electronics and Communications I. *Prerequisite: Elec. Eng. 100 and 180 or Physics 165.* (*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.

121. Electronics and Communications II. *Prerequisite: Elec. Eng. 120 and preceded or accompanied by Elec. Eng. 101.* (*4*).
Wide band amplifiers; radio-frequency amplification; modulation and detection; transmitting and receiving circuits; radio-frequency transmission lines. Lectures and laboratory.

123. Pulse Circuits. *Prerequisite: Elec. Eng. 120.* (*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.

128. **Electronics and Radio Communications.** *Prerequisite: Elec. Eng. 100. (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.

130. **Electrical Measurements.** *Prerequisite: Elec. Eng. 100. (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 four-hour laboratory.

131. **Technical Electrical Measurements.** *Prerequisite: Elec. Eng. 130 or equivalent. (2).*
Selected topics in technical electrical measurements; dielectric measurements by Schering bridge methods, watt-hour meter calibration, magnetic measurements. One lecture and one three-hour laboratory.

135. **Methods of Instrumentation — A.** *Prerequisite: Elec. Eng. 100 and 180. (3).*
Application of electrical methods to the measuring and recording of physical quantities, such as displacement, stress, strain, pressure, velocity, and acceleration; basic methods and their application to particular measurement problems.

136. **Methods of Instrumentation — B.** *Prerequisite: Elec. Eng. 5. (3).*
Similar to Elec. Eng. 135 in subject matter, but the treatment is adapted to students not majoring in electrical engineering. Studies of electron tubes and circuits are introduced as required. Lectures, demonstrations, and problems.

137. **Instrumentation Laboratory.** *To accompany Elec. Eng. 135 or 136. (1).*
Transducers of resistive, inductive, and other types; strain gages; differential transformers; frequency characteristics of transducers and recorders; amplifiers and power supplies; complete gaging systems. Laboratory experiments and special problems. One four-hour laboratory.

140. **Power Plants and Transmission Systems.** *Prerequisite: Elec. Eng. 154, or permission of instructor. (3).*
Equipment for the generation and transmission of electric energy. Excitation systems, oil circuit breakers, substations, electrical and mechanical characteristics of transmission lines, and other associated topics.

141. **Economic Applications in Electrical Engineering.** *Prerequisite: preceded or accompanied by Elec. Eng. 153 or permission of instructor. (2).*
Economic, financial, and intangible analysis, corporate finance, time element of values, comparison of alternatives, economic decay, replacement, effect of income taxes. Kelvin's Rule, Game theory, linear programing, and economics of large systems.

151. **Induction Machinery.** *Prerequisite: Elec. Eng. 154. (3).*
Theory and operating characteristics of polyphase and single-phase induction motors, performance tests, speed control, time and space harmonics, unbalanced operation, transient operation, design considerations including the use of the computer.

153. **Energy Conversion and Control I.** *Prerequisite: Elec. Eng. 10, 100, and Math. 103 or 104. (3).*
A unified and integrated treatment of the basic principles governing the dynamic behavior of physical components and systems utilizing field, torque,

current, voltage, force, and energy relations. Application to transformers, d-c and a-c machines; hydraulic, pneumatic, photo-electrical, and thermal electric elements.

154. Energy Conversion and Control II. *Prerequisite: Elec. Eng. 153 or permission of instructor. (4).*

Generalization of the basic principles of the dynamic behavior and energy conversion of physical elements, including an introduction to Lagrange's equations, Hamiltonian functions, and Legrendre transformations. Introduction to feedback control system principles and transfer functions. Laboratory experiments demonstrating and corroborating the theory developed in class. Lectures and laboratory.

155. Feedback Control Systems I. *Prerequisite: Elec. Eng. 154. (4).*

Analysis and synthesis of linear feedback control systems utilizing the Laplace transform, frequency response and root locus as methods of analysis. Laboratory experiments involve the study of several control systems and their simulation on the differential analyzer. Lectures and laboratory.

157. Introduction to Servomechanisms. *Prerequisite: Math. 103 or 104 and Elec. Eng. 100 or permission of instructor. (2).*

A theoretical study of feedback control systems; transfer function analysis; conditions governing the stability of these systems; applications to position, speed, and process control systems.

158. Principles of Electric Traction. *Prerequisite: Elec. Eng. 3 or 5. (2).*

Traffic studies, train schedules, speed-time and power curves, locomotive train haulage, signal systems, cars and locomotives, control systems, traction systems, electrification of trunk lines.

160. Fundamentals of Electrical Design. *Prerequisite: Elec. Eng. 3 and 10. (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.

170. Incoherent Electromagnetic Radiation. *Prerequisite: Elec. Eng. 10 and Math. 56. (3).*

Sources of incoherent electromagnetic radiation; black body radiation, electronic transitions, molecular transitions. The incoherent radiant field; luminous emittance, illumination, luminance, light vector, luminous intensity. Geometric optics. Receptors of radiant energy; the human eye, energy conversion from ultra violet and infrared to optical, photoelectric cells, photoconductive cells.

172. Electrical Lighting and Distribution. *(2).*

For students of architecture particularly; students of electrical engineering cannot receive credit for this course.

174. Electric Distribution, Wiring, and Control for Lighting. *Prerequisite: Elec. Eng. 3 and 170. (2).*

Selection and application of equipment, design of circuits, study of methods of installation for electric-power supply lamps.

176. Residence Lighting. *Prerequisite: preceded by Elec. Eng. 170 or 172. (2).*

For students of architecture and engineering. Co-ordination of architecture with illumination as applied to residence lighting.

180. Physical Electronics of Electron Devices I. *Prerequisite: Elec. Eng. 3 or 5; preceded by Elec. Eng. 10. (4).*

Electron tube and transistor characteristics; amplifiers, rectifiers, and equivalent circuits; electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices; energy-level diagrams for atoms, metals, and semiconductors; transistors physics. Lectures and laboratory.

181. Industrial Electronics. *Prerequisite: Elec. Eng. 100 and 180. (4).*
Applicational analysis of electronic circuits used in the manufacturing, power, and aeronautical industries, including: polyphase rectifiers, thyratron and ignitron controls, semiconductor and magnetic amplifiers, trigger circuits; introduction to feedback control. Lectures and laboratory.

187. Seminar in Professional and Industrial Practices in Electrical Engineering. *Open to seniors and graduate students. (1).*
The nature of typical engineering decisions in electronic and other research, development, and production; organizational pattern and operating and personnel practices in major engineering establishments; the nature of operations research; stages in the growth of a new engineering field; compatability between electronic and other devices and equipment; reliability, specifications; patents, origin and use of professional and commercial standards; functions of professional societies and trade associations; professional ethics; the consultant's function. Lectures, discussions, case reviews, and reports.

189. Physical Electronics of Electron Devices II. *Prerequisite: Elec. Eng. 180, or permission of the instructor. (4).*
Conformal analysis of fields in space-charge control tubes; multigrid-tube interelectrode capacities; electron transit time principles; electron optics of cathode ray focusing; solid state physics of thermionic, secondary, and photo-electric emission; mobilities, mean free times, and conductivities in semiconductors and in gaseous conducting plasmas; television pickup and camera tubes; initiation of current in thyratrons, ignitrons, and circuit breakers; Paschen's Law; radiation counter tubes. Lectures and laboratory.

201. Transients. *Prerequisite: Elec. Eng. 100. (2).*
Advanced theory of electrical circuits; Laplace transform method of solution for transients in circuits with lumped constants; introduction to the complex frequency domain.

205. Network Synthesis I. *Prerequisite: Elec. Eng. 105, or 201, or permission of instructor. (3).*
Energy relations in passive networks; complex variable theory; realizability and synthesis of driving point impedance and transfer functions.

206. Network Synthesis II. *Prerequisite: Elec. Eng. 205. (3).*
Synthesis for prescribed transfer functions; the approximation problem; synthesis for a prescribed time response; application to engineering problems.

208. Network Analysis and Feedback Amplifier Design. *Prerequisite: Elec. Eng. 205 or permission of instructor. (3).*
Analysis and design of active networks; study of sensitivity for single- and multiple-loop networks; stability and physical reliability; contour integration and Nyquist's criterion for stability; design of single-loop stable amplifiers.

210. Electromagnetic Field Theory I. *Prerequisite: Elec. Eng. 110 or equivalent (3).*
Advanced theory and problems in electric and magnetic fields, using vector methods which are introduced as required; Maxwell's equations, waves, and propagation of energy.

211. Electromagnetic Field Theory II. *Prerequisite: Elec. Eng. 210. (3).*
Maxwell's equations; plane waves through semiconductors; dispersion, polarization; reflection and refraction; retarded potentials; Hertz vector; radiation; fields and forces on moving charges; dielectric and induction heating.

212. Electric and Magnetic Properties of Solids II. *Prerequisite: Elec. Eng. 110 or 112 or permission of instructor. (3).*
Stationary energy states in resonant cavities; equivalent stationary states in the hydrogen atom; extension to higher atomic numbers; molecular binding, exchange integral; binding in solids; the effect of wave function symmetry upon distribution function; electronic properties within a periodic potential field; the different forms of electronic conduction; paramagnetism, ferrimagnetism.

215. Methods of Solving Radiation and Scattering Problems. *Prerequisite: Elec. Eng. 210 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.

220. Microwaves I. *Prerequisite: Elec. Eng. 101 and 110. (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.

221. Radiation, Propagation, and Antennas. *Prerequisite: Elec. Eng. 110 and 120. (3).*
Fundamental theory; simple antennas, arrays, and reflecting systems; ionosphere; reflection, refraction, and diffraction; tropospheric propagation.

222. Microwave Antenna Theory. *Prerequisite: Elec. Eng. 210 and 221 or permission of instructor. (3).*
Methods of solution of microwave antenna design problems, reciprocity theorem, circuit relationships, impedance concept, reaction concept, slots, mutual coupling.

224. Microwaves II. *Prerequisite: Elec. Eng. 220 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.

225. Television. *Prerequisite: preceded or accompanied by Elec. Eng. 121. (2).*
Basic principles, cathode-ray scanning devices and television receivers and transmitters.

228. Microwaves, Radiation, and Propagation. *Prerequisite: Elec. Eng. 128. (4).*
Transmission lines, standing waves, impedance transformation; Maxwell's equations, waves, wave guides, cavity resonators; antennas, arrays, radiation patterns; tropospheric and ionospheric propagation, radar equation, ducts. A special course for the guided-missile program.

232. Analog and Digital Computer Technology. *Prerequisite: Math. 103 or 104; Elec. Eng. 100 and 180, 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.

233. Digital Computer Engineering Laboratory. *Prerequisite: Elec. Eng. 232 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.

234. Theory of Networks of Switching Elements. *Prerequisite: senior standing in engineering or permission of instructor. (3).*
The use of Boolean algebra and propositional calculus in the study of two-terminal and multi-terminal 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.

235. Digital Computer Design Principles. *Prerequisite: Elec. Eng. 232. (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.

238. Digital Computer Applications. *Prerequisite: Elec. Eng. 128 and Math. 148. (3).*
Logical structure and organization of digital computers; number systems, flow diagrams, and problem preparation; special topics in digital computer applications to simulation and system study. Lectures and laboratory work on the University's computing facilities.

240. Generating Stations. *Prerequisite: Elec. Eng. 154. (2).*
Integrated performance of electrical equipment used in the generation of electrical energy. Electrical and mechanical transients of synchronous machines.

241. Electric Transmission and Distribution Systems. *Prerequisite: Elec. Eng. 100. (3).*
Mechanical features of conductors and supports; electrical studies of lines; inductance by g.m.d. method, capacitance, equivalent circuits, and circle diagrams; distribution systems; surges.

242. Electric Rates and Cost Analysis. *Prerequisite: Elec. Eng. 140. (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.

245. Power System Stability. *Prerequisite: Elec. Eng. 140. (2).*
Steady-state and transient; development of swing equation for a rotating machine and methods of calculating swing curve; equal area criterion for two-machine system; studies of actual power systems.

246. Analysis of Electric Power Systems. *Prerequisite: Elec. Eng. 102. (3).*
A study of the integrated power system, under steady-rate behavior, covering such topics as power and reactive volt-ampere distribution and control, system voltage regulation, frequency control and application of tap changing and phase shifting transformers. Symmetrical component and alpha-beta-zero component impedances of sychronous machines and other elements of the power system. The application of the power network analyzer to the study of system performance.

247. Power System Protection. *Prerequisite: Elec. Eng. 140. (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.

248. Power System Transients. *Prerequisite: Elec. Eng. 140. (2).*
A study of lightning and its effects on a power system. Insulation, and design for integrated protection. Transients due to lightning and system switching. At-

tentuation and reflection of traveling waves. Ground wires, counterpoise, and application of lightning arresters.

251. Alternating Current Apparatus. *Prerequisite: Elec. Eng. 154.* (*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.

252. Synchronous Machinery. *Prerequisite: Elec. Eng. 154.* (*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.

255. Feedback Control Systems II. *Prerequisite: Elec. Eng. 155 or Instr. Eng. 174 and 174a or permission of instructor.* (*3*).
Linear feedback control systems using circuit synthesis techniques; approximation to the frequency and time domain; sampled-data systems using z and w transforms; correlation functions; design of linear systems with random inputs; design for the minimization of the mean-square-error.

256. Feedback Control Systems III. *Prerequisite: Elec. Eng. 155 or Instr. Eng. 174 and 174a or permission of instructor.* (*3*).
Linear time-varying systems; nonlinear systems using describing function and phase space analysis; analysis of piece-wise linear systems of the optimum control type using phase-space techniques. Laboratory demonstrations of typical systems.

257. Introduction to Navigation Systems. *Prerequisite: Elec. Eng. 155 or Instr. Eng. 174.* (*2*).
A theoretical study of the basic concepts which underlie celestial, Doppler, and inertial navigation systems. Emphasis is placed on the following topics: Doppler spectrum, matrix co-ordinate transformation, Shuler tuning, and other selected topics. Theory and application of gyroscopes, accelerometers, and astrocompasses as applied to navigation systems.

260. Heat Problems in Electrical Design. *Prerequisite: permission of instructor.* (*2*).
Advanced work in the fundamentals of heat transfer by radiation, conduction, and natural and forced convection; application to specific situations.

261. Design of D.C. and Synchronous A.C. Motors and Generators. *Prerequisite: Elec. Eng. 154 and 160.* (*3*).
Calculation for machines of given ratings, use of design sheets, practical limits for many items of design, calculation of performance, and use of ventilation. Computing period.

265. Large-Scale Systems Design I. *Prerequisite: Math. 150 and permission of instructor.* (*2*).
Tools of large-scale systems design, probability theory, mathematical statistics, operations analysis, computers and computing simulation.

266. Large-Scale Systems Design II. *Prerequisite: Elec. Eng. 265* (*2*).
Steps in system design; input measurement; measures of effectiveness, preliminary design; systems analysis; component choice, analysis and test; systems test and evaluation; other tools as needed.

271. Interior Illumination, Study of Design. *Prerequisite: Elec. Eng. 170 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.

279. **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.

281. **High-Voltage Experimental Techniques.** *Prerequisite: Elec. Eng. 100 and 180. (1).*

Cathode-ray oscilloscope measurements of fast transient voltages such as occur on electric utility power lines, in automobile ignition systems, and in radar modulators; circuit breaker principles; surge generators; lightning arresters; insulation and corona problems. One four-hour laboratory.

282. **Electron Tube and Vacuum Techniques.** *Prerequisite: Elec. Eng. 180 and permission of instructor. (1).*

Laboratory exercises and the techniques employed in vacuum-tube research and engineering and in physical electronics. One four-hour laboratory.

284. **Noise in Electronic Circuits and Devices.** *Prerequisite: Elec. Eng. 100, Math. 103 or 104, and preceded or accompanied by Math. 152, 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.

285. **Information Theory in Electrical Communication.** *Prerequisite: Elec. Eng. 284 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.

286. **Microwave Electron-Beam Tubes I.** *Prerequisite: Elec. Eng. 210 or permission of instructor. May be elected for 2 hours credit without laboratory with permission of instructor. (3).*

Llewellyn-Peterson analysis; general induced-current theory; electron optics of low-density and high-density beams, conservation of momentum, Busch's theorem, confined flow, Brillouin flow, Harris flow, electrolytic tanks; space-charge wave analysis; velocity modulation, klystrons, small-signal traveling-wave tubes, magnetron amplifiers, backward-wave oscillators, double-beam tubes. Lectures and laboratory.

287. **Microwave Electron-Beam Tubes II.** *Prerequisite: Elec. Eng. 286 or permission of instructor. (3).*

Electric and magnetic lenses, periodic magnetic focusing, effect of magnetic field on space-charge wave propagation; nonlinear theory of O-type amplifiers and oscillators; nonlinear theory of M-type amplifiers and oscillators; space-charge models; omega-beta diagram, periodically loaded waveguides.

288. **Theory of Solid-State Electronic Devices.** *Prerequisite: Elec. Eng. 180 and Math. 103 or 104. (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.

289. Noise in Electron-Stream Devices. *Prerequisite: Elec. Eng. 210, 284 and 286, or permission of instructor.* I. *(2).*

Statistical mechanics of multi-electron systems; medium-like models of an electron gas, applied to electron beams, gas discharges and solids; single-velocity and Maxwellian streams; generation and propagation of noise; general discussion in three dimensions of the noise output of an electron gun; the one dimensional model, its justification and limitations; the transmission-line analogy; noise in the retarding-field diode and in the space-charge-limited equivalent diode of the electron gun of a traveling-wave amplifier; the conditions for minimum noise factor; modulation noise in a semi-conductor and the transistor noise factor. (To be offered first semester, alternate years.)

355. Seminar on the Theory of Adaptive and Optimalizing Control Systems. *Prerequisite: Elec. Eng. 155 and 232. (2).*

The analytical design of feedback control systems by perturbation theory and variational principles; study of adaptive control systems of the input-signal and extremum type; laboratory demonstrations using computers as control system elements. (Offered first semester alternate years.)

383. Topics in Physical Electronics. *Prerequisite: Elec. Eng. 180 or 189, and Math. 150. (2), without a laboratory; (3), with a laboratory.*

Suggested topics for analysis: high pressure and high temperature plasmas, including magnetohydrodynamic effects; interactions producing extreme electron temperatures; mean free paths and ion mobilities and ionization rates; ambipolar diffusions; probe measurements in gas discharges; initiation of microwave gas discharges; high density electron beam formation, focusing, hysteresis, and instability; the quantum-mechanics of electron emission; initial electron velocity effects; space charge suppression of shot noise. Lectures and optional laboratory.

386. Special Topics in Microwave Circuits and Tubes. *Prerequisite: Elec. Eng. 287 or permission of instructor. (2).*

Energy theorems for electron streams; beam-type parametric amplifiers; modulation and nonlinear bunching of beams; linear accelerators; relativistic beams, electronic waveguides. Lectures.

395. 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 multistage sounding rockets.

403. 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.

404. Interdisciplinary Seminar in Communication Sciences II. *Prerequisite: Elec. Eng. 403. (3).*

A continuation of Elec. Eng. 403.

ENGINEERING GRAPHICS

The first-year requirements in engineering graphics may be fulfilled by Graphics 1 and 2, or 21 and 22. The student will elect whichever sequence is advised by the classifier.

1. **Engineering Drawing.** I and II. (*3*).
Use of instruments; lettering, geometric constructions, principles of orthographic projection, pictorial drawing, auxiliary views, sectional views and conventions, threads and fasteners, dimensioning, detail and assembly drawings.

2. **Descriptive Geometry.** *Prerequisite: solid geometry and Eng. Graphics 1.* I and II. (*3*).
Orthographic projection applied to the representation of points, lines, and planes in all possible relative positions, and the solution of problems involving the measurement of distances and angles; intersections of straight or curved lines with plane or curved surfaces, intersections of surfaces, tangent surfaces; size and shape of plane areas and development of curved surfaces. Emphasis is placed on analytical processes and the importance of neatness, accuracy, and systematic notation in graphical solutions.

4. **Introduction to Descriptive Geometry.** *Prerequisite: solid geometry and Eng. Graphics 1 or 21.* I and II. (*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 Engineering Graphics 2.

21. **Graphics and Engineering Drawing.** *Prerequisite: solid geometry,* I and II. (*3*).
Use of instruments, representation of three dimensional systems by orthogonal projection, freehand sketching and pictorial drawing, principles of professional drafting, and conventional practices. Introduction to charts, graphs, and graphical mathematics.

22. **Graphics and Engineering Geometry.** *Prerequisite: Eng. Graphics 21.* I and II. (*3*).
The principles of descriptive geometry, and applications to general engineering. Graphical techniques; graphical mathematics, including simple integration and differentiation; graphical statics, including simple equilibrium problems and vector operations. Three dimensional space frames. Functional scales and nomography.

32. **Graphical Presentation and Computation.** *Prerequisite: permission of instructor.* I and II. (*2*).
Special geometrical constructions, graphical solutions of equations, theory of graphical scales and nomography, empirical equations, graphical calculus. Theory and execution of methods followed by construction of working charts and computing aids.

33. **Advanced Engineering Drawing.** *Prerequisite: Eng. Graphics 2, 4, or 22.* I and II. (*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.

35. **Production Illustration.** *Prerequisite: Eng. Graphics 1, 21, or equivalent.* (*2*).
Various methods of making the pictorial drawings; use of production illustration; lettering, orthographic, axonometric, oblique, and perspective projections; sectional views, exploded views, and assembly views to illustrate how things are to appear when manufactured.

41. **Mechanical Drawing for Foresters.** II. (*1*).
Use of instruments, geometric construction, 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.

101. **Mechanical Drawing for Industrial Arts and Vocational Education Teachers.** *Prerequisite: an understanding of the basic principles of mechanical drawing. Not open to engineering students.* (*2*).
Designed for industrial arts and vocational education teachers and includes the following aspects of mechanical drawing: freehand and mechanical sketching, orthographic drawing, dimensioning, conventions, sections, development, and auxiliary views. Drawing problems will be designed to meet the specific needs of the members of the class.

102. **Mechanical Drawing for Industrial Arts and Vocation Teachers.** *Prerequisite: Eng. Graphics 101 and permission of instructor.* (*2*).
Continuation of Eng. Graphics 101, for students in Education.

ENGINEERING MECHANICS

1. **Statics.** *Prerequisite: preceded or accompanied by Math. 34 or 53 and Physics 45.* I and II. (*3*).
Fundamental principles of mechanics and their application to the simpler problems of engineering; forces, components, vectors, moments, couples, friction, hydrostatics, and centroids.

2. **Mechanics of Materials.** *Prerequisite: Eng. Mech. 1 and preceded or accompanied by Math 54 or 55.* I and II. (*4*).
Application of principles of mechanics to solution of problems in stress and strain on engineering materials, including resistance to direct force, bending, torque, shear, eccentric load, deflection of beams, buckling of columns, and compounding of simple stresses.

2a. **Laboratory in Strength of Materials.** *Prerequisite: preceded or preferably accompanied by Eng. Mech. 2.* I and II. (*1*).
Behavior of engineering materials under load in both the elastic and the plastic ranges; use and calibrating of testing machines and their accessories; use of mechanical, optical, and electrical strain measuring instruments; tension, compression, torsion, bending, impact, and hardness tests; column experiments; demonstration in photoelasticity and stress coat.

3. **Dynamics.** *Prerequisite: Eng. Mech. 1 or 5 and preceded by Math 54 or 56.* 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.

4. **Fluid Mechanics.** *Prerequisite: Eng. Mech. 1 or 5 and Math. 54 or 56.* I and II. *(3).*
The basic principles of mechanics are applied to liquid and gaseous fluids. Special assumptions of ideal gases, nonviscous and viscous fluids are applied. Dynamic similitude is used as a means of solving problems and analyzing data. Special topics included are manometers, Venturi and orifice meters, equilibrium and stability of floating bodies, laminar and turbulent flow, resistance to flow, dissipation of mechanical energy into heat, circulation, lift, boundary layers, free-surface flow, adiabatic flow of ideal gases in conduits.

4a. **Fluid Mechanics Laboratory.** *Prerequsite: preceded or accompanied by Eng. Mech. 4. (1).*
Visualizing flow of liquids; Reynolds' experiment; 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.

5. **Statics and Stresses.** *Prerequisite: Physics 45 and Math. 54 or 56. (4).*
Fundamental principles of statics and their application to engineering problems; forces, moments, couples, friction, centroids, moment of inertia; application of statics to the solution of problems in stress and strain on engineering materials, including resistance to direct loads, bending, torque, shear, eccentric loads.

11. **Statics.** *Prerequisite: Physics 53, preceded or accompanied by Math. 34. (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, beams.

12. **Strength of Materials.** *Prerequisite: Eng. Mech. 11, preceded or accompanied by Math. 55. (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 under radially symmetric pressure.

13. **Dynamics.** *Prerequisite: Eng Mech. 11, accompanied by Math. 56. (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.

14. **Fluid Mechanics.** *Prerequisite: Eng. Mech. 13, accompanied by Math. 56. (4).*
Idealized fluid, Newtonian and non-Newtonian fluids, hydrostatic equilibrium; dynamics of fluids, incompressible fluid motion, Euler and Bernoulli equations, potential and stream functions, vortex motion, laminar and turbulent flows, momentum and energy relations, evaluation of energy losses; compressible fluid flow, equations of motion for ideal gas, thermodynamical considerations; dimensional analysis and similitude; flow of conduits, Reynolds' criterion, flow in channels; lift and drag; deflection of jet by moving blades, reaction machines.

100. **Seminar in Engineering Mechanics.** *(To be arranged).*

102. Experimental Stress Analysis. *Prerequisite: Eng. Mech. 2 or 12.* (2).
Review of plane stress-strain relationships; mechanical, optical, and electrical resistance strain-measuring techniques with applications to strain rosettes; dynamic, transient, and post-yield strain measurement: use of brittle coatings; fundamentals of photoelasticity with applications: similitude of models applied to structures. Recommended as a substitute for Eng. Mech. 2*a*.

103. Experimental Mechanics. *Prerequisite: Eng. Mech. 2, 3, and Elec. Eng. 5.* (2).
Analysis, design, and use of instruments for measuring and recording, under static and dynamic conditions, displacement, stress, strain, pressure, temperature, and viscosity; graphical and numerical methods of reducing experimental data and methods of determining the over-all accuracy of an experimental investigation.

112. Intermediate Mechanics of Material. *Prerequisite: Eng. Mech. 2 or equivalent and Math. 103.* (3).
Generalization of bending and torsion theory; energy principles and their application to stress and deformation analysis; introduction to plane elasticity and to photoelastic and other experimental methods; limit analysis for simple stress problems; elements of elastic instability, plate, and membrane shell theory.

113. Intermediate Mechanics of Vibrations. *Prerequisite: Eng. Mech. 3 or equivalent and Math. 103.* (3).
Free and forced vibration, with viscous damping, for lumped and continuous mechanical systems. The ordinary and partial linear differential equations used will be developed by the Lagrangian Method. Vibration of multi-mass systems, strings, bars and plates. Normal modes, mechanical impedence and Rayleigh's Method.

114. Intermediate Mechanics of Fluids. *Prerequisite: Eng. Mech. 4 or equivalent and Math. 103.* (3).
Fundamentals: continuity, stream functions, streamlines and pathlines, acceleration vorticity and rates of deformation, stresses, relationship between stresses and rates of deformation, Navier-Stokes equations of motion. Mechanics of inviscid fluids; Euler and Bernoulli equations, irrotationality, velocity potential, Laplace equation, three-dimensional irrotational flows, conformal mapping, the relaxation method, wave motion, momentum equations, hydrodynamic forces and moments, one-dimensional treatment of compressible flows, irrotational subsonic and supersonic flows, method of characteristics. Mechanics of viscous fluids; exact solutions of the Navier-Stokes equations, very slow motion, hydrodynamic stability and turbulence, dimensional analysis, boundary layers, jets, wakes, lift and drag.

120. Research in Theory of Elasticity, Structures, and Materials. *(To be arranged).*
Special problems involving application of theory and experimental investigation. Research in theory of elasticity, plasticity, photoelasticity, structures, and materials.

122. Photoelasticity. *Prerequisite: Eng. Mech. 2 and Math. 103.* (2).
Lectures and laboratory experiments involving the fundamental principles of the photoelastic method of stress determination. Covers the basic properties of light with particular reference to the use of double refraction and interference as applied to a loaded specimen; determinations of the maximum shear in various tension and bending models; methods of separating the principal stresses. Models will be constructed to suit the interests of the students.

123. Structural Mechanics. *Prerequisite: Eng. Mech. 2.* (3).
Review of plane state of stress and strain; material properties, including the effects of temperature, fatigue, and creep; failure theories; selected stress analysis

problems such as torsion of thin-walled open sections, rotating disk, and thick-walled cylinder; energy principles and elements of limit design with application.

124. Theory of Elasticity I. *Prerequisite: Eng. Mech. 112 or equivalent. (3).*
Fundamentals of the theory of elasticity; three-dimensional analysis of stress, strain, and displacements; generalized Hooke's law and its connection with the strain-energy function; thermoelastic equations. Applications to flexure and torsion of prismatic bars, membrane analogy, and problems involving plane strain and plane stress in both rectangular and polar co-ordinates, including the thermal stress and determination of the stress concentration factor.

125. Theory of Thin Elastic Plates. *Prerequisite: Eng. Mech. 112 or equivalent. (3).*
Bending of thin plates with small deflections; the exact theory of plates. Application to rectangular, circular, and other shapes with various edge and loading conditions; plates of variable thickness; plates on elastic foundations; and anisotropic plates. Bending of plates with large deflections and applications to rectangular and circular plates.

126. Stress Analysis. *Prerequisite: Eng. Mech. 2. (2).*
Basic concepts of stress and strain in two dimensions; bending of curved beams and beams on elastic foundations; fundamentals of elastic instability; an introductory analysis of plates and thin shells (membrane theory); problems of stress concentration, torsion, and curved bars under bending and axial load; fundamentals of photoelasticity.

128. Theory of Elastic Stability I. *Prerequisite: Eng. Mech. 112 or equivalent. (3).*
Buckling of slender bars with large deflections; buckling of bars under the action of lateral and direct load, with variable cross sections, with elastic supports and on elastic foundations; effect of eccentricity, initial curvature, and shear deformation; energy and other methods of determination of critical loads; buckling of frames, rings, and curved bars; lateral buckling of beams, buckling of thin plates of various shapes with small and large deflections.

129. Theory of Plasticity I. *Prerequisite: Eng. Mech. 112 or equivalent. (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.

130. Research in Dynamical Problems. *(To be arranged).*
Original investigations in the field of body motions. Problems may deal with the vibrations of mechanical systems; oscillations in fluid systems; control problems which tie together fluid motion and the motion of physical bodies. May also deal with the fundamentals of mechanics, such as the study of friction and internal hysteresis of materials.

132. Advanced Dynamics. *Prerequisite: Eng. Mech. 113, or equivalent. (3).*
Advanced dynamics of rigid bodies in systems of engineering interest. Lagrange's equations.

133. History of Dynamics. *Prerequisite: Eng. Mech. 3 and Math. 103. (2).*
Review of the important publications in which the fundamental principles of dynamics were developed The influence of astronomical theories on the development of dynamics. *Mechanical Questions,* Aristotle; *Almagest,* Ptolemy; *Revolution of the Heavenly Bodies,* Copernicus; the works of Tycho Brahe with Kepler and Leonardo da Vinci; *Two New Sciences,* Galileo; *Pendulum Clock, Centrifugal Forces, Theory of Light,* Huygens; *Principia,* Newton. The

transition from the geometrical treatment to the analytical treatment of dynamical problems; Bernoulli, Euler, d'Alembert, and Lagrange.

134. Vibration Analysis of Rotors and Reciprocating Engines. *Prerequisite: Eng. Mech. 113. (3).*

Dynamic balancing of rotors and crankshafts; torsion and vibration analysis of equivalent masses and shaft systems in reciprocating and turbo machinery; geared systems; Holzer methods of analysis; harmonic analysis of indicated gas torque; vibration absorbers; vibration stress analysis.

135. Vibrations of Continuous Elastic Systems. *Prerequisite: Eng. Mech. 112 and 113, or permission of instructor. (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; application of Rayleigh-Ritz and other methods to the approximate calculation of frequencies and normal modes of nonuniform systems.

136. Theory of Vibrations, for Naval Architects. *Prerequisite: Eng. Mech. 3 and Math. 54 or 56. (3).*

General outline of vibration theory; vibration of masts, longitudinal vibration of propulsion machinery, torsional vibration of propulsion machinery; hull vibrations, vertical, lateral, longitudinal, and torsional; other selected problems.

137. Theory of Gyroscopes. *Prerequisite: Eng. Mech. 113, or permission of instructor.* I. *(2).*

General theory; rate gyros, freely gimbaled gyros, rate of turn gyros; gyrostabilization, gyro control, and other selected topics.

140. Research in Flow of Fluids. *(To be arranged).*

Special problems in the laboratory or research in literature, such as hydraulic roughness, flow of solid suspensions, boundary layer studies, turbulence, photoviscosity, secondary flow in conduits and channels, stability of modes of fluid flow, and stratified flow.

141. Mechanics of Inviscid Fluids I. *Prerequisite: Eng. Mech. 114, and Math. 150. (3).*

Equation of continuity, stream functions, vorticity and circulation, equations of motion, persistence of irrotationality, Bernoulli equation, Laplace equation, uniqueness theorem, kinetic energy and virtual mass, three-dimensional flows, images, two-dimensional motion, conformal mapping, free streamlines. Blasius theorems; Lagaty and Taylor theorems; vortex motion, Poisson's equation, shear flows.

142. Thermodynamics. *Prerequisite: Math. 103. (2).*

Fundamental concepts; first and second laws of thermodynamics, equilibrium of homogeneous systems; applications to elastic and plastic deformations and fluid dynamics.

143. Mechanics of Viscous Fluids I. *Prerequisite: Eng. Mech. 114 or equivalent, and Math. 150.*

Stress and rate-of-deformation tensors, dissipation function, the Navier-Stokes equation, equation for diffusion of vorticity, exact solutions of the Navier-Stokes equations, boundary layers, very slow motion, energy equations; forced and free convections; elements of hydrodynamic stability; isotropic turbulence, turbulent boundary layers, jets, wakes.

200. Theory of a Continuous Medium. *Prerequisite: Eng. Mech. 112, 114 and permission of instructor. (3).*

General theory of a continuous medium and its specialization to elastic, fluid, plastic, and other special media; basic kinematics; stress and strain tensors and their invariants; conservation of momentum, conservation of energy; the restrictions placed upon the equation of state and the dissipation equations by the second law of thermodynamics.

224. **Theory of Elasticity II.** *Prerequisite: Eng. Mech. 124. (3).*
Variational methods and their application to problems of flexure and torsion; three-dimensional stress and displacement functions; nuclei of strain; application to three-dimensional problems including elastic bodies in contact and the three-dimensional solution of stress concentration. Problems of multiply-connected regions; finite deformation and nonlinear elasticity.

225. **Theory of Shells.** *Prerequisite: Eng. Mech. 124. (3).*
The general theory for deformation of thin shells with small deflections; various approximate theories, including the membrane theory. Application to various configurations with special reference to shells of revolution; stability of shells. Shells of revolution with large deflections.

228. **Theory of Elastic Stability II.** *Prerequisite: Eng Mech. 128. (3).*
Investigation of various stability criteria (equilibrium, energy, dynamic, and others) and their interrelationship in various systems, including nonconservative systems; nonlinear considerations and discussion of post-buckling characteristics of redundant structures; buckling and post-buckling behavior of plates and cylindrical shells; general instability criteria in three-dimensional elasticity; survey of plastic buckling theories.

229. **Theory of Plasticity II.** *Prerequisite: Eng. Mech. 129. (3).*
Rheological properties of single crystals; polycrystalline materials, amorphous substances and liquids; theories of plastic flow and creep; the statistical approach to irreversible rate processes; equations of state and dissipation relations.

231. **Transient Motion and Vibration of Nonlinear Systems.** *Prerequisite: Eng. Mech. 113, Math. 147, and 150. (2).*
Transient motion in linear systems caused by forces which are functions of time; methods of operational calculus used for the solution of free and forced vibrations of linear mechanical systems; methods for treating the motions of nonlinear mechanical systems.

235. **Wave Motion in Continuous Elastic Systems.** *Prerequisite: Eng. Mech. 113 or equivalent and permission of instructor. (3).*
Wave propagation in bounded and extended elastic media, including transmission, 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.

241. **Mechanics of Inviscid Fluids II.** *Prerequisite: Eng. Mech. 141 and 142; others by permission. (2).*
General three-dimensional flow of compressible and incompressible fluids; maximum and minimum theorems, Taylor-Birkhoff theorem, and Darwin's theory for virtual masses; Lagally theorem for forces and moments; stability of vortex streets and vortex sheets; long waves, method of characteristics, surface waves, group velocity, waves of finite amplitude; motion of rotating fluids, motion of stratified fluids in a gravitational field.

243. **Mechanics of Viscous Fluids II.** *Prerequisite: Eng. Mech. 143. (3).*
Stress and rate of deformation tensors and general co-ordinates. Solutions of Navier-Stokes equations for compressible and incompressible viscous fluids; Gortler's series for the boundary layer; stability of rotating fluids, gravitational or

thermal instability, and its inhibition by rotation and magnetic field, Tollmien-Schlichting waves, instability of free-surface flows, applications of Chandrasekhar's method; statistical theories of turbulence, wave-number space, and the use of Fourier transform.

ENGLISH

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 11 and 21 are elected during the first semester of the freshman year and English 12 during the second semester. Students with outstanding ability can be exempted from one or more of these courses, whereas students who are not prepared for English 11 may be required to take English 10 before taking English 11.

10. Preparatory Composition. I and II. (*3*).
A course in composition and reading for those in need of further preparation. Study and drill in diction, spelling, grammar, and punctuation; in the structure of the sentence, paragraph, and short essay; and in the techniques of reading.

11. 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.

12. Freshman Composition II. I and II. (*2*).
A continuation of English 11 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 and reports. As in English 11, essays and some imaginative literature are read and analyzed.

21. **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 FOR FRESHMEN

To serve the need of freshmen who because of their scores on placement tests or for other reasons are in need of nontechnical electives, the English Department offers these three courses. They differ from Group II courses in three respects: (1) there are no prerequisites; (2) they focus almost entirely on reading and discussion; (3) they use literature as a means of broadening the student's interest in and awareness of other humanistic subjects.

14. **Quest for Utopia.** I and 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 purpose of this survey of utopias and anti-utopias is to help the student assess the values in the present order.

15. **Literature and Philosophy.** I and II. (*3*).
Reading and analysis of significant literature as a means of introducing some philosophical issues. Authors to be read include Sophocles, Bacon, Voltaire, Dostoevsky, Omar Khayyam, Browning, Whitman, Melville, Mark Twain, and Bertrand Russell.

16. **Literature and Art.** I and 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

Prerequisite: English 11 and 21.

Group II includes courses in composition, speech, and 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. The composition course (English 35) presupposes that the student has mastered the essentials of exposition and is ready for specialized types of writing. The speech course (English 41), with its emphasis on persuasive speaking, presupposes that the student has gained from Group I the ability to organize ideas, use the library, and select evidence from his reading. The literature courses 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. Themes, outlines, or written analyses are required in each of the courses.

35. **The Technical Article.** *Prerequisite: English 12.* (*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 the *Scientific American*.

41. Public Speaking for Engineers. (*2*).
Preparation and delivery of persuasive speeches. Frequent opportunity for practice and class criticism.

51. Contemporary Literature. (*2*).
Reading and analysis of contemporary fiction, drama, and poetry.

55. Modern Biography. (*2*).
Reading and analysis of twentieth-century biographies and autobiographies.

56. Short Story. (*2*).
Reading and analysis of contemporary short stories.

63. Contemporary Drama. (*2*).
Study of representative drama from Ibsen to the present day.

65. Contemporary Novel. (*2*).
Reading and discussion of outstanding European and American novels from about 1890 to the present.

75. Contemporary Poetry. (*2*).
Study of the principal British and American poetry of the twentieth century.

GROUP III: ADVANCED COURSES

Prerequisite: English 11, 12, 21, and one course in Group II.

Group III courses in composition, speech, and 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, which are open only to juniors, seniors, and graduate students, 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. In each of these courses a considerable amount of writing is required.

119. American Public Address. I and II. (*2*), (*3 with permission of instructor.*)
Selected American speakers and speeches from Colonial times to the present. Readings, lectures, discussions, and oral and written reports.

136. Technical Report. (*2*).
Written and oral exercises, the major assignments to be correlated as closely as possible with the technical work of the student.

141. Argumentation and Debate. (*2*).
Training in the organization and the delivery of the principal types of persuasive speeches, with emphasis on conference speaking and debating.

155. American Folklore. (*2*).
A study of the life and spirit of the American people as reflected in their folksongs and ballads, tales, legends, superstitions, proverbs and sayings, games, customs, and the like. Extensive use will be made of regional and type collections and of recordings.

157. Great Poetry. (*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.

158. **Literature of Science.** (*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.

161. **Shakespeare.** (2).
A study of 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.

162. **Drama.** (*2*).
Study of significant drama in classical, Elizabethan, neoclassic, and modern western civilizations.

167. **Novel.** (*2*).
Reading and discussion of major works in the prose fiction of the eighteenth and nineteenth centuries.

175. **American Literature.** (*2*).
Readings in the works of representative leaders in American thought.

185. **Literary Masterpieces.** (*2 or 3*).
Works of exceptional merit in the various literary forms.

188. **Literature and Modern Thought.** (*3*).
A study of selected works of writers such as Steinbeck, Koestler, and Sartre in the perspective of modern thought.

192. **Major American Writers.** (*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.

193. **Major European Writers.** (*2*).
An intensive study of the works of two or three major 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.

GEOLOGY*

Professor Wilson; Professors Arnold, Ehlers, Goddard, Hibbard, Kesling, Kellum, Landes, Stumm, and Turneaure; Associate Professors Belknap, Briggs, Dorr, Eschmann, and Zumberge; Assistant Professors Clarke, Kelly, and DeNoyer.

11. **Introductory Geology.** *Not open to those who have had Geol. 99.* I. (*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

*College of Literature, Science, and the Arts

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.

98. Geology for Engineers. II and S.S. (*4*).
Geologic processes with special emphasis on structural geology, ground water, soil genesis, and the relation of geology to engineering problems. Laboratory includes rock and mineral identification, and the interpretation of geologic and topographic maps and aerial photographs. Geology 98 is required of students in civil engineering and is open to others as an elective. Lectures, laboratory, and field trips.

99. Geology and Man. *Not open to freshmen, sophomores, or to those who have had Geol. 11.* (*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 Geology 12, Introductory Geology; Geology 90, Minerals and World Affairs; and Geology 127, Ground Water Geology, are especially useful for engineering students.

INDUSTRIAL ENGINEERING*

100. Industrial Management. *Prerequisite: junior standing.* I and II. (*3*).
Management problems and methods involved in the operation of manufacturing institutions, including location, layout, equipment, motion study, time study, methods of wage payment, inspection, organization procedures, production control, material control, and budgets.

110.* Plant Layout and Materials Handling. *Prerequisite: Ind. Eng. 100.* I and II. (*3*).
Analysis and planning of the layout of industrial plants. The study and selection of material handling equipment as influenced by material, processing, production equipment, building, and related factors.

120.* Work Measurement. *Prerequisite: Ind. Eng. 100.* I and II. (*3*).
Operating methods, work-center layout according to the laws of motion economy, and time-study techniques. Recitations, problems, and demonstrations.

124. (Psych. 189) Human Performance in Man-Machine Systems. *Prerequisite: Psych. 31 or 163, or permission of instructor.* II. (*3*).
Introduction to human performance theory, including human capabilities and limitations in man-machine systems. Emphasis on principles applicable in engineering psychology.

125*. Human Engineering. *Prerequisite: Ind. Eng. 100.* I. (*3*).
The application by engineers of the basic data of vision, audition, physical movement and fatigue to the design of equipment, the improvement of operating efficiency with existing equipment, and the performance of complex tasks.

*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.

127 (Psych. 190). **Psychology of Management.** *Prerequisite: Psych. 31, or graduate standing. Permission of instructor. Credit is not given for both Psych. 94 and 190.* I. (*3*).

Primarily for advanced students in psychology, engineering, and business administration. The application of psychological principles to the management of personnel in business and industry. Conference leadership, face-to-face contacts, and interviewing situations are analyzed in terms of principles and skill requirements.

130.* Wage Incentives and Job Evaluation. *Prerequisite: Ind. Eng. 100.* I and II. (*2*).

Principles and evaluations of major types of wage incentive systems. Appraisal of various job evaluating systems and use of job evaluation in developing equitable wage structures.

135.* Management Control. *Prerequisite: Ind. Eng. 100 and 120.* I and II. (*3*).

A study of problems in the application of principles of industrial engineering to management personnel, including such things as training, working conditions, safety, wage administration, suggestion systems, employment procedures, labor relations and nonindustrial application.

140.* Production Control. *Prerequisite: Ind. Eng. 100.* I and II. (*2*).

Principles of planning and control in mass production and job lot industries. Includes analysis of operating times and plant capacity, routing, scheduling and dispatching, inventory control, and techniques of evaluating operating results.

150. Engineering Economy. *Prerequisite: Econ. 153 and Bus.Ad., General 154.* I and II. (*2*).

Economic selection of equipment, consideration of cost, methods of financing, depreciation methods, and the planning of future production.

160. Operations Research. *Prerequisite: one year of calculus.* I and II. (*3*).

Introduction to operations research; the methodology of mathematical models and its application to various industrial problems, including experimental design and analysis; introduction to queueing theory, game theory, and linear programing.

165. Data Processing. *Prerequisite: one year of calculus.* I and II. (*3*).

Digital computer arithmetic operations, circuit logic, simple programing, computer data processing in industry, and computer simulation of industrial operations.

170. Introduction to Management Sciences. *Prerequisite: preceded or accompanied by Math. 162 and Ind. Eng. 160, 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.

190. Study or Research in Selected Industrial Engineering Topics. *Prerequisite: senior or graduate standing and permission of instructor who will guide the work.* 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.

200. Advanced Study or Research. *Prerequisite: graduate standing.* I and II. *To be arranged, 3 hour maximum*).

Individual study of specialized aspects of industrial engineering.

*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.

210. Industrial Engineering Problems. *Prerequisite: Ind. Eng. 100 and senior or graduate standing.* I and II. (*3*).
The study of 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.

220. Industrial Management — Field Work. *Prerequisite: Ind. Eng. 120 and senior or graduate standing.* I and II. (*3*).
Principles of production are applied to specific problems in factory management. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A fee is required.

221. Industrial Systems — Field Work. *Prerequisite: Ind. Eng. 120 and senior or graduate standing.* 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.

223. Advanced Work Measurement. *Prerequisite: Ind. Eng. 120.* I. (*2*).
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.

226. Human Engineering Problems. *Prerequisite: Ind. Eng. 124 or 125.* II. (*3*).
Problems and field exercises on the application of human engineering methods to engineering problems. Students will formulate problems, select the experimental or other procedures for their solution and report the findings.

230. Industrial Procurement. *Prerequisite: Ind. Eng. 100.* I. (*3*).
Inventory management, selection of sources, price analysis, standards and specification, organization of a purchasing department, buying policies.

233. Inventory Theory. *Prerequisite: courses in calculus and statistics and permission of department.* I. (*3*).
Development of the inventory theory from the modern mathematical approach; discussion of elementary deterministic systems leading to the Arrow-Harris-Marschak models with uncertain demand; dynamic programing models.

240. Seminar in Industrial Engineering. *Prerequisite: Ind. Eng. 120 or permission of instructor who will guide the work.* II. (*2*).
Current topics in industrial engineering. Reading, research, and preparation of papers.

250. Operations Research Seminar. *Prerequisite: permission of department.* I. (*1 or 2*).
Case studies of methodology in operations research. Reading, research, and reports.

251. Operations Research Seminar. *Prerequisite: permission of department.* II. (*1 or 2*).
Continuation of Industrial Engineering 250.

254. Advanced Engineering Economy. *Prerequisite: Ind. Eng. 150.* II. (*2*).
Economic analysis procedures, consideration of replacement, expansion, product and new enterprise analysis and expenditures, capital budgeting, case problems.

255. Queueing Theory. *Prerequisite: Math. 161.* II. (*3*).
Poisson and Erlang distributions; Markov processes. Queueing models, queue discipline and sequencing models; use of simulation and Monte Carlo techniques

on queueing problems; queueing tables; applications to inventory control, preventive maintenance, production management, traffic control, information processing, and communications systems.

260. **Great Works of Industrial Engineering.** *Prerequisite: graduate standing or permission of instructor.* II. (*3*).
Acquaints the industrial engineer with the origins of his profession and develops an understanding of the creative process in this area. The works of the founders of scientific management and original papers by outstanding men in the field will be studied and discussed.

INSTRUMENTATION ENGINEERING

170. **Seminar on Electronic Analog Computers.** *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.

174. **Principles of Automatic Control.** *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5, and a course in differential equations.* (*3*).
Transient and steady-state analysis of linear feedback control systems; transfer functions and operational calculus. Stability analysis of single and multiple-loop systems using the Nyquist criterion. Synthesis of control systems using Nyquist plots, attenuation methods, and root-locus diagrams.

174a. **Automatic Control Laboratory.** *Prerequisite: to be taken concurrently with or following Instr. Eng. 174.* (*1*).
Laboratory experiments covering the automatic control theory presented in Inst. Eng. 174. Use of the electronic differential analyzer for simulation and as a design tool.

175. **Applications of the Electronic Differential Analyzer I.** *Prerequisite: a course in differential equations.* (*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 analyzers of the Department of Aeronautical and Astronautical Engineering.

177. **Probability in Instrumentation.** *Prerequisite: a course in differential equations.* (*2*).
Probability basis of measurement errors and random events; probability distributions; precision indices and their propagation; confidence intervals; tests for distributions; least squares fitting; linear correlation; discrete and continuous time series.

178. **Design of Electronic Analog Computers.** *Prerequisite: Elec. Eng. 128 or equivalent and Instr. Eng. 174 or Elec. Eng. 255.* (*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 analog circuits. Design of servomultipliers, time-division multipliers, function-generators, drift-stabilized power supplies, and other selected topics. Lectures and laboratory.

183. Directed Study. (*To be arranged*).
Individual study of specialized aspects of instrumentation engineering.

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

210. Theory and Design of Measuring Systems. *Prerequisite: Instr. Eng. 177 and Math. 148.* (*3*).
Static response, static sensitivity, calibration. Analysis of dynamic response. Statistical aspects of measurement including estimation of statistical parameters, theory of random processes, correlation, and special functions. Instrument errors and their propagation. Application of information theory to design of measuring systems. Analysis and laboratory investigation of instruments to measure such things as displacement, velocity, acceleration, pressure, temperature, stress, and strain. Lectures and laboratory.

214. Information Theory and Data Transmission. *Prerequisite: Instr. Eng. 177, Elec. Eng. 128 and Math. 148.* (*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.

215. Radio Telemetry Laboratory. *Prerequisite: to be taken concurrently with or following Instr. Eng. 214.* (*1*).
Laboratory experiments involving the various modulation and multiplex methods and associated instrumentation described in Instr. Eng. 214.

248. Feedback Control. *Prerequisite: Instr. Eng. 174 or Elec. Eng. 255 or equivalent, and Math. 148.* (*2*).
Alternating current carrier systems; design and use of operational amplifiers as control system elements. Analysis and synthesis of nonlinear control systems; phase plane and describing function methods. Sampled data feedback systems and z-transforms. Response of linear control systems to random inputs; correlation functions and spectral densities; optimum linear filtering.

249. Feedback Control Laboratory. *Prerequisite: to be taken concurrently with or following Instr. Eng. 248.* (*1*).
Laboratory experiments covering the feedback control theory given in Instr. Eng. 248.

250. Introduction to Nonlinear Systems. *Prerequisite: Math. 104 and 150.* (*3*).
Study of systems represented by nonlinear autonomous (unforced) differential equations, including the following: concept of phase space; singular points and their stability; conservative systems; limit cycles; jump phenomena; Van der Pol's equation; index of Poincare; theorems of Bendixson. Many physical examples are used to illustrate the theory. Solutions are illustrated on the electronic differential analyzer.

251. Theory of Nonlinear System Response. *Prerequisite: Instr. Eng. 250.* (*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.

252. **Seminar on Simulation and Solution of Nonlinear Systems.** *Prerequisite: Instr. Eng. 175 and preceded or accompanied by Instr. Eng. 250, or permission of instructor. (1).*

Supervised work on assigned problems and problems of interest to the student of the types treated in Instr. Eng. 250 and 251. The principal tool used is the electronic differential analyzer.

273. **Theory of Linear Time-Variant Systems.** *Prerequisite: Math. 148. (2).*

Linear time-variant systems with a 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. Use of electronic differential analyzer for the solution of problems is demonstrated.

274. **Sampled Data Systems.** *Prerequisite: Instr. Eng. 174 and Math. 148, or equivalent. (2).*

Concept and implications of sampling, interpolation and extrapolation; operational methods for analysis of linear systems with sampled data inputs including transforms, modified z transforms, stability determination, and evaluation of dynamic and steady state response; analysis and synthesis of sampled data feedback systems by time and frequency domain techniques; synthesis of compensation transfer functions with digital computers and lumped element linear systems; multiple rate systems; finite width sampling; analysis and synthesis of linear systems with sampled random inputs; z transform and z form techniques for numerical analysis.

275. **Applications of the Differential Analyzer II.** *Prerequisite: Instr. Eng. 175 or equivalent. (3).*

Differential analyzer solutions of a wide variety of static and dynamic engineering problems. Solution of linear and nonlinear automatic control problems. Simulation of the six degree-of-freedom dynamic rigid body equations. Solution of linear and nonlinear partial differential equations using eigenvalue and difference techniques. Error analysis of differential analyzer solutions. Lecture and laboratory.

276. **Special Topics in Automatic Control.** *Prerequisite: Aero. Eng. 174 or Elec. Eng. 255 or equivalent, and Math. 148 or equivalent. (3).*

Minimum mean-square or integral-square design of linear feedback systems; multipole control systems; final value controllers; perturbation methods for control of complex nonlinear systems; optimalizing control; optimizing control; adaptive control systems; other selected topics taken from recent literature.

277. **Random Processes in Instrumentation and Control.** *Prerequisite: Instr. Eng. 177 or equivalent and Math. 150 or equivalent. (3).*

Introduction to random processes; behavior of time-invariant linear systems with stationary random inputs; optimum filtering and prediction for stationary processes; treatment of time varying and nonlinear systems with random inputs; interpolation and filtering of sampled data.

278. **Special Topics in Random Processes.** *Prerequisite: Math. 148 or equivalent; Instr. Eng. 277 or Elec. Eng. 285 or equivalent. (2).*

Topics of current research interest to be selected from among the following: detection theory, non-linear devices with random inputs, generalizations of Wiener optimum filtering, estimation of spectra, noise in sampled data systems.

385. **Seminar.** *(To be arranged).*

MATHEMATICS*

Professor Hay; Professors Bartels, Carver, Churchill, Coburn, Copeland, Craig, Darling, Dolph, Dwyer, Fischer, Heins, P. S. Jones, Kaplan, Lyndon, Moise, Nesbitt, Piranian, Rainville, Reade, Rothe, Thrall, and Wilder; Associate Professors Brumfiel, Dushnik, Gehring, Harary, LeVeque, Mayerson, McLaughlin, Schaefer, and Wendel; Assistant Professors Addison, Brown, Clarke, Dickson, Galler, Griffin, Halpern, Higman, D. A. Jones, Kazarinoff, Kruskal, Leisenring, Livingstone, Ritt, Shields, Titus, Ullman, and Wesler; Instructors Bragg, Chu, Claborn, Davison, Finney, Goldman, Hedstrom, Hicks, Kister, Korfhage, Lazerson, Low, Newman, Palermo, Ramanujan, Rosen, and Stoddard; Lecturers Arden, Evans, Karrer, Kincaid, Mrowka, Patil, Schaetz, Shimrat, Sleator, and Stubblefield.

6. Solid Euclidean Geometry. *Prerequisite: one year of plane geometry.* I and II. (*2*).
Postulates; basic constructions and propositions; original exercises, mensuration.

7. Algebra and Trigonometry. I and II. (*4*).
Review of elementary operations; linear equations; exponents; radicals; quadratic equations; simultaneous quadratics, progressions; binomial theorem. Trigonometry — the same as in Math. 8.

8. Trigonometry. I and II. (*2*).
Trigonometric ratios; trigonometric identities and equations; inverse functions; reduction and addition formulas; laws of sines, cosines, and tangents; theory and use of logarithms; solution of triangles.

13. Algebra and Analytic Geometry. I and II. (*4*).
Review of exponents, radicals, quadratic equations; theory of equations; determinants; complex numbers; curve tracing and locus problems in Cartesian and polar co-ordinates; straight line; circle; conic sections.

13d. Mathematics Drill. *Prerequisite: one and one-half units of high school algebra, one and one-half units of geometry, one-half unit of trigonometry; Math. 33 must be taken concurrently.* I and II. (*No credit*).
A tutorial type course meeting for two hours a week and designed to assist students whose mathematics background is weak. Review of high school algebra and trigonometry, drill in elementary college algebra. Open to engineering freshmen only.

14. Plane and Solid Analytic Geometry. I and II. (*4*).
Properties of conics involving tangents and asymptotes; parametric equations; surface tracing and locus problems in space; plane; straight line; quadric surfaces; space curves; introduction to calculus; differentiation of algebraic functions.

17, 18. Analytic Geometry and Calculus. *Prerequisite: permission of chairman of department, 3220 Angell Hall.* 17, I; 18, II. (*4 each*).
For better students who would normally take Math. 13, 14, and 53. There is deeper penetration into many topics and some acceleration. Followed by Math. 98.

33. Analytic Geometry and Calculus I. *Prerequisite: one and one-half years high school algebra, one year plane geometry, one-half year trigonometry.* I and II. (*4*).
Review of school algebra, binomial theorem; functions and graphs; straight lines and conics; derivatives, differential of algebraic functions, applications; introduction to integration.

***College of Literature, Science, and the Arts**

34. Analytic Geometry and Calculus II. *Prerequisite: Math. 33.* I and II. (*4*).
Inequalities; theory of equations and curve tracing; differentiation and integration of trigonometric, logarithmic and exponential functions; polar co-ordinates; moments; formal integration.

35, 36, 37. Analytic Geometry and Calculus. *Prerequisite: permission of chairman of department, 274 West Engineering or 3220 Angell Hall.* 35, I; 36, II; 37, I. (*4 each*).
For students well qualified in mathematics. Material covered is approximately that included in Math. 33, 34, 55, and 56.

52. Calculus I. I and II. (*5*).
For students who have not had an introduction to calculus in their freshman course. The beginning of calculus, with differentiation of algebraic functions and then the material of Math. 53. Followed by Math. 54 or 55.

53. Calculus I. I and II. (*4*).
Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

54. Calculus II. *Prerequisite: Math 53 or equivalent.* I and II. (*4*).
Definite integral; definite integral as the limit of a sum; centroids; moments of inertia; infinite series; Maclaurin's series; Taylor's series; partial differentiation; multiple integral; introduction to differential equations.

55. Analytic Geometry and Calculus III. *Prerequisite: Math. 34.* I and II. (*4*).
Arc length, curvature; elements of solid analytic geometry; partial derivatives; multiple integrals; infinite series, complex numbers.

56. Analytic Geometry and Calculus IV. *Prerequisite: Math 55.* I and II. (*4*).
First order differential equations, linear differential equations with constant coefficients; permutations and combinations; elementary probability and statistics; additional topics in algebra and analysis.

73. Elementary Computer Techniques. *Prerequisite: to be taken concurrently with Math. 18, 36, 52, 53, 55 or equiv.* 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.

98, 99, 100. Analysis I, II, III. *Prerequisite: Math. 17, and 18, or their equivalent.* 98, I; 99, II; 100, I. (98, 99, *4 each;* 100, *3*).
Primarily for mathematics honors students who have had Math. 17 and 18, or their equivalent. The material covered is approximately that of Math. 54, 103, and 151, but there is a deeper penetration into many topics.

103. Introduction to Differential Equations. *Prerequisite: one year of calculus.* I and II. (*3*).
Solutions and applications of differential equations of the first order; linear equations with constant coefficients; linear equations of the second order; solution by the power series method; applications.

104. Differential Equations for Systems Analysis. *Prerequisite: one year of calculus.* I and II. (*3*).
Elementary methods for solution of ordinary differential equations; graphical, numerical, and differential analyzer methods. Linear equations and systems of linear equations. Nonlinear equations. Physical applications; notions of input and output and their applications to control of physical systems.

113. Introduction to Matrices. *Prerequisite: Math. 62 or permission of instructor.* I and II. (*3*).

Vector spaces; linear transformations and matrices; equivalent of matrices and forms; canonical forms; application to linear differential equations.

117. 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 the social sciences.

118. Optimization in Linear Systems. *Prerequisite: Math. 117 or permission of instructor.* II. (*3*).

Solution of linear equations; linear inequalities and convex geometry; linear programing; simplex method; two-person zero-sum games, *n*-person games. Emphasis on applications of these topics. Students in mathematics should elect Math. 227.

[**141. Theoretical Mechanics I.** Omitted in 1960–61].

[**142. Theoretical Mechanics II.** Omitted in 1960–61].

[**145. Celestial Mechanics.** Omitted in 1960–61].

147. Operational Mathematics. *Prerequisite: Math. 103, or 104, or 150, or 151.* 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, transsient temperatures, and other problems.

148. Operational Methods for Systems Analysis. *Prerequisite: preferably Math. 104, or 103, and 150, or 151.* 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.

150. Advanced Mathematics for Engineers. *Prerequisite: Math. 54 or 56 and preferably Math. 103 or 104.* I and II. (*4*).

Topics in advanced calculus including infinite series, Fourier series, improper integrals, partial derivatives, directional derivatives, line integrals, Green's theorem, vector analysis. Students cannot receive credit for both Math. 150 and 151.

151. Advanced Calculus. *Prerequisite: Math. 54 or 56 and preferably Math. 103.* 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. 150 and 151.

152. Fourier Series and Applications. *Prerequisite: Math. 150 or 151.* I and II. (*3*).

Orthogonal functions, Fourier series, Bessel functions, Legendre polynomials and their applications to boundary value problems in mathematical physics.

153. Introduction to Approximation Theory. *Prerequisite: Math. 150 or 151, and permission of the instructor.* II. (*3*).

For students in analysis or computer mathematics. Theorems of Weierstrass, best approximations, Tschebyscheff and orthogonal polynomials, interpolation and approximate quadrature with reference to convergence of sequences of operations.

154. Advanced Mathematics for Engineers. *Prerequisite: Math. 37. For Sci. Eng. and Unified Sci. students.* II. (*4*).
Topics in advanced calculus including infinite series, Fourier series, improper integrals, partial derivatives, direction derivatives, line integrals, Green's theorem, vector analysis and differential equations. Students cannot receive credit for more than one of Math. 150, 151 and 154.

155. Introduction to Functions of a Complex Variable with Applications. *Prerequisite: Math. 151 or 150.* I and II. (*3*).
Complex numbers; limit, continuity; derivative; conformal representation; integration; Cauchy theorems; power series; singularities; applications to engineering and mathematical physics.

157. Intermediate Course in Differential Equations. *Prerequisite: Math. 103 and 150 or 151 or equivalent.* 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.

161. Statistical Methods for Engineers I. *Prerequisite: one year of calculus.* I and II. (*3*).
Statistical methods of quality control; normal, binomial, and Poisson distributions; Shewhart control chart; sampling methods for scientific acceptance inspection. Math. 161 and 162 together form an introductory course especially designed for the needs of engineers in both experimental work and the flow of production.

162. Statistical Methods for Engineers II. *Prerequisite: Math. 161 or 163.* I and II. (*3*).
Significance tests; tests valid for small samples; introduction to linear correlation; elementary design of experiments.

163. Theory of Statistics I. *Prerequisite: one year of calculus.* I and II. (*4*).
Basic probability and statistical concepts; univariate theory; calculational methods; distribution functions; binomial, normal, and Poisson distributions. Introduction to sampling theory. This course should be followed by Math. 164. Students cannot receive credit for both Math. 161 and 163.

164. Theory of Statistics II. *Prerequisite: Math. 163.* I and II. (*4*).
Significance tests and confidence limits for large samples; exact sampling theory including derivation and the use of Student-Fisher t; variance ratio and χ^2; correlation and regression; the bivariate normal distribution; introduction to multivariate analysis. Students cannot receive credit for both Math. 162 and 164.

166. Analysis of Variance and Experimental Design. *Prerequisite: Math. 163 and 164.* I. (*3*).
Introduction to the theory of significance tests. Exact significance tests in samples from normal. The likelihood ratio principles; the method of least squares. Randomized complete blocks, Latin squares, factorial designs; incomplete blocks. The analysis of covariance; variance components; principles of experimental design.

[**172. Graphical Methods and Empirical Formulas.** Omitted in 1960–61].

173. Introduction to Digital Computers. *Prerequisite: one year of calculus.* 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, differental equations, linear programing, etc. Laboratory work in programing and operating the IBM Type 650 and Type 704 digital computers.

174. Numerical Analysis. *Prerequisite: Math. 103 or 104, and 113 and 173, 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 the IBM Type 650 and Type 704 digital computers.

[175. **Theory of the Potential Function.** Omitted in 1960–61.]

176. Vector Analysis. *Prerequisite: one year of calculus.* I. (*2*).
The formal processes of vector analysis, with applications to mechanics and geometry.

[242. **Problems in Heat Conduction and Diffusion.** Omitted in 1960–61.]

[243. **Mathematical Theory of the Mechanics of a Compressible Fluid.** Omitted in 1960–61.]

244. Advanced Topics in the Mechanics of Fluids. *Prerequisite: Math. 150 and permission of instructor.* I. (*3*).
Recent developments in the mathematical theory of the mechanics of fluids.

[245. **Advanced Mechanics.** Omitted in 1960–61.]

246. Hydrodynamics. II. (*3*).
General equations of motion of a fluid; irrotational motion of an incompressible fluid; two- and three-dimensional flow problems; transformation theory and adiabatic flow; viscosity.

[247. **Mathematical Elasticity.** Omitted in 1960–61.]

249. Methods of Partial Differential Equations. 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.

250. Methods of Mathematical Physics I. *Prerequisite: Math. 150, 152, and 155, or the equivalent.* I. (*3*).
Regular integral equations. Sturm-Liouville systems. Asymptotic developments by saddle point and stationary phase methods. First order partial differential equations.

251. Methods of Mathematical Physics II. *Prerequisite: Math. 250, 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.

[252. **Advanced Fourier Analysis.** Omitted in 1960–61.]

255. Direct Methods in the Calculus of Variations. *Prerequisite: Math. 150 and 152 or equivalent.* I. (*3*).
The method of steepest descent in relaxation theory; Dirichlet and Raleigh-Ritz principles and their application to Sturm-Liouville systems and partial differential equations.

[256. **Nonlinear Differential Equations.** Omitted in 1960–61.]

257. Special Functions in Classical Analysis. *Prerequisite: permission of instructor.* II. (*3*).
Gamma, Bessel, Legendre, hypergeometric, and elliptic functions as treated in Whittaker and Watson's *Modern Analysis*. Generalized hypergeometric functions, Hermite and Laguerre polynomials.

271. **Advanced Numerical Analysis.** *Prerequisite: Math. 174 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 Type 650 or Type 704 computers.

277. **Tensor Analysis.** I. (*3*).
Definition of tensors; tests for tensor character; manifolds; geodesics, absolute derivatives, covariant and controvariant derivatives; the curvature tensor; relative tensors; Cartesian tensors; applications to mechanics, elasticity, hydrodynamics, heat conduction, electricity, and magnetism.

MECHANICAL ENGINEERING

2. **Engineering Materials and Manufacturing Processes.** *Prerequisite: preceded or accompanied by Chem.-Met. Eng. 1 or 18.* 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.

13. **Thermodynamics and Heat Transfer.** *Prerequisite: Physics 45 and Math. 55.* 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. Study of mechanism of heat transfer processes. Conduction, thermal radiation, and convective processes. Not open to mechanical engineering students.

14. **Heat-Power Laboratory.** *Prerequisite: Mech. Eng. 13 or permission of instructor.* I and II. (*1*).
The application of thermodynamics and heat transfer to various types of machinery, equipment, and instrumentation. One three-hour laboratory. Not open to mechanical engineering students.

17. **Mechanical Engineering Laboratory.** *Prerequisite: preceded or accompanied by Mech. Eng. 106 and 111.* 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.

31. **Manufacturing Processes I.** *Prerequisite: Chem.-Met. Eng. 1 or 18 and preceded or accompanied by Eng. Mech. 2.* 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.

32. **Manufacturing Processes.** *Prerequisite: Physics 45 and Mech. Eng. 2.* I and II. (*3*).
The relationship between product design and the limitations imposed by the

processes used in manufacture. Consideration of machining, plastic-working, foundry, and welding. Three recitations and one two-hour demonstration.

33. **Manufacturing Processes II.** *Prerequisite: Mech. Eng. 31.* I and II. (*3*).
A study of machining, welding, and plastic forming of materials; 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.

80. **Dynamics of Machinery.** *Prerequisite: Eng. Mech. 3.* I and II. (*3*).
Problems in kinematic and dynamic analysis of machines; static, friction, and inertial forces in mechanical systems; vibrations in a single degree of freedom, shaft whirl, balancing. Two one-hour and one two-hour period.

82. **Machine Design I.** *Prerequisite: Eng. Mech. 2, and preceded or accompanied by Chem.-Met. Eng. 107 and Mech. Eng. 31.* I and II. (*3*).
Application of the principles of mechanics, materials, and manufacturing to the design of machine elements. Two one-hour and one two-hour periods.

83. **Machine Design.** *Prerequisite: Eng. Mech. 2 or 5, and 3.* I and II. (*3*).
Introduction to machine design, for students not in Mechanical Engineering. Incorporates elements of Mech. Eng. 80 and 82. Three one-hour periods.

86. **Machine Design II.** *Prerequisite: Mech. Eng. 80 and 82.* I and II. (*3*).
Independent design of a machine, including layout, analysis, and critical review. Two four-hour periods a week.

104. **Fundamentals of Fluid Machinery.** *Prerequisite: Mech. Eng. 105 and Eng. Mech. 4.* I and II. (*3*).
Theory, construction, and operation of the principal types of fluid machinery.

105. **Thermodynamics I.** *Prerequisite: Physics 45 and Math. 55.* 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.

106. **Thermodynamics II.** *Prerequisite: Mech. Eng. 105 and Math. 56.* I and II. (*3*).
Continuation of Mech. Eng. 105. Power and refrigeration cycles; flow through nozzles and blade passages; general thermodynamic relations, equations of state, and compressibility factors; chemical reactions; combustion; gaseous dissociation.

107. **Applied Energy Conversion.** *Prerequisite: Mech. Eng. 106 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.

108. **Experimental Research in Mechanical Engineering.** *Prerequisite: Mech. Eng. 17 and permission of the 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 semester 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 laboratory periods per week. Time to be arranged.

109. **Thermodynamics.** *Prerequisite: Mech. Eng. 105 and Math 56.* I and II. (*3*).
Vapor power cycles; vapor compression refrigeration cycles; cryogenic applications; liquefaction of gases; air-standard cycles, chemical reactions, equilibrium; Maxwell relations; equations of state and generalized charts; equations of state for liquids; thermoelectric effects and associated phenomena.

111. Heat Transfer I. *Prerequisite: Mech. Eng. 105 and Eng. Mech. 4.* I and II. (*3*).
Study of the mechanisms of heat transfer processes. Steady and transient conduction in solids, numerical and graphical methods; heat exchanger design, performance and economics; thermal radiation; convective processes, turbulent and laminar flow, steady and transient diffusion, mass transfer between phases.

112. Combustion. *Prerequisite: Mech. Eng. 106, preceded or accompanied by Mech. Eng. 111 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.

114. Internal-Combustion Engines. *Prerequisite: Mech. Eng. 106.* 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, gas turbines, ramjets, and rockets; thermodynamics of cycles, combustion, ignition, fuel metering and injection, supercharging, and compounded engines.

116. Design of Internal-Combustion Engines. *Prerequisite: Mech. Eng. 82, and preceded or accompanied by Mech. Eng. 114.* I and II. (*3*).
Calculations, design of important details, and layout drawings of a standard diesel or Otto type internal-combustion engine. Drawing and problems. Two four-hour periods.

123. Industrial Air Conditioning. *Prerequisite: Mech. Eng. 105 or 13.* I. (*2*).
Fans and fan laws, air flow, dust collection, spray booth exhaust systems, pneumatic conveying, vapor exhaust, air conditioning for health and safety, and related topics.

125. Heating and Air Conditioning. *Prerequisite: Mech. Eng. 105.* I and II. (*3*).
Theory, design, and construction of warm-air, steam, hot-water, and fan-heating systems; central heating; air conditioning and temperature control.

126. Design of Heating and Air-Conditioning Systems. *Prerequisite: Mech. Eng. 125.* 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 computation for the size of principal equipment. Two four-hour periods.

127. Air-Conditioning Laboratory. *Prerequisite: Mech. Eng. 17 and 125.* I. (*3*).
Advanced experimental study in the field of air conditioning.

128. 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.

129. Cryogenics and Refrigeration. *Prerequisite: Mech. Eng. 106 and preceded or accompanied by Mech. Eng. 111.* 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.

132. Manufacturing Engineering. *Prerequisite: Mech. Eng. 32 or Mech. Eng. 33.* I and II. (*3*).
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 one-hour recitations and two two-hour laboratory periods.

133. Analysis of Manufacturing Processes. *Prerequisite: Eng. Mech. 2 and Mech. Eng. 80.* I. *(3)*.

Principles, methods, and instrumentation used in making engineering analyses of product design and machining processes; planning of investigations; design of mechanical dynamometers; electrical strain gages; transducer characteristics; related topics. (Two lecture and two three-hour laboratory periods.

137. Plastic Forming of Metals I. *Prerequisite: Mech. Eng. 33 and Math. 103* I. *(3)*.

Plastic deformation of metals with respect to their mechanical properties and metallurgical characteristics; fundamental concepts and assumptions; normal and shear stresses; true stress and true strain; basic yielding criteria; plastic stress and strain relationship; work of deformational analysis of extrusion of ideal plastic metals and strain hardening metals; temperature and strain rate effect; analysis of piercing, forging, wire drawing, and simple rolling operations.

141. Dynamics and Thermodynamics of Compressible Flow. *Prerequisite: Mech. Eng. 106 and 111.* II. *(3)*.

One-dimensional compressible flow involving change of area, normal shock, friction, and heat transfer. Two-dimensional subsonic and supersonic flow, method of characteristics, and oblique shocks.

142. Design Theory of Pumping Machinery. *Prerequisite: Mech. Eng. 104.* 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 turbomachinery.

144. Fluid Mechanics II. *Prerequisite: Eng. Mech. 4 and Math. 150 or 151.* I. *(3)*.

Dimensional analysis, basic concepts, equations of continuity, stream lines and stream surfaces, vorticity and circulation; equations of motion; irrotational flow theory, mathematical techniques for solution of flow equations; complex variables, conformal mapping with applications to solution of two-dimensional flow problems.

145. Introduction to Viscous Flow Theory. *Prerequisite: Mech. Eng. 144 or Eng. Mech. 114 or permission of instructor.* II. *(3)*.

Fundamental concepts, the Navier-Stokes equations, exact and approximate solutions of the Navier-Stokes equations; stability of laminar flow, turbulent flow, basic equations, isotropic turbulence, turbulent diffusion, turbulent shear flow; boundary layers.

151. Instrumentation and Automatic Control. *Prerequisite: Math. 103 or 104, preceded or accompanied by Elec. Eng. 7 or equivalent.* I. *(3)*.

Methods and instruments for measuring and recording displacement, velocity, acceleration, and force — introduction to the principles of automatic control systems encountered in mechanical engineering; the Laplace transform; the Nyquist criterion; design considerations for feedback control systems.

153. Automotive Power Trains. *Prerequisite: Mech. Eng. 82.* I. *(3)*.

Theory and design of automotive clutches, mechanical and hydraulic transmissions, differentials and axles. Lectures, recitations, and calculations.

154. Automotive Chassis. *Prerequisite: Mech. Eng. 82.* I. *(3)*.

Performance of automobile and truck suspension, steering, brakes, axles, and frames. Problems of cost, size, and weight reduction. Power-weight ratio, acceleration, gradability, stability, maneuverability, and ride comfort.

155. Automotive Laboratory. *Prerequisite: Mech. Eng. 17, preceded or accompanied by Mech. Eng. 114.* 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. Four or five hours each week.

156. Automotive Frames and Bodies. *Prerequisite: Mech. Eng. 82.* II. (*3*).
Frames, bodies, and cabs in automobiles, trucks, and tractors; unit-body and conventional frame and body construction; convertibles and hardtops, structural efficiency of frame and body components; design of cab and body mountings; effect of bending and torsional rigidity on the performance of the body; problems of road shocks, body shake, noise, and vibration. Three one-hour periods.

164. Gas Turbines and Jet Propulsion. *Prerequisite: Mech. Eng. 106.* I and II. (*3*).
Thermodynamics, theoretical cycles of combustion, fuels, gas turbine cycle, regenerators, compressors, turbines, and blading; fundamentals of the jet engine. Lectures, recitations, and problems.

165. Rocket Motors. *Prerequisite: Mech. Eng. 106.* II. (*2*).
Rocket power plant, including thermodynamics, flow of fluids and combustion; theory and application of propellants; liquid propellant feed systems; heat transfer; performance and testing.

166. Design of Gas Turbines. *Prerequisite: Mech. Eng. 82 and 164.* II. (*3*).
Calculation and design of centrifugal and axial flow compressors; radial and axial flow turbines with layout drawings; drawing and problems. Two four-hour periods.

170. Diesel Power Plants. *Prerequisite: Mech. Eng. 106.* I. (*2*).
Construction and operation of diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries.

171. Dimensional and Quality Control. *Prerequisite: Mech. Eng. 32.* II. (*3*).
Various methods and instrumentation for inspecting and controlling dimensions of fabricated products. Mechanical, electrical, statistical, and other methods for flaw detection, surface finish, and size control. Two two-hour periods.

172. Welding. *Prerequisite: Chem.-Met. Eng. 107 or 117 or 127 or permission of instructor.* I. (*2*).
Engineering approach to welding, including consideration of welding metallurgy, stresses, distortion, shrinkage, costs, and the capabilities and limitations of welding equipment as they relate to the design and application of weldments. Laboratory assignments include evaluation and use of all of the common welding processes, inspection, and testing procedures.

173. Gas Welding. *Prerequisite: Mech. Eng. 172 or permission of instructor.* I and II. (*2*).
Theory and equipment of gas welding, its applications to industry, and its cost. Practice in the welding and brazing of steels, cast iron, and nonferrous metals; testing of standard test specimens of joints welded by gas; training in manual and machine cutting and practice in pipe and aircraft tube welding. One hour class and one three-hour laboratory. Graduate credit not allowed for mechanical or industrial engineering graduate students.

174. Electric Welding. *Prerequisite: Mech. Eng. 172 or permission of instructor.* I and II. (*2*).
Theoretical and practical knowledge of the principles of direct and alternating current arc welding, and practice in atomic hydrogen and inert arc welding as

applied to industry. Training in welding in the four positions; welding costs and the standard welding tests to evaluate the different types of welds. One hour class and one three-hour laboratory.

180. Mechanical Vibrations. *Prerequisite: Mech. Eng. 80 or 83.* I and II. (*3*).
Analysis, reduction, and isolation of machine vibrations. Mounting of machines and equipment; critical speeds and torsional vibrations of rotors; balancing of machines; vibration absorbers and dampers.

181. Design of Manufacturing Equipment. *Prerequisite: Mech. Eng. 82.* 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.

182. Manufacturing Considerations in Design. *Prerequisite: Mech. Eng. 82 or 83.* 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.

183. Wear Consideration in Design. *Prerequisite: Mech. Eng. 82 or 83.* I and 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.

184. Synthesis of Mechanisms. *Prerequisite: Math. 56 and Mech. Eng. 80 or 83.* 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.

185. Mechanical Analysis Laboratory. *Prerequisite: Mech. Eng. 80.* I and II. (*3*).
Measurements of kinematic and dynamic quantities in mechanical systems; use of measurements in experimental analysis and design; study of input-output effects; experimental techniques; analog methods. Laboratory, analysis, reports. Two three-hour periods per week.

186. Stress and Strength Considerations in Design. *Prerequisite: Mech. Eng. 82 or 83.* 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.

187. Lubrication and Bearing Analyses. *Prerequisite: Mech. Eng. 82.* II. (*3*).
Viscosity; hydrostatic and hydrodynamic analysis of journal and thrust bearings; lubrication of rolling surfaces; thin-film lubrication; bearing materials; methods of lubrication; bearing design.

200. 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 including air conditioning, automotive engines, transmissions, chassis, suspensions, and bodies; design, stress and strength analysis, dynamics of machinery; design and interpretation of experiments; fluids machinery; heat and power; manufacturing; thermodynamics and heat transfer. 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 semester.

The course may be elected in more than one semester with approval of the adviser.

203. **Advanced 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.

205. **Advanced Thermodynamics.** *Prerequisite: Mech. Eng. 106.* I. (*3*).
Definitions and scope of thermodynamics, first and second laws, Maxwell's relations, Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.

207. **Advanced Mechanical Engineering Problems.** *Prerequisite: preceded by Math. 57 or Math. 103.* 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.

211. **Heat Transfer II.** *Prerequisite: Mech. Eng. 105, 111, and Math. 103.* I. (*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. Dynamics of thermal instrumentation and heat exchangers.

212. **Heat Transfer III.** *Prerequisite: Mech. Eng. 105 and 111.* II. (*3*).
Study of the nature of convective processes involving the transfer of heat, mass and momentum. Boundary layer theory. Analogy between heat and momentum transfer. Condensation and boiling phenomena, two-phase flow. Natural convective processes, steady and transient diffusion, mass transfer between phases.

214. **Advanced Theory of Internal-Combustion Engines.** *Prerequisite: Mech. Eng. 114.* II. (*3*).
Balance and vibration; advanced thermodynamics of engines; chemical equilibrium and kinetics of combustion; theory and control of detonation; combustion analysis; principles underlying recent advances in engines.

237. **Plastic Forming of Metals II.** *Prerequisite: Mech. Eng. 137 or equivalent.* II. (*3*).
The theory of dislocation and slip mechanism; stress tensor and invariants, strain tensor and invariants; plastic stress-strain relations, theory and experimental data; slip line fields in two dimensional flow problems; construction of slip lines; application of slip lines in extrusion and forging; analysis of deep drawing and hydroforming; tube reducing and nosing with conical dies; theories of rolling; nonsymmetric flow through circular tools; bendability of sheet metals.

240. **Theory of Land Locomotion.** *Prerequisite: Math. 103 or permission of instructor.* I. (*3*).
The mechanics of vehicle mobility; locomotion on wheels, tracks, etc.; soil properties as related to vehicle mobility; vehicle performance, trafficability, and economy in off-road operation.

242. **Land Locomotion Laboratory.** *Prerequisite: Mech. Eng. 240 or permission of instructor.* I and II. (*3*).
Measurements of soil properties as related to vehicle mobility; model testing in soil bins; relations between load, sinkage, and tractive effort in soils of various types under wheel and track loading. Two four-hour periods.

255. Advanced Automobile Testing and Research. *Prerequisite: Mech. Eng. 155 or 161, and permission of instructor.* I and II. (*3*).
Advanced experimental and research work. Laboratory and reports.

273. Machinability. *Prerequisite: Mech. Eng. 132.* II. (*3*).
Metal-cutting theory and its application to practical problems. Basic theory of tool wear, cutting forces, surface finish, and chip formation is studied in class and correlated with work in the laboratory. Special research problems are investigated. Field trips to local manufacturing plants are included.

300. Professional Problem. I and II. (*9*).
Professional degree candidates 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.

304. Fluids Machinery Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. (*To be arranged*).
Reports and discussions on library study and laboratory research in selected topics.

305. Seminar in Thermodynamics. *Prerequisite: Mech. Eng. 205 or permission of instructor.* II. (*3*).
Thermodynamic analysis of rectification, low-temperature phenomena equilibrium, metastable states, and compressible flow.

308. Heat-Power Seminar. *Prerequisite: graduate standing and permission of instructor.* Offered upon sufficient demand. (*To be arranged*).
Reports and discussions on library study and laboratory research in selected topics.

312. Heat Transfer IV. *Prerequisite: Mech. Eng. 211 and 212, Math. 152 or equivalents.* 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.

METEOROLOGY

4. Weather, Climate, and Life (Geog. 4). *Prerequisite: standing of at least second semester freshman. Not open to students who have taken Meteor. 104.* I. (*3*).
An elementary description of the atmosphere, its characteristics and behavior; weather and climate as basic factors in life and civilization.

104. Introductory Meteorology — Weather (Geog. 104). *Prerequisite: preceded or accompanied by Math. 7 or equivalent. No credit allowed in a degree program in meteorology.* I and II. (*3*).
Wind and storm systems, cloud and precipitation, and other weather processes as revealed by meteorological research, with an elementary discussion of weather instruments and forecasting. Lectures, term paper, and field trips.

105. Introductory Meteorology — Climate (Geog. 106). *Prerequisite: Meteor. 4 or 104. No credit allowed in a degree program in meteorology.* II. (*3*).
Climatic elements, controls, and regimes with a discussion of their distribution,

classification, and fluctuation, and of the significance of climatic influences in the modern world. Lectures and term paper.

110. Meteorology for Teachers. *Prerequisite: upperclass or graduate standing or permission of instructor. Not open to engineering students. (2-3).*

Lectures and discussions on elementary meteorology, combined with work-shop 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.

115. Micrometeorology I. *Prerequisite: senior or graduate standing.* I. *(3).*

The physical processes which govern microweather and microclimate; temperature, humidity, and wind near the ground in relation to height, time, soil, vegetation, and topography. Lectures and field experiments.

120. Principles of Meteorology. *Prerequisite: Math. 54 and Physics 46 or equivalent; no credit allowed in a degree program in meteorology.* 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. Lectures and problems.

122. Atmospheric Thermodynamics and Radiation. *Prerequisite: Math. 54 and Physics 46 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.

126. Dynamic Meteorology. *Prerequisite: Math. 54 and Physics 46 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; gradient wind; thermal and isallobaric wind components; local change of pressure; atmospheric turbulence and turbulent transfer processes; the jet stream; weather prediction by high-speed computing methods.

132. Synoptic Meteorology. *Prerequisite: preceded or accompanied by Meteor. 122 or 126.* I. *(3).*

Air mass analysis, representative and conservative properties, types of hydrometeors; 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.

135. Laboratory in Synoptic Meteorology I. *Prerequisite: preceded or accompanied by Meteor. 132.* I. *(3).*

Principles of air mass analysis and frontal discontinuities applied to construction of meteorological charts from current and past weather data. Map projections, meteorological communications and analytical codes; measurement and uses of geostrophic and gradient winds; jet stream analysis; graphical addition and subtraction for construction of thickness patterns; basic principles of prognosis from thermodynamic diagrams, isallobaric and isobaric analyses.

136. Laboratory in Synoptic Meteorology II. *Prerequisite: Meteor. 135.* II. *(3).*

Application 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. Prediction and verification.

144. Physical Meteorology. *Prerequisite: Meteor. 122.* II. (*3*).
Cloud and precipitation physics; aircraft icing; radar meteorology; atmospheric electricity; atmospheric optics and visibility. Lectures and problems.

153. Physical Climatology. *Prerequisite: preceded or accompanied by Meteor. 122 or 126.* 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. Lectures and exercises.

162. Meteorological Instrumentation. *Prerequisite: Meteor. 122 or 126 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.

166. Micrometeorological Instrumentation. *Prerequisite: preceded or accompanied by Meteor. 115 or 162.* II. (*3*).
Analysis of requirements for instrumentation; measurement of radiation, temperature, 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.

180. Applied Meteorology. *Prerequisite: Meteor. 104 or 120 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.

182. Hydrology and Hydrometeorological Design. *Prerequisite: preceded or accompanied by Meteor.* 144. I. (*4*).
The hydrograph and the various factors that affect and determine its characteristics; precipitation, evaporation, transpiration, infiltration; the unit hydrograph; the distribution graph; maximum flood flows and frequency of occurrence; normal flow and low flow; effect of forests, cultivation, and drainage; yield of wells; stream flow records; hydrological and hydrometeorological aspects of the design of structures. Lectures, laboratory, computation, and drawing.

186. Meteorological Analysis and Design Criteria. *Prerequisite: preceded or accompanied by Meteor. 122 and 126, or equivalent.* II. (*4*).
Analysis of meteorological aspects of engineering problems; use of meteorological design criteria for air pollution control through specification of plant location, stack height, nozzle effect, exit velocity, and temperature, and scheduling waste release; meteorological design factors in determining wind and precipitation loading of structures; etc. Lectures, laboratory, and computation.

215. Micrometeorology II. *Prerequisite: Meteor. 115 and 122 or permission of instructor.* II. (*3*).
Laminar and turbulent flow in the atmosphere; transfer of matter, momentum, and heat; eddy diffusion; evaporation from natural surfaces. Lectures and problems.

256. Laboratory in Applied Climatology. *Prerequisite: Meteor. 182 and 186 or equivalent.* I. (*3*).
Realistic interpretation of climatic information; space and time interpolation and extrapolation of climatic factors; combined effects of weather elements; meth-

ods of determining the specific applications of climatic knowledge. Lectures and the analysis of practical examples.

291. Special Problems in Atmospheric Science. *Prerequisite: permission of in-instructor.* I and II. (*To be arranged*).

Supervised analysis of selected problems in various areas of meteorology and associated fields.

293. 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.

295. Current Topics in Meteorology. *Prerequisite: permission of instructor.* I and II. (*2*).

Advances in specific fields of atmospheric science, as revealed by recent research. Lectures, discussion, and assigned reading.

297. 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.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

1. Introduction to the Design and Construction of Small Pleasure Craft. *Prerequisite: one year high school algebra. May not be elected for credit by students in the College of Engineering.* II. (*3*).

Nomenclature, delineation of hull form, displacement, initial stability and power to carry sail, metallic and plastic construction, powering, machinery and general arrangements.

11. Introduction to Practice. *Prerequisite: sophomore standing and Eng. Graphics 1 and 2.* I and II. (*2*).

Types of ships, 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.

12. Form Calculations I. *Prerequisite: Nav. Arch. 11, Math. 53, or 55, and Eng. Mech. 1.* 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.

13. Form Calculations II. *Prerequisite: preceded or accompanied by Nav. Arch. 12.* I and II. (*2*).

Preparation of a body plan from given offsets; the necessary calculations for the preparation of hydrostatic curves, curves of floodable and permissible length, and the determination of the location of watertight bulkheads.

21. Structural Design I. *Prerequisite: Eng. Mech. 2 and Nav. Arch. 12.* I and II. (*3*).

Design of the ship's principal structure and fastenings to meet the general and local strength requirements. Application of the Classification Society's rules to framing, shell, decks, bulkheads, welding, riveting, and testing.

123. Advanced Structural Design. I and II. (*To be arranged*).

124. Directed Research in Ship Structure. *Prerequisite: Nav. Arch 123.* I and II. (*Hours to be arranged*).

127. Stress Analysis of Structures in Ship Design. *Prerequisite: Eng. Mech. 126.* I. (*2*).

Bending of beams under action of axial and lateral loads, reciprocal theorem; elastic energy, Castigliano's theorem, continuous beam and frames, moment distribution method; analysis of bulkheads, double bottoms and plating supported by a grillage system of stiffeners; buckling of reinforced rectangular plates; effective width of plating, shear lag effects; stress distribution in superstructures due to bending; effect of bulkheads on bending moment distribution. Treatment of dynamic bending moment and local stresses due to slamming and motions in a seaway. Introduction to submarine analysis. Environmental conditions of ship structural materials.

131. Ship Dynamics. *Prerequisite: Nav. Arch. 13, Eng. Mech. 4, and Math. 103.* I. (*2*).

The motion of ships at sea, rolling, pitching, sea-keeping qualities; steering and maneuvering.

132. 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 students block out initial design characteristics for the ship.

133. Ship Design II. *Prerequisite: Nav. Arch. 132 and accompanied by Nav. Arch. 134.* I and II. (*2*).

Basing his work on the design started in Nav. Arch. 132, the student prepares the preliminary design drawings and final calculations for the subject vessel.

134. Structural Design II. *Prerequisite: Nav. Arch. 21 and accompanied by Nav. Arch. 133.* I and II. (*2*).

Student develops the "Midship Section" and "Structural Profile and Decks" for the vessel designed in Nav. Arch. 132 and Nav. Arch. 133 and makes freeboard, strength, and steel weight calculations.

135. Advanced Ship Drawing and Design. I and II. (*To be arranged*).

136. Small Craft Design I. *Prerequisite: Nav. Arch. 12.* II. (*2*).

Design of small commerical and pleasure craft.

137. Shipbuilding Contracts and Cost Estimating. *Prerequisite: junior standing.* I. (*2*).

Principal features of ship specifications and contracts; methods and practices of cost estimating and production control of ships.

138. Economics of Ship Design and Operation. *Prerequisite: Nav. Arch. 132.* 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.

141. Marine Propulsion Machinery. *Prerequisite: Mech. Eng. 105 and preceded or accompanied by Eng. Mech. 4.* I. (*3*).

Principles of construction and operation of main propulsion machinery and auxiliary plant.

142. Design of Marine Steam Generators. *Prerequisite: Nav. Arch. 146.* I and II. (*3*).

Heat transfer calculations. Design and layout drawings are prepared for a marine and steam generator.

143. Design of Marine Propulsion Machinery. *Prerequisite: Nav. Arch. 146 or permission of instructor.* I and II. *(3).*

Design calculations and principal drawings are prepared for either a steam or oil engine suitable for propelling a vessel.

144. Design of Marine Power Plants II. *Prerequisite: Nav. Arch. 146.* I and II. *(3).*

Design calculations to establish the heat balance of an approved machinery installation. A preliminary machinery arrangement and piping diagrams are prepared.

145. Advanced Reading and Seminar in Marine Engineering. I and II. *(To be arranged).*

146. Design of Marine Power Plants I. *Prerequisite: Nav. Arch. 147.* I and II. *(2).*

Calculations on performance and preliminary design of main and auxiliary machinery.

147. Marine Auxiliary Machinery. *Prerequisite: Nav. Arch. 141 and preceded or accompanied by Elec. Eng. 5.* II. *(3).*

Piping systems; electrical distribution; engine room auxiliaries; deck machinery; steering gear; and emergency apparatus.

151. Resistance, Power, Propellers. *Prerequisite: Nav. Arch. 12 and Eng. Mech. 4.* 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 model resistance and propulsion experiments carried out in the towing tank and the ship powering predictions and calculations. Four recitations and one three hour laboratory.

152. Advanced Ship Model Testing. *Prerequisite: Nav. Arch. 151.* I and II. *(2 to 3).*

Special problems and ship model testing will be investigated varying with the student's interest.

153. Research in Ship Hydrodynamics. *Prerequisite: Nav. Arch. 152.* I and II. *(To be arranged).*

154. Advanced Reading and Seminar in Naval Architecture. I and II. *(To be arranged).*

156. Thesis Research. *Prerequisite: Nav. Arch. 132 or design course in Option 2 and Nav. Arch. 151.* I and II. *(3).*

Research and experimental work necessary in connection with thesis required for the degree of Master of Science in Engineering.

NUCLEAR ENGINEERING

190. Elements of Nuclear Engineering. *Open to senior and graduate students, or others with permission of instructor.* I and II. *(3).*

An introductory survey of nuclear engineering for those in field other than nuclear engineering. Elementary nuclear physics, neutron mechanics, the nuclear reactor, radiation shielding, instrumentation and control, chemical separation and processing, and nuclear power plant systems are the principal topics surveyed.

191. Introduction to Nuclear Engineering. *Prerequisite: senior and graduate standing, Math. 103 or equivalent.* I and II. *(3).*

Intended to give the student a broad background in the aspects of modern physics prerequisite to an understanding of the production of nuclear energy. Review of vector analysis, classical mechanics, particularly scattering laws, electromagnetic theory; molecular structure, kinetic theory of matter; electromagnetic radiation and the quantum theory; specific heat, special theory of relativity, atomic structure and spectra, Bohr-Sommerfeld quantization rules. and the Schroedinger equation; nuclear structure and stability, radioactivity, nuclear reaction; particle accelerators, neutron cross sections, and fission.

192. Measurement in Nuclear Engineering. *Prerequisite: preceded or accompanied by Nuclear Eng. 191.* I and II. (*2*).

Practice in the application of radiation-matter interaction to problems in measurement and instrumentation. Study of ionization chambers, proportional and Geiger-Mueller counter systems, scintillation counters and related circuitry. Instruments are used to study fundamental nuclear phenomena and the characteristic properties of alpha, beta, gamma, and neutron radiation. Lecture and laboratory.

193. Handling of Radioactive Materials. *Nuclear Eng. 191, 192, 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.

194. Application of Analog Computer in Nuclear Engineering. *Prerequisite: preceded or accompanied by Nuclear Eng. 295.* I and II. (*2*).

Basic theory and principles of operation of the electronic analog computer. Practice in the operation of the computer. Solution of linear and non-linear problems in nuclear engineering such as fission product buildup and decay, nuclear reactor kinetics and control. Solution of systems of linear and non-linear partial differential equations by harmonic analysis and difference techniques. Lecture and laboratory.

291. Interaction of Radiation and Matter. *Prerequisite: Nuclear Eng. 191 or permission of instructor.* I and II. (*3*).

Review of nuclear structure and the nature of radioactivity. Analysis of the major processes by which radiation interacts with matter; photoelectric process, Thomson scatter, Compton scatter, pair production, bremmstrahlung, Cerenkov radiation, Wigner effect. Both mechanism and cross section are studied. The application of these processes to produce radiation effects, to actuate instruments, and also in the design of shielding is considered.

292. Nuclear Reactor Instrumentation and Control. *Prerequisite: Nuclear Eng. 191 and 192.* (*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.

293. Radiation Shielding. *Prerequisite: Nuclear Eng. 191, 192, and 291.* (*3*).

A macroscopic study of the absorption of nuclear radiations 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.

294. Wave Mechanics in Nuclear Engineering. *Prerequisite: Nuclear Eng. 191.* I and II. *(3).*
Formulation of wave description of matter through the Schroedinger wave equation. Application to box problem and hydrogen-like atom. Energy level transition probabilities. Finite thickness potential barriers and transmission problems—alpha decay model. Particle and particle-wave interactions.

295. Theory of Nuclear Reactors. *Prerequisite: Nuclear Eng. 191 and Math. 150.* I and II. *(3).*
Development of a neutron balance equation and its application in an investigation of the problems of criticality and controllability of homogeneous nuclear reactors.

297. Nuclear Power Plant Engineering. *Prerequisite: Nuclear Eng. 295 (3).*
Application of reactor core theory, reactor control, shielding, fluid flow, heat transfer, thermodynamics, stress and strain and economic parameters to integrated nuclear powerplant designs. Examination of significant nuclear powerplant concepts and applications.

298. Nuclear Reactor Laboratory. *Prerequisite: Nuclear Eng. 295* I and II. *(3).*
Characteristics and operation of a nuclear reactor and the use of a reactor as a radiation source, using the one megawatt Ford Nuclear Reactor in the Phoenix Memorial Laboratory. Reactor start-up and operation, control rod calibration, temperature coefficient of reactivity, flux distribution within the reactor. Neutron and gamma-ray shielding, fission, absorption, and scattering cross sections for thermal neutrons, activation analysis, neutron damage of materials, neutron slowing down and diffusion. Lectures and laboratory session.

299. Directed Research in Nuclear Engineering. I and II. *(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 semester by mutual agreement between the student and the 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.

394. Radiation Effects in Solids. *Prerequisite: Nuclear Eng. 291, 294, or equivalent. (3).*
Theory of atomic displacements; ionization effects in solids, nature and proper ties of crystal defects, radiation research tools, radiation effects in metals and alloys, semi-conductors, dielectrics and ceramics, magnetic materials, and polymers.

395. Advanced Reactor Theory. *Prerequisite:Nuclear Eng. 295 and Math. 152. (3).*
General formulation of the transport problem with application to refinements of calculation techniques for studying neutron and gamma-ray distributions. Perturbation theory with applications to both steady state and time varying systems. Thermal problems such as thermalization of neutrons, the calculation of thermal parameters, estimates of the Doppler effect on resonances, and related problems. Neutron age theory, specialized formulations of the Boltzmann equations and their use in the study of fast reactor systems. The theory of multi-group calculations, the activation of probes.

396. Thermonuclear Theory I. *Prerequisite: Nuclear Eng. 295, Elec. Eng. 210, Math. 152 or equivalent. (3).*
Fundamentals of the physics of fusion and of ionized gases. Basic problems in connection with the use of the fusion process as a practical source of energy. Nuclear reactions of charged particles are discussed. The basic equations describing the collective behavior of charged particles are formulated. Some general physical implications of these equations are examined. Special problems such as pinch criteria, pinch stability, and wave propagation in plasmas are investigated in detail.

397. Thermonuclear Theory II. *Prerequisite: Nuclear Eng. 396.* (*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, stability, plasma oscillations, diffusion.

398. Advanced Nuclear Power Plant Engineering. *Nuclear Eng. 297.* (*3*).
Detailed analytical investigation and experimental demonstration of specific problems involving the interrelations between nucleonics, heat transfer, thermodynamics, stress and strain parameters, and fluid flow theory which occur in the design of nuclear powerplants.

399. Special Topics in Neutron and Reactor Theory. *Permission of instructor.* (*2*).
Selected advanced topics in the physics of nuclear reactors. Specific subject matter will change from semester to semester, but will include such topics as reactor core design, neutron-induced nuclear reactions, neutron optics, and others.

PHYSICS*

Professor Dennison; Professors Case, Crane, Glaser, Hazen, Katz, Laporte, McCormick, Parkinson, Sawyer, Uhlenbeck, Wiedenbeck, Wolfe; Associate Professors Franken, Hough, Krimm, Peters, Trilling; Assistant Professors Chagnon, Coffin, Ford, Goldberg, Hecht, Jones, Lewis, Meecham, Meyer, Perl, Sands, Sherman, Sinclair, Terwilliger; Instructors Roe, Vander Velde.

45. Mechanics, Sound, and Heat. *Prerequisite: preceded by Math. 33; or accompanied by Math. 53.* I and II. (*5*).
Two lectures, three recitations, and one two-hour laboratory.

46. Electricity and Light. *Prerequisite: Physics 45.* I and II. (*5*).
Two lectures, three recitations, and one two-hour laboratory.

53. Elementary Mechanics. *Prerequisite: preceded or accompanied by Math. 33 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.

54. Electricity, Light, and Modern Physics. *Prerequisite: Physics 53 and preceded or accompanied by Math. 54 or equivalent.* II. (*4*).
Electricity and magnetism, physical optics, atomic and nuclear structure. One lecture, three recitations, and one laboratory.

103. Introduction to the Use of Radioactive Isotopes. *Prerequisite: Physics 26 or 46.* II. (*2*).
Sources, properties, and methods of measuring radiations; determination of safe dosage; tracer techniques and their applications.

105. Modern Physics. *Prerequisite: Physics 26 or 46.* 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.

* College of Literature, Science, and the Arts

147. Electrical Measurements. *Prerequisite: Physics 26 or 46, and Math. 54.* I and II. (*4*).
Direct, alternating, and transient currents; measurements of inductance, capacitance, and losses due to hysteresis. Two lectures and one afternoon of laboratory.

150. Honors Course for Juniors. *Prerequisite: permission.* I and II. (*1*).
Original work under direction of individual staff members.

165. Electron Tubes. *Prerequisite: Physics 180 and Math. 103.* 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.

166. Electronic Circuits. *Prerequisite: Physics 165.* 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.

171. Intermediate Mechanics. *Prerequisite: Physics 26 or 46 and Math. 56 or equivalent.* I and II. (*3*).
Study of the motion of particles and rigid bodies using Newtonian force methods. Such topics as harmonic oscillators, coupled oscillators, and planetary motion will be considered.

172. Mechanics of Fluids. *Prerequisite: Physics 171.* 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 hydramagnetics.

173. Introduction to Physics of the Solid State. *Prerequisite: Physics 196 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.

177. Applications of Physical Measurements to Biology. *Prerequisite: Physics 26 and eight hours of biological science.* I. (*3*).
A review of physical instruments and techniques which are applicable to the study of biological materials.

178. Introduction to Physics of Macromolecules. *Prerequisite: Math. 54 and Physics 186, or permission of instructor.* II. (*3*).
Physical principles underlying the behavior and characterization of macromolecular systems, with emphasis on applications to biological processes.

180. Intermediate Electricity and Magnetism. *Prerequisite: Physics 26 or 46 and Math. 56 or equivalent.* II. (*3*).
The laws and principles of electrostatics, moving electric charges, and electromagnetism; alternating current circuit theory, including transients.

181. Heat and Thermodynamics. *Prerequisite: Physics 26 or 46 and Math. 103.* II. (*3*).
Thermal expansion, specific heats, changes of state, and van der Waals' equation; elementary kinetic theory and the absolute scale of temperature.

183. Heat Laboratory. *Prerequisite: to follow or accompany Physics 181.* II. (*2*).
Use of modern methods and instruments for the measurement of thermal quantities.

185. Introduction to Infrared Spectra. *Prerequisite: Physics 26 or 46 and Math. 54.* I. (*2*).
The elements of infrared spectroscopy and the basic principles involved in the interpretation of Raman and infrared data in terms of molecular structure.

186. Light. *Prerequisite: Physics 26 or 46 and Math. 56 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.

188. Light Laboratory. *Prerequisite: to accompany or follow Physics 186.* I. (*2*).
Experiments in interference, diffraction, and polarization, with use of photography and optical instruments.

190. Honors Course for Seniors. *Prerequisite: permission.* I and II. (*1*).
Original work under direction of individual staff members.

191, 192. Introduction to Theoretical Physics. *Prerequisite: Physics 171 and Math. 150 or 154.* 191, I; 192, 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.

193, 194. Applied Spectroscopy. *Prerequisite: Physics 196.* 193, I; 194, II. (*4 each*).
Equipment and methods for spectrochemical analysis, with laboratory practice. Lecture and laboratory.

196. Atomic and Molecular Structure. *Prerequisite: Physics 26, Chem. 4, Math. 103, and five hours of intermediate physics or physical chemistry.* I and II. (*3*).
A critical discussion of developments in atomic and molecular structure based upon fundamental experiments and interpreted in part in terms of Schroedinger's equation.

197. Nuclear Physics. *Prerequisite: Physics 196.* II. (*3*).
Properties and systematics of nuclei; nuclear forces and nuclear models; understood from an experimentalist's point of view.

198. Introduction to Quantum Theory. *Prerequisite: Physics 171 and 196.* II. (*3*).
An introduction to the concepts of quantum theory. Development of Schroedinger's wave mechanics and Heisenberg's matrix mechanics with appplications to simple systems.

199. Laboratory in Nuclear Physics. *Prerequisite: to accompany or follow Physics 197.* II. (*2*).
Equipment is available for a large variety of measurements on the characteristics of different nuclear transformations.

205, 206. Electricity and Magnetism. *Prerequisite: Physics 180 and Math. 150 or 154.* 205, I; 206, II. (*3 each*).
Electromagnetic theory; Maxwell's equations and the radiation from a Hertzian oscillator; connections with the special relativity theory.

207, 208. Theoretical Mechanics. *Prerequisite: an adequate knowledge of differential equations; Physics 207 is a prerequisite for Physics 208; an introductory course in mechanics is desirable.* 207, I; 208, II. (*3 each*).
Lagrange equations of motion; the principle of least action, Hamilton's principle, the Hamilton-Jacobi equation; Poisson brackets.

209. Thermodynamics. *Prerequisite: Physics 181.* II. (*3*).
The two laws and their foundation; gas equilibria and dilute solutions; phase rule of Gibbs; theory of binary mixtures.

210. Kinetic Theory of Matter. *Prerequisite: Physics 209.* 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.

211, 212. Quantum Theory. *Prerequisite: Physics 196. Physics 211 is a prerequisite for Physics 212.* 211, I; 212, II. (*3 each*).

Wave mechanics, matrix mechanics, and methods of quantizations, with applications.

215. 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.

218. Physics of Continuous Media. II. (*3*).
219. Physics of the Solid State. I. (*3*).
224. Cosmic Radiation. II. (*3*).
225. Theory of Neutron Diffusion. I. (*3*).
226. High Energy Nuclear Physics. II. (*3*).
231. Advanced Electromagnetic Theory with Application to Modern Diffraction Problems. I. (*2*).
233. Special Problems in Fluid Dynamics. I. (*3*).
234. Random Processes in Physical Theory and Computation. II. (*3*).
238. Nuclear Theory. II. (*3*).
241. Magnetic Resonance. I. (*2 or 3*).
242. Advanced Atomic Physics. II. (*2 or 3*).
256. Molecular Spectra and Molecular Structure. II. (*3*).
306, 307. Seminar. Topic to be announced each semester. I and II. (*2* or *3*).
309, 310. Advanced Nuclear Physics Seminar. I and II. (*2 or 3*).
311, 312. Eperimental Seminar. I and II. (*2 or 3*).
313, 314. Advanced Theoretical Physics Seminar. I and II. (*2 or 3*).
315, 316. High Energy Physics Seminar. I and II. (*2 or 3*).

SCIENCE ENGINEERING

Certain courses have been and are being developed through the interdepartmental co-operation specifically for the Science Engineering degree program. 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.

110. Thermodynamics. *Prerequisite: Math. 55 and Chem. 14.* (*4*).

Introduction to thermodynamics.

112. Rate Processes. *Prerequisite: Sci. Eng. 110 and Math. 56.* (*4*).

A unified study of heat, mass, momentum transfer, and chemical kinetics, with emphasis upon identification of rate processes, measurement, correlation, and the application of rate data and theories to process design.

Committees and Faculty*

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ex officio

M. J. Sinnott, term, 1956–60
L. N. Holland, term, 1959–61
L. M. Legatski, term, 1958–62
A. Marin, term, 1959–63

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*Listed for the academic year, 1959-60.

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JAMES A. NICHOLLS, M.S., *Lecturer in Aeronautical Engineering and Research Engineer, University of Michigan Research Institute*

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LARS THOMASSEN, Ph.D., *Professor of Chemical and Metallurgical Engineering*
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JOSEPH J. MARTIN, D.Sc., *Professor of Chemical and Metallurgical Engineering*
GEORGE BRYMER WILLIAMS, Ph.D., *Professor of Chemical and Metallurgical Engineering*
STUART WINSTON CHURCHILL, Ph.D., *Professor of Chemical Engineering*
JESSE LOUIS YORK, Ph.D., *Professor of Chemical and Metallurgical Engineering*
LAWRENCE H. VAN VLACK, Ph.D., *Professor of Materials Engineering, Department of Chemical and Metallurgical Engineering*
LLOYD L. KEMPE, Ph.D., *Professor of Chemical Engineering and Professor of Bacteriology, Medical School*
EDWIN HAROLD YOUNG, M.S.E., *Professor of Chemical and Metallurgical Engineering*
JOHN CROWE BRIER, M.S., *Professor Emeritus of Chemical Engineering*
LEO LEHR CARRICK, Ph.D., *Professor Emertius of Chemical Engineering*

DONALD WILLIAM MCCREADY, Ph.D., *Associate Professor of Chemical Engineering*
RICHARD EMORY TOWNSEND, M.S.E., Ch.E., *Associate Professor of Chemical and Metallurgical Engineering*
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DAVID VINCENT RAGONE, Sc.D., *Associate Professor of Metallurgical Engineering*
EDWARD ERNEST HUCKE, Sc.D., *Associate Professor of Metallurgical Engineering*
GUISEPPE PARRAVANO, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*
KENNETH FRASER GORDON, Sc.D., *Associate Professor of Chemical Engineering*
WILBUR CHARLES BIGELOW, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*
WILLIAM ALLEN SPINDLER, M.S., *Assistant Professor of Metallurgical Engineering*
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PAUL KARL TROJAN, M.S.E., *Instructor in Metallurgical Engineering*
RICHARD EARL BALZHISER, M.S.E., *Instructor in Chemical Engineering and in Nuclear Engineering*
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JAMES ARTHUR FORD, M.S.E., *Instructor in Chemical and Metallurgical Engineering*
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ROBERT L. NORMAN, M.S.E., *Instructor in Chemical and Metallurgical Engineering*
JOHN GRENNAN, *Instructor Emeritus in Foundry Practice*

CIVIL ENGINEERING

EARNEST BOYCE, M.S., C.E., *Professor of Municipal and Sanitary Engineering and Chairman of the Department of Civil Engineering, and Professor of Public Health Engineering, School of Public Health*
WALTER CLIFFORD SADLER,* M.S., C.E., LL.B., *Professor of Civil Engineering*
LAWRENCE CARNAHAN MAUGH, Ph.D., *Professor of Civil Engineering*

*Deceased October 14, 1959

WILLIAM STUART HOUSEL, M.S.E., *Professor of Civil Engineering*
BRUCE GILBERT JOHNSTON, Ph.D., *Professor of Structural Engineering*
ERNEST FREDERICK BRATER, Ph.D., *Professor of Hydraulic Engineering*
WALTER JOHNSON EMMONS, A.M., *Professor of Highway Engineering and Associate Dean and Secretary of the College of Engineering.* On retirement furlough, 1959-60.
VICTOR LYLE STREETER, Sc.D., *Professor of Hydraulics*
EDGAR WENDELL HEWSON, Ph.D., *Professor of Meteorology*
JOHN CLAYTON KOHL, B.S.E., (C.E.), *Professor of Civil Engineering and Director of the Transportation Institute*
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HAROLD JOSEPH WELCH, B.S. (C.E.), *Instructor in Civil Engineering*
FRANK ROLLAND BELLAIRE, M.S., *Lecturer in Meteorology and Associate Research Meteorologist, University of Michigan Research Institute*

DONALD JAMES PORTMAN, Ph.D., *Lecturer in Meteorology and Associate Research Meteorologist, University of Michigan Research Institute*
DAVID LLOYDE JONES, M.S., *Lecturer in Meteorology and Associate Research Meteorologist, University of Michigan Research Institute*
FLOYD CHALMERS ELDER, M.S., *Lecturer in Meteorology and Associate Research Meteorologist, University of Michigan Research Institute*
EDWARD S. EPSTEIN, Ph.D., *Lecturer in Meteorology and Research Associate, University of Michigan Research Institute*
BRUCE DOUGLAS GREENSHIELDS, Ph.D., *Lecturer in Transportation Engineering and in Engineering Mechanics, and Assistant Director of the Transportation Institute*
CLINTON LOUIS HEIMBACH, M.S.C.D., *Lecturer in Civil Engineering*

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MELVILLE BIGHAM STOUT, M.S., *Professor of Electrical Engineering*
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HARRY H. GOODE, M.A., *Professor of Electrical Engineering*
ALAN BRECK MACNEE, Sc.D., *Professor of Electrical Engineering*
HEMPSTEAD STRATTON BULL, M.S., *Professor of Electrical Engineering*
JOHN JOSEPH CAREY, M.S. (E.E.), *Professor of Electrical Engineering*
NORMAN ROSS SCOTT, Ph.D., *Professor of Electrical Engineering*
LOUIS JOHN CUTRONA, Ph.D., *Professor of Electrical Engineering*. On leave, 1959–60.
JAMES CARLISLE MOUZON, Ph.D., *Professor of Electrical Engineering, and Associate Dean of the College of Engineering*
RAYMOND FRED MOSHER, S.M., *Professor of Electrical Engineering*
KEEVE MILTON SIEGEL, M.S., *Professor of Electrical Engineering*
WILLIAM KERR, Ph.D., *Professor of Nuclear Engineering and of Electrical Engineering and Associate Director, Michigan Memorial—Phoenix Project*
GORDON E. PETERSON, Ph.D., *Professor of Electrical Engineering, Professor of Speech in the College of Literature, Science, and the Arts, and Director of the Speech Research Laboratory*
JOSEPH AUBREY BOYD, Ph.D., *Professor of Electrical Engineering and Director of the Willow Run Laboratories*
NELSON WARNER SPENCER, M.S.E. (E.E.), *Professor of Electrical Engineering*
FRED T. HADDOCK, M.S., *Professor of Electrical Engineering, and Professor of Astronomy, College of Literature, Science, and the Arts.* Absent on leave, 1959–60.

RICHARD KEMP BROWN, Ph.D., *Professor of Electrical Engineering*
JOHN A.M. LYON, Ph.D., *Professor of Electrical Engineering*
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CHIAO-MIN CHU, Ph.D., *Associate Professor of Electrical Engineering*
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FRANK RICHARD FINCH, Ph.B., *Professor Emeritus of Engineering Drawing*
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MARTIN J. ORBECK, C.E., M.S.E., *Professor Emeritus of Engineering Drawing*
DEAN ESTES HOBART, B.S., *Professor Emeritus of Engineering Drawing*
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MAURICE BARKLEY EICHELBERGER, B.S., *Associate Professor of Engineering Graphics*
ROBERT HORACE HOISINGTON, M.S., *Associate Professor of Engineering Graphics and Assistant to the Dean, College of Engineering*
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THOMAS JOHN BLACK, M.S., *Instructor in Engineering Graphics*
JAMES ROBERT CAIRNS, M.S.E., *Instructor in Engineering Graphics*
PHILIP EDWARD WEBB, M.S.E., *Instructor in Engineering Graphics*

*Retired January 1960

ENGINEERING MECHANICS

RUSSELL ALGER DODGE, M.S.E., *Professor of Engineering Mechanics and Chairman of the Department of Engineering Mechanics*
JESSE ORMONDROYD, A.B., *Professor of Engineering Mechanics*
RICHARD THOMAS LIDDICOAT, Ph.D., *Professor of Engineering Mechanics*
ROBERT LAWRENCE HESS, Ph.D., *Professor of Engineering Mechanics and Assistant Director, Willow Run Laboratories*
ERNEST FRANK MASUR, Ph.D., *Professor of Engineering Mechanics*
CHIA-SHUN YIH, Ph.D., *Professor of Engineering Mechanics*
SAMUEL KELLY CLARK, Ph.D., *Professor of Engineering Mechanics*
ROBERT MORPHET HAYTHORNTHWAITE, Ph.D., *Professor of Engineering Science*
EDWARD LEERDRUP ERIKSEN, B.C.E., *Professor Emeritus of Engineering Mechanics*
FERDINAND NORTHRUP MENEFEE, C.E., D.Eng., *Professor Emeritus of Engineering Mechanics*
HOLGER MADS HANSEN, B.C.E., *Professor Emeritus of Engineering Mechanics*
CHARLES THOMAS OLMSTED, B.S. (C.E.), *Professor Emeritus of Engineering Mechanics*
FRANKLIN L. EVERETT, Ph.D., *Associate Professor of Engineering Mechanics*
JOHN HERMANN ENNS, Ph.D., *Associate Professor of Engineering Mechanics*
EDWARD AXEL YATES, M.S.E., *Associate Professor of Engineering Mechanics*
HADLEY JAMES SMITH, Ph.D., *Associate Professor of Engineering Mechanics*
RAYMOND A. YAGLE, M.S.E., *Assistant Professor of Engineering Mechanics*
TERRY B. KHAMMASH, Ph.D., *Assistant Professor of Engineering Mechanics and of Nuclear Engineering*
WALTER RALPH DEBLER, Ph.D., *Assistant Professor of Engineering Mechanics*
WILLIAM PAUL GRAEBEL, Ph.D., *Assistant Professor of Engineering Mechanics*
MOVSES JEREMY KALDJIAN, Ph.D., *Assistant Professor of Engineering Mechanics*
BERTRAM HERZOG, M.S., *Instructor in Engineering Mechanics*
JOSEPH E. MATAR, M.S., *Instructor in Engineering Mechanics*
LOUIS WILLIAM WOLF, M.S.E., *Instructor in Engineering Mechanics*
WILLIAM WALTER O'DELL, JR., M.S.E., *Instructor in Engineering Mechanics*
DAVID RICHARD JENKINS, M.S. (Eng.Mech.), *Instructor in Engineering Mechanics*
GEORGE HAZEN STICKNEY, M.B.A., M.S.E., *Instructor in Engineering Mechanics*
BRUCE DOUGLAS GREENSHIELDS, Ph.D., *Lecturer in Engineering Mechanics, Lecturer in Transportation Engineering, Department of Civil Engineering, and Assistant Director of the Transportation Institute*

ENGLISH

CARL GUNARD BRANDT, LL.M., *Professor of English and Chairman of the Department of English in the College of Engineering, and Lecturer in Speech in the College of Literature, Science, and the Arts*

CARL EDWIN BURKLUND, Ph.D., *Professor of English, College of Engineering*

IVAN HENRY WALTON, A.M., *Professor of English, College of Engineering*

WEBSTER EARL BRITTON, Ph.D., *Professor of English, College of Engineering*

GEORGE MIDDLETON MCEWEN, Ph.D., *Professor of English, College of Engineering*

WILFRED MINNICH SENSEMAN, Ph.D., *Professor of English, College of Engineering*

JOSHUA MCCLENNEN, Ph.D., *Professor of English, College of Engineering*

JOSEPH RALEIGH NELSON, A.M., *Professor Emeritus of English, Counselor Emeritus to Foreign Students, and Director Emeritus of the International Center*

JESSE EARL THORNTON, A.M., *Professor Emeritus of English, College of Engineering*

WILLIAM HENRY EGLY, A.M., *Associate Professor of English, College of Engineering.* On retirement furlough, 1959-60.

THOMAS MITCHELL SAWYER, JR., Ph.D., *Associate Professor of English, College of Engineering*

ROBERT PERCY WEEKS, Ph.D., *Associate Professor of English, College of Engineering*

DONALD ARTHUR RINGE, Ph.D., *Associate Professor of English, College of Engineering*

STEPHEN SADLER STANTON, Ph.D., *Associate Professor of English, College of Engineering*

ROBERT D. BRACKETT, A.M., *Associate Professor Emeritus of English, College of Engineering*

WILLIAM BYRON DICKENS, Ph.D., *Assistant Professor of English, College of Engineering*

CHESTER FISHER CHAPIN, Ph.D., *Assistant Professor of English, College of Engineering*

RALPH ANDREW LOOMIS, Ph.D., *Assistant Professor of English, College of Engineering*

EDWARD MERL SHAFTER, JR., Ph.D., *Assistant Professor of English, College of Engineering*

NIEL KLENDENON SNORTUM, Ph.D., *Assistant Professor of English, College of Engineering*

WARNE CONWELL HOLCOMBE, Ph.D., *Assistant Professor of English, College of Engineering*

RICHARD JOHN ROSS, Ph.D., *Assistant Professor of English, College of Engineering*

EDMUND PENDLETON DANDRIDGE, JR., Ph.D., *Assistant Professor English, College of Engineering*

W. Harry Mack, A.M., *Assistant Professor Emeritus of English, College of Engineering*
Thomas C. Edwards, A.M., *Instructor in English, College of Engineering*
Arthur Willard Forbes, A.M., *Instructor in English, College of Engineering*
Roger Milliken Jones, M.A., *Instructor in English, College of Engineering*
Peter Roberts Klaver, M.A., *Instructor in English, College of Engineering*
Richard Emerson Young, M.A., *Instructor in English, College of Engineering*
Dwight Ward Stevenson, M.A., *Instructor in English, College of Engineering*
William Victor Holtz, M.A., *Instructor in English, College of Engineering*
Donald Aloys Herman, M.A., *Lecturer in English, College of Engineering*

INDUSTRIAL ENGINEERING

Wyeth Allen, B.M.E., D.Eng., *Professor of Industrial Engineering and Chairman of the Department of Industrial Engineering*
Merrill Meeks Flood, Ph.D., *Professor of Industrial Engineering and Senior Research Mathematician, Mental Health Research Institute*
Robert McDowell Thrall, Ph.D., *Professor of Operations Analysis, Department of Industrial Engineering, Professor of Mathematics, College of Literature, Science, and the Arts and Research Mathematician, Willow Run Laboratories*
Frederick Lee Black, A.B., *Professor of Industrial Engineering, Assistant Director, College of Engineering Industry Program, and Director of Business Relations, School of Business Administration*
James Arnold Gage, M.S. (M.E.), *Professor of Industrial Engineering.* On leave, 1959–60.
Charles Burton Gordy, Ph.D., *Professor Emeritus of Industrial Engineering*
Quentin C. Vines, B.S.E. (E.E.), M.E., *Associate Professor of Industrial Engineering*
Wilbert Steffy, B.S.E. (Ind.-Mech.), B.S.E. (M.E.), *Associate Professor of Industrial Engineering*
Fritz B. Harris, M.S. (Auto.E.), Ph.D., *Associate Professor of Industrial Engineering.* On leave, 1959–60.
Edward Lupton Page, M.S.E. (I.E.), *Associate Professor of Industrial Engineering*
Richard Watson Berkeley, B.S.E. (M.&I.E.), *Assistant Professor of Industrial Engineering*
Clyde Wimouth Johnson, AB., *Assistant Professor of Industrial Engineering*
Richard Christian Wilson, M.S., *Instructor in Industrial Engineering*

Richard Virdin Evans, D.Eng., *Instructor in Industrial Engineering and Lecturer in Mathematics, College of Literature, Science, and the Arts*
Dean H. Wilson, B.S.E. (E.E.), *Lecturer in Industrial Engineering and Research Engineer, Willow Run Laboratories*
Roger Ryan Crane, S.M., *Lecturer in Industrial Engineering*
Herbert Wycoff Hadcock, M.B.A., *Lecturer in Industrial Engineering*
Edward Morris Lewis, Ph.D., *Lecturer in Industrial Engineering and Research Engineer, Willow Run Laboratories*
Edward Richard Allan, Jr., M.S. (I.E.), *Lecturer in Industrial Engineering*
Walton Milton Hancock, Ph.D., *Lecturer in Industrial Engineering, and Associate Research Engineer, Willow Run Laboratories*
Joseph Elbert Hoagbin, M.S., *Professor-Consultant in Industrial Engineering and Professor-Consultant, ICA Waseda University Program*

MECHANICAL ENGINEERING

Gordon John Van Wylen, Sc.D., *Professor of Mechanical Engineering and Chairman of the Department of Mechanical Engineering*
Edward Thomas Vincent, B.Sc., *Professor of Mechanical Engineering*
Axel Marin, B.S.E. (M.E.), *Professor of Mechanical Engineering*
Richmond Clay Porter, M.E., M.S., *Professor of Mechanical Engineering*
Frank Leroy Schwartz, M.E., Ph.D., *Professor of Mechanical Engineering*
Lester Vern Colwell, M.S., *Professor of Mechanical Engineering*
Floyd Newton Calhoon, M.S., *Professor of Mechanical Engineering*
Jay Arthur Bolt, M.S., M.E., *Professor of Mechanical Engineering*
Joseph Edward Shigley, M.S.E., *Professor of Mechanical Engineering*
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, Willow Run Laboratories*
Charles Lipson, Ph.D., *Professor of Mechanical Engineering*
William Horace Graves, B.S.E. (Ch.E.), *Professor of Automotive Engineering*
John Alden Clark, Sc.D., *Professor of Mechanical Engineering*
John Raymond Pearson, M.Sc.M.E., *Professor of Mechanical Engineering*
Keith Willis Hall, B.S.M.E., *Professor of Mechanical Engineering*
Ransom Smith Hawley, B.S. (E.E.), M.E., *Professor Emeritus of Mechanical Engineering*
Orlan William Boston, M.S.E., M.E., *Professor Emeritus of Mechanical Engineering and of Production Engineering*
Walter Edwin Lay, B.M.E., *Professor Emeritus of Mechanical Engineering*
Hugh Edward Keeler, M.S.E., M.E., *Professor Emeritus of Mechanical Engineering*
Arnet Berthold Epple, M.S., *Associate Professor of Mechanical Engineering*

JOSEPH REID AKERMAN, Ph.D., *Associate Professor of Mechanical Engineering*

HERBERT HERLE ALVORD, M.S.E., *Associate Professor of Mechanical Engineering*

JOSEPH D'ATSKO, M.S.E., *Associate Professor of Mechanical Engineering*

ARTHUR GENE HANSEN, Ph.D., *Associate Professor of Mechanical Engineering.*

WILLIAM MIRSKY, Ph.D., *Associate Professor of Mechanical Engineering*

FREDERICK GNICHTEL HAMMITT, Ph.D., *Associate Professor of Mechanical Engineering and of Nuclear Engineering*

ROBERT CHARLES JUVINALL, M.S.M.E., *Associate Professor of Mechanical Engineering*

CHIN TSE YANG, Ph.D., *Associate Professor of Mechanical Engineering*

HOWARD REX COLBY, M.S.E., *Associate Professor of Mechanical Engineering*

LESLIE E. WAGNER, M.A., *Assistant Professor of Mechanical Engineering*

FREDERICK JOHN VESPER, M.S.E., *Assistant Professor of Mechanical Engineering*

JOSEPH ANTHONY SWEENEY, JR., B.S.E. (M.E.), *Assistant Professor of Mechanical Engineering*

JOHN GRAHAM YOUNG, B.S.E. (M.E.), *Assistant Professor of Mechanical Engineering and Assistant to the Dean of the College of Engineering*

LELAND JAMES QUACKENBUSH, M.S.E., *Assistant Professor of Mechanical Engineering*

JULIAN ROSS FREDERICK, Ph.D., *Assistant Professor of Mechanical Engineering*

FREDERICK KENT BOUTWELL, Ph.D., *Assistant Professor of Mechanical Engineering*

VEDAT S. ARPACI, Sc.D., *Assistant Professor of Mechanical Engineering*

JOSEPH CASMERE MAZUR, M.S.E., *Assistant Professor of Mechanical Engineering*

HARRY JAMES WATSON, B.M.E., *Assistant Professor Emeritus of Mechanical Engineering*

KENNETH C. LUDEMA, M.S.E., *Instructor in Mechanical Engineering*

FRANKLIN HERBERT WESTERVELT, M.S. (M.E.), *Instructor in Mechanical Engineering*

RICHARD EDWIN SONNTAG, M.S.E., *Instructor in Mechanical Engineering*

HERMAN MERTE, JR., M.S.E., *Instructor in Mechanical Engineering*

ROBERT MACORMAC CADDELL, M.S.E., *Lecturer in Mechanical Engineering*

WILLIAM TELFER, *Instructor Emeritus in the Working, Treating and Welding of Steel*

NAVAL ARCHITECTURE AND MARINE ENGINEERING

RICHARD BAILEY COUCH, Ae.E., *Professor of Naval Architecture and Marine Engineering and Chairman of the Department of Naval Architecture and Marine Engineering*
HENRY CARTER ADAMS 2d, M.S., *Professor of Naval Architecture and Marine Engineering*
HARRY BELL BENFORD, B.S.E. (Nav. Arch. and Mar.E.), *Professor of Naval Architecture and Marine Engineering.* On leave, 1959-60.
EDWARD MILTON BRAGG, S.B., *Professor Emeritus of Naval Architecture and Marine Engineering*
LOUIS A. BAIER, B. Mar. E., N.A., *Professor Emeritus of Naval Architecture and Marine Engineering*
GEORGE LAUMAN WEST, JR., B.S.E. (Nav. Arch. and Mar.E.), *Associate Professor of Naval Architecture and Marine Engineering and of Nuclear Engineering*
FINN CHRISTIAN MICHELSEN, M.S.E., *Instructor in Naval Architecture and Marine Engineering*
CHARLES LYMAN WRIGHT, JR., S.B., *Lecturer in Naval Architecture and Marine Engineering*

NUCLEAR ENGINEERING

HENRY JACOB GOMBERG, Ph.D., *Professor of Nuclear Engineering and Chairman of the Department of Nuclear Engineering, and Director, Michigan Memorial–Phoenix Project*
WILLIAM KERR, Ph.D., *Professor of Nuclear Engineering and of Electrical Engineering and Associate Director, Michigan Memorial–Phoenix Project*
LLOYD EARL BROWNELL, Ph.D., *Professor of Nuclear Engineering and of Chemical and Metallurgical Engineering*
RICHARD KENT OSBORN, Ph.D., *Professor of Nuclear Engineering*
CHIHIRO KIKUCHI, Ph.D., *Professor of Nuclear Engineering*
JOHN SWINTON KING, Ph.D., *Associate Professor of Nuclear Engineering*
FREDERICK GNICHTEL HAMMITT, Ph.D., *Associate Professor of Nuclear Engineering and Mechanical Engineering*
PAUL FREDERICK ZWEIFEL, Ph.D., *Associate Professor of Nuclear Engineering*
GEORGE LAUMAN WEST, JR., B.S.E., *Associate Professor of Nuclear Engineering and of Naval Architecture and Marine Engineering*
EDWARD ANTHONY MARTIN, Ph.D., *Assistant Professor of Nuclear Engineering and of Electrical Engineering*
TERRY B. KAMMASH, Ph.D., *Assistant Professor of Nuclear Engineering and of Engineering Mechanics*
CHARLES WILLIAM RICKER, M.S., *Lecturer in Nuclear Engineering and Laboratory Director, Phoenix Memorial Laboratory*
GEZA LESLIE GYOREY, M.S.E., *Lecturer in Nuclear Engineering*

Registration Schedules

Each of the following groups of students is allotted a definite period for admission to the gymnasiums for registration. Come exactly on time, neither early nor late.

You will enable yourself and others to enter on time if you complete all registration forms distinctly and according to directions on the forms—*before you enter the gymnasiums.* Elections should be approved as specified in the *Announcement* of your school or college.

FIRST SEMESTER, 1960-1961

WEDNESDAY SEPTEMBER 14, 1960

A.M.			P.M.		
8:00— 8:10	Patt	—Pea	1:00—1:10	Sa	—Sarg
8:10— 8:20	Peb	—Pere	1:10—1:20	Sarh	—Schl
8:20— 8:30	Perf	—Pete	1:20—1:30	Schm	—Schwartz, R.
8:30— 8:40	Petf	—Pick	1:30—1:40	Schwartz, S.	—Send
8:40— 8:50	Picl	—Pli	1:40—1:50	Sene	—Shel
8:50— 9:00	Plj	—Pop	1:50—2:00	Shem	—Siel
9:00— 9:10	Poq	—Pow	2:00—2:10	Siem	—Sk
9:10— 9:20	Pox	—Pri	2:10—2:20	Sl	—Smith, L.
9:20— 9:30	Prj	—Qur	2:20—2:30	Smith, M.	—Sol
9:30— 9:40	Qus	—Ram	2:30—2:40	Som	—Stah
9:40— 9:50	Ran	—Raz	2:40—2:50	Stai	—Steu
9:50—10:00	Rb	—Reid, S.	2:50—3:00	Stev	—Sto
10:00—10:10	Reid, T	—Rex	3:00—3:10	Stp	—Sup
10:10—10:20	Rey	—Richa	3:10—3:20	Suq	—Tas
10:20—10:30	Richb	—Ris	3:20—3:30	Tat	—Thomp
10:30—10:40	Rit	—Robertsn	3:30—3:40	Thomq	—Toml
10:40—10:50	Robertso	—Rod	3:40—3:50	Tomm	—Tup
10:50—11:00	Roe	—Rop	3:50—4:00	Tuq	—Vandeq
11:00—11:10	Roq	—Rosm	4:00—4:10	Vander	—Ver
11:10—11:20	Rosn	—Rot	4:10—4:20	Ves	—Walc
11:20—11:30	Rou	—Rz	4.20—4:30	Wald	—Wark

THURSDAY SEPTEMBER 15, 1960

A.M.			P.M.		
8:00— 8:10	Warl	—Webe	1:00—1:10	Brb	—Brown, F.
8:10— 8:20	Webf	—Wer	1:10—1:20	Brown, G.	—Buc
8:20— 8:30	Wes	—Wh	1:20—1:30	Bud	—Bur
8:30— 8:40	Wi	—Willi	1:30—1:40	Bus	—Cam
8:40— 8:50	Willj	—Wolc	1:40—1:50	Can	—Car
8:50— 9:00	Wold	—Wre	1:50—2:00	Cas	—Cha
9:00— 9:10	Wrf	—Yz	2:00—2:10	Chb	—Ci
9:10— 9:20	Za	—Zz	2:10—2:20	Cj	—Cohe
9:20— 9:30	Aa	—Alc	2:20—2:30	Cohf	—Con
9:30— 9:40	Ald	—Anderse	2:30—2:40	Coo	—Cou
9:40— 9:50	Andersf	—Ark	2:40—2:50	Cov	—Cro
9:50—10:00	Arl	—Bab	2:50—3:00	Crp	—Dam
10:00—10:10	Bac	—Baq	3:00—3:10	Dan	—Daz
10:10—10:20	Bar	—Bas	3:10—3:20	Db	—Deng
10:20—10:30	Bat	—Bec	3:20—3:30	Denh	—Din
10:30—10:40	Bed	—Benr	3:30—3:40	Dio	—Dou
10:40—10:50	Bens	—Bes	3:40—3:50	Dov	—Dup
10:50—11:00	Bet	—Blac	3:50—4:00	Duq	—Eg
11:00—11:10	Blad	—Boe	4:00—4:10	Eh	—En
11:10—11:20	Bof	—Bot	4:10—4:20	Eo	—Fan
11:20—11:30	Bou	—Bra	4:20—4:30	Fao	—Fil

FRIDAY SEPTEMBER 16, 1960

A.M.			P.M.		
8:00— 8:10	Fim	—Foc	1:00—1:10	Kan	—Kea
8:10— 8:20	Fod	—Fran	1:10—1:20	Keb	—Ker
8:20— 8:30	Frao	—Fz	1:20—1:30	Kes	—Kiq
8:30— 8:40	Ga	—Gau	1:30—1:40	Kir	—Kni
8:40— 8:50	Gav	—Gill	1:40—1:50	Knj	—Koth
8:50— 9:00	Gilm	—Goldl	1:50—2:00	Koti	—Krug
9:00— 9:10	Goldm	—Grah	2:00—2:10	Kruh	—Lami
9:10— 9:20	Grai	—Gri	2:10—2:20	Lamj	—Lawre
9:20— 9:30	Grj	—Had	2:20—2:30	Lawrf	—Lewi
9:30— 9:40	Hae	—Ham	2:30—2:40	Lewj	—Luca
9:40— 9:50	Han	—Harrisn	2:40—2:50	Lucb	—M(a)cGi
9:50—10:00	Harriso	—Hd	2:50—3:00	M(a)cGj	—Mall
10:00—10:10	Hea	—Henl	3:00—3:10	Malm	—Mat
10:10—10:20	Henm	—Hile	3:10—3:20	Mau	—Miller, E.
10:20—10:30	Hilf	—Holl	3:20—3:30	Miller, F.	—Moro
10:30—10:40	Holm	—How	3:30—3:40	Morp	—Nax
10:40—10:50	Hox	—Hur	3:40—4:00	Nay	—Nz
10:50—11:00	Hus	—Jack	4:00—4:10	Oa	—Pak
11:00—11:10	Jacl	—Jog	4:10—4:20	Pal	—Pats
11:10—11:20	Joh	—Jones, J.			
11:20—11:30	Jones, K.	—Kam			

SATURDAY SEPTEMBER 17, 1960

Any student may register from 9:00 to 11:30 A.M. Saturday registration is inadvisable, however, as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

SECOND SEMESTER, 1960-1961

WEDNESDAY FEBRUARY 8, 1961

A.M.			P.M.		
8:00— 8:10	Sa	—Sarg	1:00—1:10	Warl	—Webe
8:10— 8:20	Sarh	—Schl	1:10—1:20	Webf	—Wer
8:20— 8:30	Schm	—Schwartz, R.	1:20—1:30	Wes	—Wh
8:30— 8:40	Schwartz, S.	—Send	1:30—1:40	Wi	—Willi
8:40— 8:50	Sene	—Shel	1:40—1:50	Willj	—Wolc
8:50— 9:00	Shem	—Siel	1:50—2:00	Wold	—Wre
9:00— 9:10	Siem	—Sk	2:00—2:10	Wrf	—Yz
9:10— 9:20	Sl	—Smith, L.	2:10—2:20	Za	—Zz
9:20— 9:30	Smith, M.	—Sol	2:20—2:30	Aa	—Alc
9:30— 9:40	Som	—Stah	2:30—2:40	Ald	—Anderse
9:40— 9:50	Stai	—Steu	2:40—2:50	Andersf	—Ark
9:50—10:00	Stev	—Sto	2:50—3:00	Arl	—Bab
10:00—10:10	Stp	—Sup	3:00—3:10	Bac	—Baq
10:10—10:20	Suq	—Tas	3:10—3:20	Bar	—Bas
10:20—10:30	Tat	—Thomp	3:20—3:30	Bat	—Bec
10:30—10:40	Thomq	—Toml	3:30—3:40	Bed	—Benr
10:40—10:50	Tomm	—Tup	3:40—3:50	Bens	—Bes
10:50—11:00	Tuq	—Vandeq	3:50—4:00	Bet	—Blac
11:00—11:10	Vander	—Ver	4:00—4:10	Blad	—Boe
11:10—11:20	Ves	—Walc	4:10—4:20	Bof	—Bot
11:20—11:30	Wald	—Wark	4:20—4:30	Bou	—Bra

THURSDAY FEBRUARY 9, 1961

A.M.			P.M.		
8:00— 8:10	Brb	—Brown, F.	1:00—1:10	Fim	—Foc
8:10— 8:20	Brown, G.	—Buc	1:10—1:20	Fod	—Fran
8:20— 8:30	Bud	—Bur	1:20—1:30	Frao	—Fz
8:30— 8:40	Bus	—Cam	1:30—1:40	Ga	—Gau
8:40— 8:50	Can	—Car	1:40—1:50	Gav	—Gill
8:50— 9:00	Cas	—Cha	1:50—2:00	Gilm	—Goldl
9:00— 9:10	Chb	—Ci	2:00—2:10	Goldm	—Grah
9:10— 9:20	Cj	—Cohe	2:10—2:20	Grai	—Gri
9:20— 9:30	Cohf	—Con	2:20—2:30	Grj	—Had
9:30— 9:40	Coo	—Cou	2:30—2:40	Hae	—Ham
9:40— 9:50	Cov	—Cro	2:40—2:50	Han	—Harrisn
9:50—10:00	Crp	—Dam	2:50—3:00	Harriso	—Hd
10:00—10:10	Dan	—Daz	3:00—3:10	Hea	—Henl
10:10—10:20	Db	—Deng	3:10—3:20	Henm	—Hile
10:20—10:30	Denh	—Din	3:20—3:30	Hilf	—Holl
10:30—10:40	Dio	—Dou	3:30—3:40	Holm	—How
10:40—10:50	Dov	—Dup	3:40—3:50	Hox	—Hur
10:50—11:00	Duq	—Eg	3:50—4:00	Hus	—Jack
11:00—11:10	Eh	—En	4:00—4:10	Jacl	—Jog
11:10—11:20	Eo	—Fan	4:10—4:20	Joh	—Jones, J.
11:20—11:30	Fao	—Fil	4:20—4:30	Jones, K.	—Kam

FRIDAY FEBRUARY 10, 1961

A.M.			P.M.		
8:00— 8:10	Kan	—Kea	1:00—1:10	Mj	—Moro
8:10— 8:20	Keb	—Ker	1:10—1:20	Morp	—Munm
8:20— 8:30	Kes	—Kiq	1:20—1:30	Munn	—Nax
8:30— 8:40	Kir	—Kni	1:30—1:40	Nay	—Ne
8:40— 8:50	Knj	—Koth	1:40—1:50	Nf	—Nz
8:50— 9:00	Koti	—Krug	1:50—2:00	Oa	—Opa
9:00— 9:10	Kruh	—Lami	2:00—2:10	Opb	—Pak
9:10— 9:20	Lamj	—Lawre	2:10—2:20	Pal	—Pats
9:20— 9:30	Lawrf	—Leis	2:20—2:30	Patt	—Pere
9:30— 9:40	Leit	—Lewi	2:30—2:40	Perf	—Pick
9:40— 9:50	Lewj	—Lit	2:40—2:50	Picl	—Pop
9:50—10:00	Liu	—Luca	2:50—3:00	Poq	—Pri
10:00—10:10	Lucb	—M(a)cClel	3:00—3:10	Prj	—Ram
10:10—10:20	M(a)cClem	—M(a)cGi	3:10—3:20	Ran	—Reid, S.
10:20—10:30	M(a)cGj	—M(a)cMa	3:20—3:30	Reid, T.	—Richa
10:30—10:40	M(a)cMb	—Mall	3:30—3:40	Richb	—Robertsn
10:40—10:50	Malm	—Marsg	3:40—4:00	Robertso	—Rop
10:50—11:00	Marsh	—Mat	4:00—4:10	Roq	—Rot
11:00—11:10	Mau	—Mere	4:10—4:20	Rou	—Rz
11:10—11:20	Merf	—Miller, E.			
11:20—11:30	Miller, F.	—Miz			

SATURDAY FEBRUARY 11, 1961

Any student may register from 9:00 to 11:30 A.M. Saturday registration is inadvisable, however, as many sections of course offerings will be closed. It is essential that registration and classification be completed according to schedule.

Index

University of Michigan Official Publication

The 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.

General Information

Announcements:

- Architecture and Design, College of
- Business Administration, School of
  - Graduate
  - Undergraduate
- Dearborn Center
- 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

OTHER BULLETINS

Extension courses
Bulletins describing the work of various departments and curriculums

For general information concerning the University, address University of Michigan, Ann Arbor, Michigan.