announcement

College of Engineering

1959/1960

THE UNIVERSITY OF MICHIGAN

OFFICIAL PUBLICATION

VOL. 60, NO. 127, MAY 1, 1959

Entered as second-class matter at the Post Office at Ann Arbor, Michigan. Issued triweekly July through March and semiweekly April through June by The University of Michigan. Office of publication, Ann Arbor, Michigan.

University of Michigan Official Publication

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Announcement

Published by the University Ann Arbor

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Summer session classes begin	June 22, Monday
Independence Day, a holiday	July 4, Saturday
Summer session ends	August 15, Saturday

FIRST SEMESTER

Orientation period	September 14–19, Monday–Saturday
*Registration	September 16–19, Wednesday–Saturday
First semester classes begin	September 21, Monday
Thanksgiving recess begins	November 25, Wednesday (evening)
Classes resume	November 30, Monday (morning)
Christmas recess begins	December 19, Saturday (noon)

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Classes resume	January 4, Monday (morning)
Classes end	January 16, Saturday
Study period	January 17, Sunday
Examination period	January 18–28, Monday–Thursday
Midyear Graduation	January 23, Saturday
First semester ends	January 30, Saturday

SECOND SEMESTER

Orientation period	February 1–6. Monday–Saturday
*Registration	February 3–6, Wednesday–Saturday
Second semester classes begin	February 8, Monday
Spring recess begins	March 26, Saturday (noon)
Classes resume	April 4, Monday (morning)
Classes end	May 25, Wednesday
Study period	May 26, Thursday
Examination period	May 27–June 7, Friday–Tuesday
Commencement	June 11, Saturday

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

This calendar is subject to revision.

*For registration schedules, see pages 166 and 167.

COLLEGE OF ENGINEERING

HARLAN HATCHER, Ph.D., Litt.D., LL.D., *President of the University*
MARVIN LEMMON NIEHUSS, LL.B., *Vice-President and Dean of Faculties*
STEPHEN STANLEY ATTWOOD, M.S., *Dean of the College of Engineering*
GLENN VERNON EDMONSON, M.E., *Associate Dean of the College of Engineering*
WALTER JOHNSON EMMONS,* B.S., A.M., *Associate Dean and Secretary of the College of Engineering*
ROBERT ROY WHITE, Ph.D., *Associate Dean of the College of Engineering*
ARLEN ROOSEVELT HELLWARTH, M.S., *Assistant Dean and Secretary of the College of Engineering*

General Information

Engineering has been defined as "the art and science by which the properties of matter and the sources of power in nature are made useful to man in structures, machines, and manufactured products."

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

Only through continued practice or exercise of judgment can one acquire the stature of an engineer. 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.

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

*On retirement furlough 1959–60.

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 graduates to enter understandingly into scientific investigation in several fields of engineering and, at the same time, to impart such knowledge of the usual engineering practice as will make graduates immediately useful in any subordinate position to which they may be called.

Doing is an essential phase of engineering education, and laboratory work under the supervision of those who have had professional experience as well as full scientific background has always been the practice at Michigan. The faculty are encouraged to be active in research and professional practice with the aim of improving their teaching and keeping informed on new developments in their fields of the profession.

Experience has clearly demonstrated that teaching, particularly in science and its applications, reaches its highest type only in an atmosphere of research and steady progress in more thorough understanding of the subjects taught. Such teaching is 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, in the field, and in the University of Michigan Research Institute. This was established as the Department of Engineering Research in 1920, for the purpose of encouraging research in engineering and as an agency for stimulating co-operation with industry 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, the student should have mental ability and alertness of a high order, good health, and perseverance. The plainest indication of such ability is evident in superior grades in high school, particularly in mathematics and science. A serious mistake is frequently made in regarding manual dexterity and ingenuity or an interest in mechanical things as an indication of engineering ability.

The choice of a career is a most important one and should be based on sound and complete information and on guidance.* The admissions officer of the University and the officers and program advisers of the College of Engineering will gladly be of any possible service in this connection.

The programs offered by the College of Engineering cover a wide spectrum, from "science engineering" for those interested in the scientific side of engineering as evident in research and development to "industrial engineering" for those planning careers in manufacturing. The final decision as to the particular program desired need not be made until the end of the second year.

*Such information may be obtained from the pamphlet, *Engineering as a Career*, prepared by the Engineers' Council for Professional Development, 29 West 39th Street, New York City, and through local engineering societies.

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; the hydraulic, sanitary, and structural laboratories of civil engineering; the general mechanical engineering laboratory, which includes the engines, turbines, pumps, fans, compressors, and pertinent hydraulic machinery; the fluid mechanics and physical testing laboratories with their special equipment for engineering mechanics; drafting and computing rooms; and the 360-foot naval tank with dynamometers for testing ship models.

Directly across the street, the **East Engineering Building** (1923) houses the machine-tool laboratory with more than one hundred modern types of machine tools; the machinability laboratory fully equipped with dynamometers; the gaging and measuring laboratory; a complete foundry and melting laboratory; metal-working, welding, heat-treating, spectrographic (mass, infrared, ultraviolet, etc.), and metallographic laboratories; the X-ray laboratory equipped for radiography and diffraction studies; process operations laboratory; catalytic pilot plants; the petroleum, gas, electrochemical, high pressure, paper, paint and varnish, plastics, and measurements laboratories of chemical engineering; and the highway and soil mechanics laboratory. The **East Engineering Addition** (1947) contains two subsonic wind tunnels, supersonic jet, structures, propulsion, and instrumentation laboratories of aeronautical engineering; the electrical machinery, communications, photometry electronics, servomechanisms, and other laboratories of electrical engineering; and the meteorological laboratory.

The **Automotive Laboratory** (1956) on the North Campus, generously equipped by the industry of the state, provides modern test cells for instruction and research on automotive and aircraft engines and gas turbines; a vehicle laboratory for work on chassis, body, and suspension, as well as the complete vehicle; also shops and the various special instruments and laboratories associated with the important work in the automotive field.

The **North Campus** includes also the Mortimer E. Cooley Building, which now serves the Engineering Research Institute and the Industrial Program of the Engineering College as well as providing conference rooms for other activities; the Fluids Engineering Laboratory, which serves all departments concerned with fluid flow; the Phoenix Memorial Laboratory and accompanying Ford Nuclear Reactor, which provides facilities for research in the field of atomic energy and support the program in nuclear engineering; and special supersonic and low turbulence wind tunnels.

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 and with auxiliary equipment.

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 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 this location nearly ideal for summer instruction in surveying and geology.

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 College, Emmanuel Missionary

College, Kalamazoo College, Eastern Michigan College, and Western 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 two additional years 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.

Similar programs sometimes can be arranged with the College of Literature, Science, and the Arts of the University and such 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 27 and 31.

Students may be admitted with advanced standing from junior colleges or other institutions (see pages 14–17).

PLACEMENT

The young graduate from an engineering school must continue his education by internship in industry or professional work before he can develop into a fully competent engineer. For this reason, his first professional experiences after leaving school are of the greatest importance in his continued development, and the College of Engineering considers the proper placement of its graduates an essential part of its functions.

Most of the leading companies which employ engineers visit the College at least annually for the purpose of recruiting students for their training programs and operations. Students are usually notified well in advance of these visits and so are enabled to discuss the various opportunities with members of the faculty and to indicate their preference for interviews.

Students make all appointments for placement interviews at the Engineering Placement Office, 347 West Engineering Building. Likewise, any resident student who desires employment, either permanent, temporary, or part-time, may register at this same office.

In order to assist students with placement and with the transition to professional and industrial work, the Engineering Placement Office conducts meetings on such subjects as techniques for obtaining employment, opportunities for engineering graduates, and professional problems during the first semester of the academic year. See page 159.

The interest of the College in the proper employment of its graduates by no means ceases when the student leaves the campus. Graduates are invited to communicate with the Engineering Placement Office or with members of the faculty whenever they feel that the College can be of assistance in helping them to find more suitable positions.

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, sports groups, glee clubs, and other organizations provide excellent opportunities, and engineering students are encouraged to take an active part in them. They constitute an important part of the University life 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.

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 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
Stump Speakers' Society of Sigma Rho Tau, intercollegiate engineering speakers' society
Tau Beta Pi, national engineering honor society
Triangles, junior honor society
Vulcans, senior honor society

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 student loans, write to the Office of Student Affairs, 2011 Student Activities Building.

The Committee on Scholarships of the College has under its jurisdiction those scholarships and aid funds which have been established for the special benefits of students in engineering. Applications may be addressed directly to this committee at the office of the Dean.

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. *(See page 12 about enrollment deposit.)*

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 students' 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.*

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. Students shall pay all accounts due the University not later than the last day of classes of each semester or summer session. Student loans which fall due during any semester or summer session and which are not paid or renewed are subject to this regulation; however, 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. Freshmen must present an application for admission directly to the Director of Admissions. The transcript of academic record presented by students transferring from other colleges usually includes a satisfactory statement concerning character. Applications should be addressed to the Assistant Dean of the College of Engineering. University Health Service approval is required in all cases. See page 158.

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. Effective with the fall semester beginning in September 1959, *new undergraduate students, both freshmen and transfers, and former students returning after an absence of one or more semesters,* will be 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 advanced 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.

	UNITS
A. ENGLISH	
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 Studies of the First Year.

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. A grade of work distinctly above passing is presupposed.

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 for admission. Freshmen are not admitted to the University on the basis of test results in lieu of satisfactory high school records. All out-of-state freshman applicants are required to take the College Board Scholastic Aptitude Test, preferably in December or January of the senior year.

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 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, and the work in drawing and some of the engineering mechanics if his institution offers adequate instruction in these fields. The remaining requirements for graduation may then generally be completed in two years.

The student is urged to write to the 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, 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.

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 other low grade.

Students desiring excuse from courses in drawing 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, engineer, 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 to 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 for 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.

Studies of the First Year

The first-year program is outlined in very general terms. Considerable flexibility is desired in order to accommodate students with varying degrees of ability and high school preparation and also those who enter with very definite professional objectives.

After one year a student is expected to choose the degree program in which he plans to graduate. Variation among the several programs is not so pronounced as to make transfer difficult in the second year should the student decide that he wishes to do so. Programs leading to the several degrees and typical semester schedules will be found in the following section. The first-year schedules include the following subjects:

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Mathematics	4	Mathematics	4
English	4	English	2 or 4
Drawing	3	Drawing	3
Chemistry or Physics	4 or 5	Chemistry, Physics, or Engineering Mechanics	4 to 7
Physical Education*	0	Physical Education*	0
	15 or 16		15 or 16
Air Science*	2	Air Science*	2
Military Science*	2	Military Science*	2
Naval Science*	3	Naval Science*	3

All entering freshmen are required to take placement tests in English, chemistry, and mathematics during the orientation period.

Mathematics 33 and 34 normally will be assigned in the first two semesters to those who have had in high school 1½ units of algebra, solid geometry, and trigonometry. Sequences in mathematics, however, are listed on page 20 for those who enter with less or more than this preparation.

English 11, Theme Writing, and English 21, Speech, are generally prescribed for the first semester. Those found not to be prepared for English 11 will be assigned to English 10, Preparatory Composition. English 12, Expository Writing, and English, Group II, which offers a choice of several courses, are taken in the second semester by most students.

Drawing 1, the basic course, and Drawing 2, Descriptive Geometry, come in the first and second semesters, respectively, unless the student chooses to commence with the S Schedule which is explained on page 21. Such students elect Drawing 21, Graphics and Engineering Drawing, followed by Drawing 22, Graphics and Engineering Geometry.

Chemistry is not required as a science unit for admission although it is strongly recommended. Those who have had no chemistry in high school will take Chemistry 1, followed by Chemistry 4 or 6, depending

*Those who choose to enroll in one of the three ROTC programs are excused from taking physical education.

upon the degree program which the student believes he will enter. Those with average preparation will elect Chemistry 3 in the first semester and Chemistry 4 or 6 in the second semester. One with excellent preparation will be allowed to elect Chemistry 5E which, in Schedule T, explained on page 21, completes his basic requirement in this subject in one semester. Students in Schedule S take Chemistry 14 in the second semester and must have a sound preparation.

Students in Schedule S take Physics 53, Elementary Mechanics, in the first semester. Other students, if they have completed their chemistry and have done well in Mathematics 33, may be placed in Physics 45, Mechanics, Sound, and Heat, in the second semester.

Engineering Mechanics 11, Statics, is scheduled for students in Schedule S in the second semester.

The scholastic requirements for graduation are expressed in terms of the quality and level of attainment reached by the student and not in terms of the total number of credit hours acquired in college. *The basic level of attainment* required of all students in every program is demonstrated ability in English, drawing, mathematics, chemistry, and physics equivalent, respectively, to the satisfactory completion of the following courses: English 12 and 21, Drawing 2 or 22, Mathematics 56 or 37, Chemistry 5E or 15, 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.

The tabulation on page 20 indicates the required courses at the University for those entering with various degrees of preparation and ability in mathematics and chemistry.

As indicated, it is clearly to the advantage of the student to elect a full 4-unit program in mathematics through college algebra, or at least a 3½-unit program including trigonometry. He should also elect one unit of chemistry and one of physics. Advanced placement programs are available in some high schools and the opportunities which they offer should not be overlooked.

By carefully planning his high school program, a superior student may materially decrease the time required to graduate from the University. Depending upon his preparation and ability, as indicated by high school standing and orientation period examinations, he may save six credit hours in the mathematics sequence and three credit hours in chemistry. He would then be able to graduate with but 131 credit hours instead of the 140 credit hours required of the average entering freshman. This alone represents the saving of the equivalent of a summer session or a semester of half-time work. In addition, students who have attained a sufficiently high degree of proficiency in English composition and speech, drawing, and other subjects in which attainment levels are stated in the several degree programs may be able to save additional time in the completion of their degree requirements.

Physical education twice a week throughout the year (without credit in hours) is required of all first-year students unless enrolled in air, military, or naval science.

Enrollment in one of the ROTC programs is not required.* If elected, hours of credit and the grades earned in air, military, and naval science will be recorded and included in the computation of semester grade averages.

The adviser in consultation with the student will arrange a schedule intended to adjust irregularities as quickly as possible. Students are required to remove all admission deficiencies during their first year, unless granted an extension of time.

Units Presented				Mathematics Courses to Be Elected (See course descriptions pages 121–125)	
Group	Alg.	Geom.	Trig.	Courses	Hours
1	1	1	0	Math. 6, 7, — 33, 34, 55, 56	22
2	1	1½	0	Math. — 7, — 33, 34, 55, 56	20
3	2	1	0	Math. 6, — 8, 33, 34, 55, 56	20
4	1½	1½	0	Math. — — 8, 33, 34, 55, 56	18
5	2	1½	0	Math. — — 8, 33, 34, 55, 56	18
6	2	1	½	Math. 6, — — 33, 34, 55, 56	18
7	1½	1½	½	Math. — — — 33, 34, 55, 56	16
8	2	1½	½	Math. — — — 33, 34, 55, 56, *or*	16
				— — — 35, 36, 37	12

Students who do not present credits listed in Group 7 of the above tabulation are advised to take, if possible, the lacking school algebra, solid geometry, or trigonometry during the summer preceding the first semester of the freshman year.

Students of superior ability, prepared as indicated above, may make more rapid progress by electing courses as follows:

Groups 4 and 5: Math. 8 and 33 in the first semester.

Group 8: Math. 35, 36, 37 in place of Math. 33, 34, 55, 56, a saving of four credit hours in Schedule T.

Chemistry 5E, in place of two four-hour courses, a saving of three credit hours in Schedule T.

*See statement concerning Reserve Officers' Training Corps, page 56.

Undergraduate Degree Programs

Accreditation. All degree programs of the College of Engineering which are normally examined by the Engineers' Council for Professional Development are accredited by that body.

Choice of Schedules. Students entering without deficiencies have the choice of two schedules of study for the first year, as stated below. Schedule S is required for those who plan to continue with science engineering and may also be elected, up to the capacity of the classes, by those who plan to enter any one of the other degree programs. Schedule T is the traditional pattern which has been followed for many years and may be selected by all students except those in science engineering. In Schedule S, physics and mechanics are introduced in the first year. These subjects are deferred to the sophomore year for those who begin with Schedule T. Whichever schedule is selected by the student, it is expected that he will follow that schedule in science for four semesters.

Attainment Levels and Professional Subjects. As stated under Studies of the First Year, graduation requirements are expressed in terms of attainment rather than in terms of a fixed number of credit hours.

Each degree program is composed of two groups of subjects. Group A, below, includes subjects in certain basic areas common, with minor exceptions, to all programs. These must be elected and passed or equivalent proficiencies must be demonstrated. Group B is composed chiefly of professional subjects and varies in the several degree programs. The Group A subjects with the credit normally assigned to them are as follows:

	HOURS	
Schedule	*T*	*S*
English 11, 12, 21	6	6
Math. 8, 33, 34, 55, 56, or 35, 36 37	12–18	12–18
Chem. 5E, or two 4-hour courses	5 or 8	–
Chem. 14, 15	–	8
Draw. 1, 2, or 21, 22	6	–
Draw. 21, 22	–	6
Chem.-Met. Eng. 1* and Mech. Eng. 2*	5	–
Eng. Mech. 11	–	3
Physics 45, 46	10	–
Physics 53, 54	–	8
	44–53	43–49

The degree of attainment in the several subjects of Group A will be determined from a consideration of a student's scholastic records supplemented, generally, by examinations given during the orientation period which precedes the opening of each semester.

Students admitted without deficiency, with normal high school preparation, may expect to graduate with 140 credit hours. Those of high ability

*Chem.-Met. Eng. 1 and Mech. Eng. 2 are not required of students who plan to continue in chemical, metallurgical, or materials engineering. Mech. Eng. 2 is not required of those in civil or mechanical engineering. The hours of credit assigned to these subjects are included in Group B of the respective programs.

and with preparation beyond that required for admission may materially expedite their progress toward the degree.

Courses taken at other recognized colleges or universities, if passed with at least a C grade, will be accepted for appropriate credit.

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 classifier 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.

Co-operative Programs with Industry. In certain fields a desirable combination of theory and practice is available 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.

AERONAUTICAL 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 and design, 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Econ. 53, 54*	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, Strength and Elasticity of Materials II	3
Mech. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, Direct and Alternating Current Apparatus and Circuits	4
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, Aircraft Structures I	3
Aero. Eng. 131, Aircraft Structures II	4
Aero. Eng. 141, Mechanics of Flight I	2
Aero. Eng. 142, Mechanics of Flight II	3
Aero. Eng. 143, Aircraft Control Systems	3
Aero. Eng. 163, Aircraft Propulsion I	3
Aero. Eng. 164, Aircraft Propulsion II	4
Nontechnical electives	9
Group options and electives†	10
Total, professional subjects and electives	87

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

†A maximum of 4 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 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Physics 45	5	Physics 46	5
Aero. Eng. 1	1	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Elective	3	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
	16		15

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

CHEMICAL ENGINEERING

Program Adviser: Professor Williams, 3213 East Engineering

Chemical engineering is concerned mainly with the development and application of manufacturing processes in which chemical or certain physical changes of materials are involved. The chemical engineer is essentially a process engineer and is concerned primarily with the design, construction, and operation of equipment and plants in which these processes take place.

Certain basic or unit operations such as fluid flow, heat transfer, evaporation, filtration, distillation, crushing, extracting, and drying are common to the processing of different materials in most industries. Any manufacturing process with which the chemical engineer deals is made up of a sequence of such operations. Knowledge of these unit operations and their commercial applications is one of his distinguishing characteristics.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	39–48
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Economics 153	3
Bus.Ad., Accounting 100	3
Eng. Mech. 3, Dynamics	3
Eng. Mech. 5, Statics and Stresses	4
Elec. Eng. 5, Apparatus and Circuits	4
Chemistry 23, Analytical	4
Chemistry 61, 161R, Organic	8
Chemistry 182, 183, Physical	6
Chemistry, elective*	2
Chem.-Met. Eng. 2, Engineering Calculations	3
Chem.-Met. Eng. 16, Measurements Laboratory	3
Chem.-Met. Eng. 111, Thermodynamics	3
Chem.-Met Eng. 113, Unit Operations	4
Chem.-Met. Eng. 115, Unit Operations Design	3
Chem.-Met. Eng. 117,† Metals and Alloys	3
Chem.-Met. Eng. 118, Structure of Solids	3
Chem.-Met. Eng. 121, Design of Process Equipment	3
Chem.-Met. Eng. 129, Engineering Operations Laboratory	3
Chem.-Met. Eng. 130, Chemical Process Design	3
Engineering Materials, elective, (see below)	3
Nontechnical electives	9
Free electives‡	8
Total, professional subjects and electives	92

At least one course in materials is to be chosen with the approval of the adviser from the offerings of the Department of Chemical and Metallurgical Engineering or some other department. The selection may be in any of several areas such as ceramic or organic materials, metals, soils, plastics, and X-ray studies of materials.

The elective hours are provided so that a student may study in areas suited to his particular needs and interests. The elective courses should

*The elective in chemistry is to be chosen from Chem. 107, 161L, 171, 191.

†Chem.-Met. Eng. 127 and 128 may be substituted for Chem.-Met. Eng. 117 and 3 hours of electives (not nontechnical).

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

not be selected haphazardly but should represent groupings or sequences which will accomplish some reasonable objective. The student should plan his elective units for several semesters in advance with the advice of his counselor. Some elective sequences in the technical subjects are suggested as follows:

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
Materials: Chem.-Met. Eng. 122, 124, 125, 126, 136; Eng. Mech. 126
Nuclear: Nuc. Eng. 190, 191
Polymers: Chem.-Met. Eng. 125, †232; Phys. 179
Petroleum: *Geol. 98, 237; Chem.-Met. Eng. †235

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Physics 45	5	Physics 46	5
Chem.-Met. Eng. 2	3	Chem. 182	3
Electives	4	Chem.-Met. Eng. 111	3
	—	Elective	3
	16		—
SUMMER SESSION			18
Chem. 61	6		

FIFTH SEMESTER		SIXTH SEMESTER	
Chem. 183	3	Bus.Ad., Accounting 100	3
Chem. 161R	2	Chem.-Met. Eng. 16	3
Elec. Eng. 5	4	Chem.-Met. Eng. 115	3
Eng. Mech. 5	4	Chem.-Met. Eng. 118	3
Chem.-Met. Eng. 113	4	Eng. Mech. 3	3
	—		—
	17		15

SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem. elective	2	Econ. 153	3
English, Group III	2	Chem.-Met. Eng. 121	3
Chem.-Met. Eng. 117	3	Chem.-Met. Eng. 130	3
Chem.-Met. Eng. 129	3	Eng. Materials, elective	3
Electives	6	Electives	4
	—		—
	16		16

*Acceptable as nontechnical electives.
†Courses which may be substituted for Chem.-Met. Eng. 130 in the chemical engineering program.
‡The program may be completed in eight semesters without a summer session if seventeen- to eighteen-hour semester schedules can be carried successfully and the sequences are carefully planned. Qualified students may elect the Math. 35, 36, 37 sequence to reduce the total hours.

COMBINED PROGRAMS

CHEMICAL ENGINEERING AND METALLURGICAL ENGINEERING

Degrees in both chemical and metallurgical engineering may be earned by taking the courses, or their alternates, required for both degrees. Students in the chemical engineering program who desire to earn a degree in metallurgy as well will find that they must add Chem.-Met. Eng. 13, 119, and 124 and elect Chem.-Met. Eng. 127 and 128 rather than Chem.-Met. Eng. 117 for a total of thirteen hours for additional courses. Students in the metallurgical program who desire to earn a degree in chemical engineering as well must elect Chem. 61 and 161R, Chem.-Met. Eng. 113 and 115 instead of Chem.-Met. Eng. 114, and Chem.-Met. Eng. 130 in addition for a total of fourteen extra hours.

CHEMICAL ENGINEERING AND CHEMISTRY

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

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

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	
If any of this German is satisfied by entrance credits, an equivalent amount of work in foreign language must be substituted.		

	HOURS	HOURS
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 GROUPS		9
Econ. 53, 54	6	
Bus.Ad., Accounting 100	3	
ENGINEERING COURSES		48
Eng. Mech. 3, 5	7	
Elec. Eng. 5	4	
Drawing 1, 2	6	
Chem.-Met. Eng. 2, 111, 113, 115, 117, 118, 121, 129, 130	28	
Elective in engineering materials	3	
ELECTIVES IN HUMANITIES		6
Total		155 to 163

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 (Civil Engineering) are required to complete the following:

A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	HOURS
Total, normally (see page 21)	42–51
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Civ. Eng. 1, 2, 3, Surveying	10
English, Groups II and III	4
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
Elec. Eng. 5, Electrical Apparatus and Circuits	4
Mech. Eng. 13, Thermodynamics and Heat Transfer	4
Civ. Eng. 20, Structural Drafting	2
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
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)	8
Total, professional subjects and electives	89

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 group option 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

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

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 18.

SUMMER SESSION (at Camp Davis)

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

THIRD SEMESTER		FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	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

FIFTH SEMESTER		SIXTH SEMESTER	
Civ. Eng. 140	3	Civ. Eng. 121	3
Eng. Mech. 4	3	Civ. Eng. 23	3
Civ. Eng. 22	3	Civ. Eng. 141	2
Civ. Eng. 65	3	Civ. Eng. 52	3
Civ. Eng. 20	2	Eng. Mech. 3	3
Elective	2	Elective	2
	16		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Civ. Eng. 135	3	Civ. Eng. 180	2
Elec. Eng. 5	4	Mech. Eng. 13	4
Civ. Eng. 53	2	Electives	10
Electives	7		16
	16		

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 8–9, 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. 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		34 (to 39)
Math. 33, 34, 55, 56 or 35, 36, 37	16 (or 12)	
Chem. 3, 4, or 5E and Psych. 31	8 (or 9)	
Geology (at Camp Davis)	4	
Physics 45, 46	10	
SOCIAL SCIENCE GROUP		9
Bus.Ad. Accounting 100	3	
Economics 53, 54	6	
ENGINEERING GROUP		82
Drawing 1, 2	6	
Chem.-Met. Eng. 1	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, 20, 22, 23, 30, 52, 53, 65, 121, 135, 140, 141, 180, group options	49	
ELECTIVES IN COLLEGE OF L.S. & A.		5
Total		167–172

*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.

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 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. Gaseous Electronics, Radiation, Radio-Astronomy Observatory, Servomechanisms, 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
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. 13, Thermodynamics and Heat Transfer	4
Mech. Eng. 83, Machine Design	3
Elec. Eng. 3, Circuits I	4

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

	HOURS
Elec. Eng. 4, DC Machinery	2
Elec. Eng. 10, Principles of Electricity & Magnetism	3
Elec. Eng. 100, Circuits II	4
Elec. Eng. 101, Networks and Lines	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. 150, AC Machinery	4
Elec. Eng. 160, Electrical Design	4
Elec. Eng. 180, Electron and Semiconductor Devices I	4
Nontechnical electives	6
Electives†	11
Total, professional subjects and electives	87

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS
Math. 55 (or 53)	4
Physics 45	5
Elec. Eng. 3	4
Elective	3
	16

FOURTH SEMESTER	HOURS
Math. 56 (or 54)	4
Physics 46	5
Elec. Eng. 10	3
Elective	3
	15

FIFTH SEMESTER	
Elec. Eng. 4	2
Elec. Eng. 100	4
Eng. Mech. 5	4
Math. 103 or 104	3
Econ. 53*	3
	16

SIXTH SEMESTER	
Elec. Eng. 141	2
Elec. Eng. 150	4
Elec. Eng. 180	4
Eng. Mech. 3	3
Econ. 54*	3
	16

SUMMER SESSION	
Elec. Eng. 130	3
Mech. Eng. 13	4
	7

SEVENTH SEMESTER	
Elec. Eng. 101	3
Elec. Eng. 120	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

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

ENGINEERING MECHANICS

Program Adviser: Associate Professor S. K. Clark, 201 West Engineering

The purpose of the program in engineering mechanics is to prepare men for theoretical and research work in engineering fields. Although most men trained in this field of engineering are engaged in technical work, many, like other engineers, find their way into supervision and management. Men with this training are sought by the research and development laboratories of the large utilities, automotive and aircraft industries, and the federal government. Representative problems given to these men include analysis of stresses due to static or dynamic loading, thermal changes, or drawing of metals; studies in photoelasticity; problems in instrumentation; analysis of fluid motion with applications to engineering problems; vibration analysis and elimination; problems in heat conduction; and the thermodynamics of materials.

The major areas of study in engineering mechanics are strength of materials, elasticity and plasticity, dynamics and vibrations, and fluid mechanics and thermodynamics. Emphasis is placed on analysis as a means of solving problems and, consequently, advanced mathematics and advanced mechanics play an important part in this training.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups 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
Civ. Eng. 21, Theory of Structures	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 135, Methods of Instrumentation, or Eng. Mech. 103, Experimental Mechanics, or Instr. Eng. 172, Instrument Dynamics	3
Mech. Eng. 105, Thermodynamics	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Mechanics of Materials	4
Eng. Mech. 2*a*, Strength of Materials Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 112, Intermediate Mechanics of Materials	3

	HOURS
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)	19
Total, professional subjects and electives	87

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

Suggested group options are:

- Aerodynamics
- Aeromechanics
- Chemical Engineering
- Electrical Engineering
- Hydraulics
- Instrumentation
- Internal Combustion
- Machine Design
- Metallurgy
- Naval Architecture
- Nuclear Engineering
- Propulsion
- Structures

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 Allen, 231 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 a well-equipped laboratory.

*A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Econ. 153*	3
Eng. Mech. 3, Dynamics	3
Eng. Mech. 5, Statics and Stresses	4
Chem.-Met. Eng. 107, Metals and Alloys	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. 32, Manufacturing Processes	3
Mech. Eng. 83, Machine Design	3
Mech. Eng. 86, Machine Design II	3
Mech. Eng. 132, Manufacturing Engineering	3
Ind. Eng. 100, Industrial Management	3
Ind. Eng. 110, Plant Layout and Material 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
Group options and electives‡	6
Total, professional subjects and electives	87

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS
Math. 55 (or 53)	4
Physics 45	5
Bus.Ad., Accounting 100	3
Chem.-Met. Eng. 107	3
Elective	2
	17

FOURTH SEMESTER	HOURS
Math. 56 (or 54)	4
Physics 46	5
Bus.Ad., General 154	3
Mech. Eng. 13	4
	16

*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.

‡Advanced air, military, or naval science (300 or 400 series) may be used for these electives.

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

FIFTH SEMESTER		SIXTH SEMESTER	
Math. 161	3	Math. 162	3
Mech. Eng. 32	3	Mech. Eng. 132	3
Ind. Eng. 100	3	Ind. Eng. 120	3
Eng. Mech. 3	3	Ind. Eng. 110	3
Elec. Eng. 5	4	Mech. Eng. 83	3
		Mech. Eng. 14	1
	16		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Ind. Eng. 160	3	English, Group III	2
Econ. 153	3	Ind. Eng. 165	3
Ind. Eng. 130	2	Ind. Eng. 150	2
Mech. Eng. 86	3	Ind. Eng. 140	2
Electives	5	Ind. Eng. 135	3
		Elective	3
	16		15

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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	39–48
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
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	3
Chem. 23, Analytical	4
Chem. 61, Organic	6
Chem. 182, 183, Physical	6
Science Eng. 110, Chem.-Met. Eng. 111, or equivalent, Thermodynamics	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	92

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 18.

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.

	HOURS		HOURS
Physics 45	5	Eng. Mech. 2	4
Eng. Mech. 1	3	Electives	5
	16		18
SUMMER SESSION			
Eng. Mech. 3	3		
Elec. Eng. 5	4		
	7		
FIFTH SEMESTER		SIXTH SEMESTER	
Math. 103 (or 161)	3	Chem. 183	3
Chem. 61	6	Chem.-Met. Eng. 16	3
Chem. 182	3	Chem.-Met. Eng. 118	3
Sci. Eng. 110	3	Eng. Mech. 4	3
Elective	2	Electives and options	6
	17		18
SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem.-Met. Eng. 124	3	Chem.-Met. Eng. 122	4
Chem.-Met. Eng. 125	4	Chem.-Met. Eng. 128	3
Chem.-Met. Eng. 127	4	Electives and options	10
Electives and options	6		17
	17		

MATHEMATICS

Program Co-advisers: Professor Bartels, 274A 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
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	87

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 6 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 use of power, the design and development of a wide variety of products and machinery, and the methods and operations of manufacture. As such, he engages in the design and manufacture of automobiles and other transportation means; internal combustion engines and gas and steam turbines; fluids machinery; production and materials handling machinery and equipment; heating, ventilating, air-conditioning and refrigeration equipment; consumer goods such as home appliances; and many more items. He is responsible for the development, selection, and operation of manufacturing processes. He plays a significant role in the development of nuclear power and in the operation of power plants.

The mechanical engineer is employed in all industries. The automotive, machine tool, and home appliance firms are obvious examples. Perhaps somewhat less obviously, the mechanical engineer is engaged in large numbers in the aircraft, chemical, basic materials, and electrical 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 group options and 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 on page 165. 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53

	HOURS
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Econ. 53 and 54, or Econ. 153 and three hours nontechnical elective	6
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	2
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
Group options and electives†	17
Total, professional subjects and electives	89

The group options and 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 in a broader manner.

The student is encouraged to formulate his own sequence of group option and 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*).

†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 18.

THIRD SEMESTER	HOURS
Math. 55 (or 53)	4
Physics 45	5
Eng. Mech. 1	3
Nontechnical electives	3 or 4
	15 or 16

FOURTH SEMESTER	HOURS
Math. 56 (or 54)	4
Physics 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nontechnical elective	2 or 3
	16 or 17

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

FIFTH SEMESTER	
Mech. Eng. 33	3
Mech. Eng. 80	2
Mech. Eng. 106	3
Eng. Mech. 4	3
Chem.-Met. Eng. 107	3
Nontechnical elective	3
	17

SIXTH SEMESTER*	
Mech. Eng. 17	2
Mech. Eng. 82	3
Mech. Eng. 111	3
Elec. Eng. 5	4
Math. 103	3
	15

SEVENTH SEMESTER*	
Mech. Eng. 86	3
Mech. Eng. 104	3
Elec. Eng. 7	4
Econ. 153	3
Group option and elective	3
	16

EIGHTH SEMESTER*	
Group options and electives	15
English, Group III	2
	17

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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	39–48
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Economics 153	3
Bus.Ad., Accounting 100	3
Eng. Mech. 5, Statics and Stresses	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, Apparatus and Circuits	4
Mech. Eng. 83, Machine Design	3
Chemistry 23, Analytical	4
Chemistry 182, 183, Physical	6
Chemistry or Physics, elective	3
Chem.-Met. Eng. 2, Engineering Calculations	3
Chem.-Met. Eng. 13, Processing of Cast Metals	2
Chem.-Met. Eng. 16, Measurements Laboratory	3
Chem.-Met. Eng. 111, Thermodynamics	3
Chem.-Met. Eng. 114, Unit Operations	4
Chem.-Met. Eng. 118, Structure of Solids	3
Chem.-Met. Eng. 119, Metallurgical Process Design	4
Chem.-Met. Eng. 121, Design of Process Equipment	3
Chem.-Met. Eng. 124, X-ray Studies of Engineering Material	3
Chem.-Met. Eng. 127, Physical Metallurgy I	4
Chem.-Met. Eng. 128, Physical Metallurgy II	3
Chem.-Met. Eng. 129, Engineering Operations Laboratory	3
Nontechnical electives	13
Technical electives*	4
Total, professional subjects and electives	92

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

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Chem. 23	4	Chem. 182	3
Physics 45	5	Physics 46	5
Chem.-Met. Eng. 2	3	Chem.-Met. Eng. 111	3
Elective	2	Elective	3
	18		18

SUMMER SESSION	
Eng. Mech. 5	4
Bus.Ad., Accounting 100	3
	7

FIFTH SEMESTER		SIXTH SEMESTER	
Chem. 183	3	Chem.-Met. Eng. 16	3
Eng. Mech. 3	3	Chem.-Met. Eng. 118	3
Elec. Eng. 5	4	Econ. 153	3
Chem.-Met. Eng. 13	2	Chem. or Phys. elective	3
Electives	5	Electives	5
	17		17

SEVENTH SEMESTER		EIGHTH SEMESTER	
English, Group III	2	Chem.-Met. Eng. 119	4
Mech. Eng. 83	3	Chem.-Met. Eng. 121	3
Chem.-Met. Eng. 114	4	Chem.-Met. Eng. 124	3
Chem.-Met. Eng. 127	4	Chem.-Met. Eng. 128	3
Electives	4	Chem.-Met. Eng. 129	3
	17		16

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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
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*	9
Electives in humanities and social science	13
Total, professional subjects and electives	87

*A maximum of 4 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 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55 (or 53)	4	Math. 56 (or 54)	4
Physics 45	5	Physics 46	5
Eng. Mech. 1	4	Eng. Mech. 2	4
English, Group II	2	Eng. Mech. 3	3
Elective	3	Elective	2
	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		
Meteor. 182	4		18
	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 I 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 II 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 civil, 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
Draw. 33	2
Math. 103	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. 126, Stress Analysis	2
Eng. Mech. 136, Theory of Vibrations	3
Mech. Eng. 17, Heat-Power Laboratory	2
Mech. Eng. 82, Machine Design I	3
Mech. Eng. 80, Dynamics of Machinery	2
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	2
Nav. Arch. 151, Resistance, Power, Propellers	3
Nontechnical electives	9
Group options and electives	20
Total, professional subjects and electives	87

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

1. NAVAL ARCHITECTURE. Adviser: Professor Adams

For those principally interested in ship design and hull construction:

	HOURS
Nav. Arch. 13, Form Calculations II	2
Nav. Arch. 127, Stress Analysis of Structures in Ship Design	2
Nav. Arch. 131, Ship Dynamics	2
Nav. Arch. 132, Ship Design I	2
Nav. Arch. 133, Ship Design II	3
Nav. Arch. 134, Structural Design II	2
Nav. Arch. 137, Shipbuilding Contracts and Cost Estimating	2
Nav. Arch. 141, Marine Propulsion Machinery	2
Nav. Arch. 152, Ship Model Theory	3

2. MARINE ENGINEERING. Adviser: Assistant Professor West

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

	HOURS
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 108, Mechanical Engineering Laboratory	3
Mech. Eng. 111, Heat Transfer I	3
Nav. Arch. 144, Design of Marine Power Plants II	3
Nav. Arch. 146, Design of Marine Power Plants I	2
Nuclear Eng. 190, Elements of Nuclear Engineering	3

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS
Math. 55 (or 53)	4
Eng. Mech. 1	3
Physics 45	5
Nav. Arch. 11	2
Draw. 33	2
	16

FOURTH SEMESTER	HOURS
Math. 56 (or 54)	4
Physics 46	5
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nav. Arch. 12	3
	17

SUMMER SESSION	
Math. 103	3
Mech. Eng. 105	3
	6

FIFTH SEMESTER	*Option* 1	2
Eng. Mech. 3	3	3
Nav. Arch. 21	3	3
Nav. Arch. 141	2	–
Eng. Mech. 4	3	3
Mech. Eng. 17	2	2
Nav. Arch. 13	2	–
Mech. Eng. 104	–	3
Mech. Eng. 106	–	3
	15	17

SIXTH SEMESTER	*Option* 1	2
Mech. Eng. 80	2	2
Mech. Eng. 82	3	3
Nav. Arch. 147	2	2
Elec. Eng. 5	4	4
Nav. Arch. 152	3	–
Mech. Eng. 111	–	3
Eng. Mech. 126	2	2
Elective	2	2
	18	18

SEVENTH SEMESTER	*Option* 1	2
Nav. Arch. 131	2	–
Nav. Arch. 137	2	–
Econ. 153	3	3
Nav. Arch. 146	–	2
Mech. Eng. 108	–	3
Eng. Mech. 136	3	3
Nav. Arch. 127	2	–
Nav. Arch. 132	2	–
Elective	3	3
	17	14

EIGHTH SEMESTER	*Option* 1	2
English, Group III	2	2
Nav. Arch. 151	3	3
Nav. Arch. 144	–	3
Nav. Arch. 133	3	–
Nav. Arch. 134	2	–
Nuclear Eng. 190	–	3
Electives	4	4
	14	15

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 in 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:

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Modern language	8
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
Physics 165, Electron Tubes	3
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	31
Total, professional subjects and electives	87

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*	3
	31

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

SCIENCE

Program Adviser: Professor Churchill, 3036 East Engineering

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

The science engineering program is excellent preparation for postgraduate work in engineering or applied science as well as for immediate employment in the expanding fields of engineering research and development.

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 the specialized engineering courses necessary for the bachelor's degree in the other engineering programs. Any student enrolled in the science engineering program, however, can transfer into one of the specialized programs at the end of the fourth semester (second year) if such interests develop.

REQUIREMENTS

Candidates for the degree of Bachelor of Science in Engineering (Science) are required to complete the program outlined below. The student will be 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.

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total, normally (see page 21, Schedule S)	47–49
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Engineering science, including engineering materials, strength of materials, dynamics, fluid mechanics, thermodynamics, electromagnetics and energy conversion, network analysis, electronics and systems, rate processes	33
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 at least 3 hours of advanced mathematics	12
Electives in English, literature, fine arts, or philosophy	6–10

	HOURS
Electives in anthropology, economics, geography, history, journalism, political science, psychology, or sociology	14–10
Electives*	6
Total, professional subjects and electives	88

SUGGESTED SCHEDULE

For studies of the first year, see page 18.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55	4	Math. 56	4
Chemistry 15	4	Physics 54	4
Eng. Mech. 12	4	Eng. Mech. 13	3
Electives	4	Elec. Eng. 9	3
		Elective	3
	16		17

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

SEVENTH SEMESTER		EIGHTH SEMESTER	
Elective (math., physics, chem.)	3	Elective (math., physics, chem.)	3
Electives (engineering)	6	Electives (engineering)	7
Electives	8	Electives	8
	17		18

Special Fields

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

*A maximum of 6 hours of advanced air, army, or naval science (300 and 400 series) may be used as electives in this group.

INSTRUMENTATION ENGINEERING

The recent developments in the broad engineering application of the principles of measurement, communication, and control, as exemplified by the extensive use of telemetry, computer simulation, and automatic control, make desirable the education of men in this important field. It appears that the best preparation can be achieved at present 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 pages 67 and 118).

Undergraduate students may start these special studies by electing one or more of the following courses: Instr. Eng. 172, Introduction to Instrument Dynamics (*2*); 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 SCIENCE

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*); Bus.Ad., Management 110, Principles of Organization (*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 68). 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

Each male student enrolled in The University of Michigan who meets certain requirements has the opportunity to enroll in the Army ROTC, the Navy ROTC, or the Air Force ROTC. Enrollment is voluntary, but the University and the armed forces expect each student who volunteers to enroll in ROTC to meet the full obligations accepted.

The objective of the ROTC is to train well-qualified reserve officers for the armed forces. Each student who voluntarily enrolls in any one of these three officer training corps accepts the obligation of: (1) continuing his studies in the ROTC, unless excused by regulations of the Army, Navy, or Air Force, until graduation; (2) serving as an officer for specified times.

By voluntarily enrolling in ROTC, each student adds to his own degree requirement the completion of the freshman-sophomore program in the Army and the Air Force. At the beginning of the junior year, the Army or Air Force student may apply to continue in ROTC. If accepted, he adds to his degree requirement the completion of the junior and senior years. Students accepted in the Navy ROTC program commit themselves as freshmen to a four-year program as a degree requirement.

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 Knapp, Middlebrook, C. Smith, and W. Smith; Instructors Brown, Friedwald, Lodigiani, and Lowery. Department office, North Hall.

The Department of Air Science offers a four-year generalized course of study designed to develop in selected 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.

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.

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 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. Local orientation flights and Air Force Base visitations are available.

COURSES OFFERED IN AIR SCIENCE

Air Science I. Foundations of Air Power. (*2 each*).
101. An introduction to military air power, research and development, aircraft industry, general aviation, aircraft, and aerodynamics.
102. A continuation to include control, navigation, propulsion, space vehicles, military instruments of national security, and careers in the Air Force. Lecture and Laboratory.
Air Science II. Foundations of Air Power. (*2 each*).
201. Careers in the Air Force, introduction to aerial warfare, targets, and weapons.
202. Aircraft and missiles, bases, and operations. Lecture and laboratory.
Air Science III. Air Force Officer Development. (*3 each*).
301. Knowledge and skills required of a junior officer in the Air Force. Includes staff organization and functions, communicating, instructing and techniques of problem solving.
302. 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.
Air Science IV. Global Relations. (*3 each*).
401. A study of global relations with special attention to weather, navigation, and international tensions.
402. Military aspects of world political geography and preparation for active commissioned service. Lecture and laboratory.

MILITARY SCIENCE AND TACTICS

Professor Woodman; Assistant Professors Boswell, Farrell, Henderson, and Trost. 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, Griffith, Hirsch, Palmer, Riley, and Samuelson; Instructors Benson, Browning, Durham, Moshgat, 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 two years' active duty. 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.

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.

201. Naval Weapons. I. *(3)*.
A basic familiarity course in modern naval weapons and the purpose of each, stressing the following specifics: ballistics and ordnance, automatic control equipment, fire control problem, fleet air defense.

202. Naval Weapons. II. *(3)*.
Instruction in the general nature, basic principles, employment, and control of naval weapon systems stressing the following areas: guided missiles, nuclear weapons, attack carrier striking force, anti-submarine warfare, amphibious warfare.

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. II. (*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. Naval Administration. II. (*3*).
Develops a thorough understanding of the principles of leadership, good personnel management, and naval justice.
402S. Navy Supply. II. (*3*).
For Navy Supply Corps candidates only. Procurement, receipt, storage, issue, and accounting for all commissary operations and management (15 sessions only; remaining 30 sessions combined with Naval Science 402 in study of naval justice and leadership).
402N. Amphibious Warfare. II. (*3*).
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare (15 sessions only; remaining 30 sessions deals 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 Kuethe and Nichols; Associate Professors Adamson and Isakson

A program is offered leading to the degree of M.S.E. (Aeronautical 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, design, mechanics of flight, guidance and control, and instrumentation. Ordinarily the candidate may include three to four hours of nontechnical 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 Martin and Van Vlack; Associate Professors Ragone and Young; Assistant Professor 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 (Civil) 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, electrical engineering design, electrical measurements and instrumentation, electric power engineering, electronics, illumination engineering, and industrial electronics and control.

ENGINEERING MATERIALS

Advisory Committee: Professors Martin and Van Vlack; Associate Professors Ragone and Young; Assistant Professor 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, Dodge, Masur, and Yih; Associate Professor Clark

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

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 master's degree 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 in Engineering Mechanics, 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.

INDUSTRIAL ENGINEERING

Program Adviser: Associate Professor Steffy

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 fifteen 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 172, 174, 174*a* and 177; and other courses approved by the Committee on Instrumentation. The systems-engineering concept is emphasized throughout the program.

MANAGEMENT SCIENCE

Advisory Committee: Professors Rauch, Dwyer, Fitts, Flood; 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 page 55.

MECHANICAL ENGINEERING

Program Adviser: Professor Porter

The degree of Master of Science in Engineering (Mechanical) is offered in the following fields: aeronautical propulsion, air conditioning, automotive, fluids machinery, heat–power, land locomotion, machine design, and manufacturing.

An applicant for the master's degree in any of the above-mentioned fields 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 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.

METALLURGICAL ENGINEERING

Advisory Committee: Professors Martin and Van Vlack; Associate Professors Ragone and Young; Assistant Professor Gordon

The requirements for this degree include Chem.-Met. Eng. 211, 218, and 210 (4 hours) and a minimum of one course from each of the following groups of courses: Chem.-Met. Eng. 207, 217, 241, 244, 251; Chem.-Met. Eng. 216, 219, 240, 243; and Chem.-Met. Eng. 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 (Naval Architecture and Marine Engineering) degree usually include Nav. Arch. 123, 135, 153, and 145 or 154.

It is also possible to obtain a combined degree Master of Science in Engineering (Marine and Nuclear). 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 and Kerr; Associate Professor 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 20 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 (Sanitary) is generally open to graduates in civil, chemical, and mechanical engineering. A student is expected to elect at least 15 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 ENGINEER—Ae.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 M.S.E. level or its equivalent, taken at this University with a grade average of B or better. Successful completion of a qualifying examination for admission to candidacy is required.

The total graduate program shall include:

1. At least 24 hours in the area of the department or program cited in the degree. The department or program advisers may specify these hours in greater detail.

2. At least 6 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 9 hours in mathematics beyond the B.S.E. mathematics requirements of the department cited in the degree.

DOCTOR'S DEGREES

DOCTOR OF PHILOSOPHY—Ph.D.
DOCTOR OF SCIENCE—Sc.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, Professor Hootkins, 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 Areo. Eng. 110 and 114 designed primarily for graduate students. Not open to students who have elected Areo. 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. Aircraft Structures I. *Prerequisite: Eng. Mech. 123.* (*3*).
Fundamentals of aircraft stress analysis. Application of the basic equations of strength of materials and elasticity to aircraft structural elements, including single and multi-cell box beams, fuselage frames, and wing ribs. Introduction to thermal stress.

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

133. Aircraft Structures III. *Prerequisite: Aero. Eng. 131.* (*3*).
Complete strength and deflection analysis of built-up wing structures with effective and ineffective skin. Effects of differential bending, warping of cross-sections, and shear lag are discussed.

134. **Structures at Elevated Temperatures.** *Prerequisite: Aero. Eng. 131 or 135.* (*3*).
Aerodynamic heating of high-speed aircraft. Steady and transient conditions of thermal stresses. Properties of materials and structures under conditions of temperature and load.

135. **Principles of Aircraft 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. 142.* (*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. **Aircraft Propulsion I.** *Prerequisite: Mech. Eng. 105, Aero. Eng. 110 or Mech. Eng. 106.* (*3*).
Introduction to aerothermodynamics and applications to problems in aircraft propulsion. Discussion of the momentum theorem, one-dimensional flow systems with heat addition, shock waves, diffusers, compressors, and turbines.

164. **Aircraft Propulsion II.** *Prerequisite: Aero. Eng. 163 or equivalent.* (*4*).
Performance and analysis of aircraft propulsion systems including the recip-

rocating engine-propeller, turboprop, turbojet, ramjet, pulse-jet, and rocket. Lectures and laboratory.

165. Principles of Aircraft 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. Aircraft 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. (2).*
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.

170. Seminar on Electronic Analog Computers. Elect as Instr. Eng. 170.

172. Introduction to Instrument Dynamics. Elect as Instr. Eng. 172.

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. Lecture and laboratory.

174. Principles of Automatic Control. Elect as Instr. Eng. 174 and 174*a*.

175. Applications of the Electronic Differential Analyzer I. Elect as Instr. Eng. 175.

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.

177. Probability in Instrumentation. Elect as Instr. Eng. 177.

178. Design of Electronic Analog Computers. Elect as Instr. Eng. 178.

179. Gyrokinetics. *Prerequisite: a course in differential equations. (3).*
Dynamics of rigid bodies, review of elementary mechanics, energy integral, Lagrangian and Hamiltonian methods, Euler's equations. Theory and application of gyroscopes for control and guidance.

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.

210. **Advanced Engineering Measurements.** Elect as Instr. Eng. 210.

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.

214. **Information Theory and Radio Telemetry.** Elect as Instr. Eng. 214.

215. **Radio Telemetry Laboratory.** Elect as Instr. Eng. 215.

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. **Structural Analysis of Thin Wings.** *Prerequisite: Aero. Eng. 131 or equivalent, Math. 150.* (*3*).
Application of the theorem of minimum potential and complementary energy, Galerkin's method, finite difference approximations, and relaxation procedures to the deformation and stress analysis of low aspect ratio wings.

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.

246. **Flight Mechanics of Space Vehicles.** *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.

248. Feedback Control. Elect as Instr. Eng. 248 and 249.

250. Introduction to Nonlinear Systems. Elect as Instr. Eng. 250.

251. Theory of Nonlinear System Response. Elect as Instr. Eng. 251.

252. Seminar on Simulation and Solution of Nonlinear Systems. Elect as Instr. Eng. 252.

262. Combustion and Flame Propagation. *Prerequisite: permission of instructor.* (*2*).

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.

273. Theory of Linear Time–Variant Systems. Elect as Instr. Eng. 273.

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.

275. Applications of the Differential Analyzer. Elect as Instr. Eng. 275.

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.

BACTERIOLOGY*

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

109. Bacteriology for Engineers. I. (*4–2*).

Lectures and laboratory. Principles and techniques of microbiology with an introduction of their application to the several fields of engineering.

151. Bacterial Physiology. *Prerequisite: Bact. 101 or Bact. 109.* II. (*4–2*).

Lectures and laboratory. Study of the structure and function of bacterial cells.

*Medical School

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. (*2*).
Lectures and laboratory to illustrate the application of microbiology in industry.

BUSINESS ADMINISTRATION*

Professors Dixon, Dykstra, Moore, Schmidt, and Woodworth; Associate Professors Jones and Rewoldt; Assistant Professors Bett and Leabo.

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.

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.

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.

111. Thermodynamics. *Prerequisite: Chem.-Met. Eng. 2 and Math. 54 or 56. (3).*
Laws of energy applied to continuous or flow processes, chemical equalibria, properties of materials and solutions, heat, work, and the concept of availability.

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. (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. (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. (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. (This is a combination of the current Chem.-Met. Eng. 104 and 131.)

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.* II. *(3).*

Chemical engineering calculations on unsteady-state heat and mass transfer, stagewise or column-plate operations, chemical reactions, fluid flow, and thermodynamics.

204. Polymerization Processes. *Prerequisite: Chem.-Met. Eng. 125. (3).*

Mechanisms of polymerization, copolymerization, and degradation; effects of reaction variables on molecular weight, molecular weight distribution, branching, and crosslinking. Lectures, recitations, and laboratory.

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.

208. Structures and Properties of High Polymers. *Prerequisite: Chem.-Met. Eng. 125. (3).*
Properties of polymeric materials in relation to the molecular and structural characteristics of the polymer, the behavior of compounding agents, and the conditions of fabrication. Lectures, recitations, and laboratory.

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. *Prerequisite: 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).*
Structure 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. 114 or 115 and 117, 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: preceded or accompanied by Chem.-Met. Eng. 130.* I. *(3).*
Properties of petroleum gases and liquid under pressure, the production and processing of natural gas and crude oil.

238. **Fermentation Processes.** *Prerequisite: Bact. 111E 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.

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

296. Nuclear Reactor Fuels and Fuels Processing. *Prerequisite: Nuclear Eng. 191 or permission of instructor.* (*3*).
Origin, preparation, and refining of virgin and reprocessed reactor fuels. Basic nuclear reactions and processes for recovery of radioactive fission products.

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*

Professors Anderson, Brockway, Elderfield, Elving, Halford, Parry, and Westrum; Associate Professors Bernstein, Case, Meinke, Rulfs, Smith, Tamres, Taylor, and Vaughan; Assistant Professors Geiduschek, Nordman, Stiles, and Weatherill; Dr. Atkinson, Dr. Berry, Dr. De Rocco, Dr. Gordus, Dr. Hartzler, Dr. Ireland, Dr. Jaselskis, and Dr. Schilt.

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.

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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.

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: Chem. 20 and calculus.* 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. 13.* 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. 14.* 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. 2.* I and II. (*3*).
Triangulation, local control surveys, astronomical observations, Public Land surveys. Computation and adjustment, field observations.

4. Basic Surveying. *Prerequisite: Math. 13.* 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; circular curves, computation, use of calculating machines.

5. **Surveying Problems.** *Prerequisite: Civ. Eng. 4 or approximate equivalent.* I and II. (*2*).

A short course for students with surveying experience to prepare them for further work in surveying, such as Civ. Eng. 2 or 3.

12. **Surveying.** *Prerequisite: Math. 13.* (*3*).

Similar to Civ. Eng. 1. Designed for forestry students.

20. **Structural Drafting.** *Prerequisite: Draw. 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.* (*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. **Geodesy.** *Prerequisite: Civ. Eng. 101.* (*2*).

Methods employed and field covered by the U. S. Coast and Geodetic Survey.

105. **Geodetic Measurements and Electronic Computers.** *Prerequisite: Math. 54.* (*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. Advanced Surveying. (*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*).

Surveys for streets, grades, paving, sewers, property lines, subdivisions.

113. Aerial Photogrammetry and Mapping. *Prerequisite: preparation in trigonometry and physics.* (*2*).

Map projections and map making from aerial photographs.

115. Boundary Surveys. *Prerequisite: Civ. Eng. 1 or equivalent.* (*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. (*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 (formerly Civ. Eng. 230). Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 23 and 121.* 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. 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.* (*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.* II. (2).

Laboratory exercises to demonstrate principles of water purification and sewage treatment; development of basic design data.

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.* (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.* (*To be arranged*).
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 of 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. Text, 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. II. (*3*).
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.

232. **Numerical and Experimental Stress Analysis.** (*3*).
Stress-strain relations; strain gaging and strain-rosette analysis; structural test methods. Numerical stress analysis. Bending of flat plate with numerical analysis of special plate problems.

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 ma-

terials, 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.

DRAWING (ENGINEERING)

The first-year requirements in engineering drawing may be fulfilled by Drawing 1 and 2, or 21 and 22. The student will elect whichever sequence is advised by the classifier. Drawing 21 and 22 are primarily for Schedule S.

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. Draw. 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.

21. Graphics and Engineering Drawing. *Prerequisite: solid geometry, preceded or accompanied by Math. 33 and Physics 53.* (Primarily for Schedule S.) 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. Draw. 21, preceded or accompanied by Math. 34 and Eng. Mech. 11.* (Primarily for Schedule S.) 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: Eng. Draw. 2 or 22, or permission of instructor.* I and II. (*2*).

Analysis of the construction and use of charts; study of the purpose, scope, and use of chart forms with reference to the presentation of specific data; construction and use of computing charts, including nomographs.

33. **Advanced Engineering Drawing.** *Prerequisite: Eng. Draw. 2 or equivalent.* 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. Draw. 1 or its 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 constructions, lettering practice, orthographic projection, dimensioning, and elementary working drawings. As far as possible, drawing assignments are taken from material with which the forestry student will later have contact.

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. Draw. 101 and permission of instructor.* (*2*).

Continuation of Eng. Draw. 101, for students in Education.

ECONOMICS*

Professor Ackley; Professors Boulding, Dickinson, Haber, Katona, Morgan, Paton, Peterson, Remer, and Stolper; Associate Professors Brazer, Lansing, Levinson, Palmer, Smith, and Suits; Assistant Professors Bornstein and Mueller; Lecturers Anderson, Demsetz, Patrick, and Shearer. 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. Students successfully completing these courses will be admitted to advanced study in economics.

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.

101, 102. Money and Credit. *Prerequisite: Econ. 53 and 54. Econ. 101 is prerequisite to Econ. 102.* 101, I and II; 102, I and II. (*3 each*).

Nature and functions 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*).

The background, development, and current aspects of the major problems of wage earners and labor relations. 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 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. 51 and 52.* 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.

*College of Literature, Science, and the Arts

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.* I. (*3*).
Nature and problems of the transportation industry from the standpoint of government regulation.

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 Economic Society. I and II. (*3*).
For 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.

ELECTRICAL ENGINEERING

3. Circuits I. *Prerequisite: preceded or accompanied by Math. 53 or preceded by Math. 34.* (*4*).
Direct-current and alternating-current circuits. Kirchhoff'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 four-hour computing period, and one four-hour laboratory.

4. Direct-Current Machinery. *Prerequisite: Elec. Eng. 3.* (*2*).
Dynamo structure, analysis of the magnetic circuit; motor and generator operating characteristics, losses and heating, armature windings, commutation; special d.c. machines such as the Rosenberg generator and the amplidyne. One lecture and one four-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 tech-

niques. 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.

82. Introduction to Industrial Electronics I. *Prerequisite: Math. 8 and 13, or permission of instructor. (2).*

Discussion of force actions and energy relations of electrostatic and electromagnetic fields; capacitance and inductance of systems and conductors. Introduction of Kirchhoff's laws; network theorems; elementary treatment of electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices and electron tube characteristics. Introduction to rectifier circuits; elementary amplifier and oscillator circuits.

83. Introduction to Industrial Electronics II. *Prerequisite: Elec. Eng. 82 or permission of instructor. (2).*

Application of electron tubes and semiconductors as circuit elements. Amplifiers, oscillators, waveform generation, multivibrators and sawtooth generators, introduction to feedback theory as applied to amplifiers and elementary control systems. Study of electronic instruments. Introduction to electronic system design and operation.

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 closed-loop systems including transient and steady-state response. Discussion of electronic equipment and systems, computers, control systems, and special instruments and devices. Lectures and laboratory.

100. Circuits II. *Prerequisite: Elec. Eng. 3. (4).*

Representation of complex waveforms, effective and average values, power, effects in circuits; network theorems; networks by loop and node methods; impedance-admittance inversions; locus diagrams; three-phase circuits; harmonic analysis; Fourier integral; transients by classical and Laplace methods; electrical lines with distributed constants.

101. Networks and Lines. *Prerequisite: Elec. Eng. 100. (3).*
General network analysis; artificial lines, attenuators, filters, equalizers; transmission of electric waves on lines; reflections at terminals. Lectures.

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.

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. Materials in Electrical Engineering. *Prerequisite: Elec. Eng. 10 or permission of instructor. (2).*
Electric and magnetic properties of materials commonly used in the electrical engineering application. A discussion of insulators, semiconductors, conductors, dielectric and magnetic phenomena as affected by frequency, temperature, and other environmental factors. Nonlinear magnetic and dielectric materials. Characteristics of devices making use of these properties.

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. 100 and 150, 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. 150, or preceded by Elec. Eng. 5. (2).*
Corporate finance, cost of replacements, economic decay, obsolescence, plant location, and conductor section.

150. Alternating-Current Machinery. *Prerequisite: Elec. Eng. 4. (4).*
Theory and operating characteristics of transformers, polyphase synchronous and induction machines; various types of single-phase motors, selsyn devices. Lectures and laboratory.

151. Induction Machinery. *Prerequisite: Elec. Eng. 150. (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.

155. Automatic Control Systems. *Prerequisite: Elec. Eng. 87 or Elec. Eng. 7 and 100 or Elec. Eng. 100 and 180. (4).*
Study of the dynamic performance of d.c. and a.c. motors using automatic open-loop control. Characteristics of closed-loop control systems; transfer function analysis and conditions governing the stability of closed-loop control systems;

applications to speed, voltage regulations, and process control systems. 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. Illumination and Photometry. *Prerequisite: preceded by Physics 46, and preceded or accompanied by Math. 54.* (2).

Concepts, quantities, units; theory and use of typical measuring devices; calculation of illumination from point, line, and surface sources of light; laws of vision as they affect lighting; characteristics of lamps; industrial, office, school, and residence lighting. Two lectures and one two-hour laboratory.

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. Electron and Semiconductor Devices I. *Prerequisite: Elec. Eng. 3 or 5; preceded or accompanied 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; transistor 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 patterns and operating and personnel practices in major engineering establishments; the nature of operations research; stages in the growth of a new engineering field; compatibility 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.

188. Photoelectric Cells and Their Applications. *Prerequisite: permission of instructor.* (*2*).

Operating characteristics of photoelectric cells; amplifying circuits and relays; industrial applications; photoelectric photometers. Lectures and laboratory.

189. Electron and Semiconductor Devices II. *Prerequisite: Elec. Eng. 180, or permission of instructor.* (*4*).

Conformal analysis of fields in space-charge control tubes; transit-time loading, electron transit-time principles; electron optics of cathode-ray focusing; secondary emission and photoelectric phenomena; television pickup and memory storage tubes; initiation of current in thyratrons, ignitrons, glow tubes, and circuit breakers; Paschen's law; radiation-counter tubes.

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. 101.* (*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 Materials. *Prerequisite: Elec. Eng. 110 or 112 or permission of instructor.* (*3*).

Structure of matter. Theory of dielectric constants; dielectric breakdown. Ferroelectricity and ferromagnetism. Conductors and insulators. Electromagnetic waves in isotropic and anisotropic media. Discussion of selected solid-state devices.

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: preceded or accompanied by Elec. Eng. 121.* (*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 systems.

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. 100 and 150.* (*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 and 140.* (*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. 100 and 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 the 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 and 150.* (*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 and 150.* (*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. Attentuation and reflection of traveling waves. Ground wires, counterpoise, and application of lightning arresters.

251. Alternating Current Apparatus. *Prerequisite: Elec. Eng. 150.* (*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. 150.* (*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. Servomechanisms I. *Prerequisite: preceded or accompanied by Elec. Eng. 201 or Math. 147.* (*3*).
Design of automatic control systems, including mathematical theory. Labora-

tory work on the analysis of several control systems and their simulation on the differential analyzer. Two lectures and one four-hour laboratory.

256. Servomechanisms II. *Prerequisite: Elec. Eng. 255 or equivalent.* (*3*).

Analysis and synthesis of linear control systems using log-modulus contour, root locus, zero-pole configuration, and analysis of nonlinear control systems using phase-plane techniques. Lectures and laboratory demonstrations on the differential analyzer.

257. Introduction to Navigation Systems. *Prerequisite: Elec. Eng. 255 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. 150 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.

283. **Physical Electronics.** *Prerequisite: Elec. Eng. 180 and Math. 150.* (*3 or 2*).
Theory of thermionic, photoelectric, and field emission; initial electron velocity effects; space-charge suppression of shot noise; high-density beam formulation, focusing, hysteresis, and instability. Probe measurements, ambipolar diffusion, balance relationships, electron and ion characteristic frequencies in plasmas; electron and ion mobilities and ionization rates; initiation of microwave gas discharges. Lectures and optional 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.* (*2*).
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.** *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 high density beams, conservation of momentum, Busch's theorem, confined flow, Brillouin flow; space-charge wave analysis; velocity modulation, klystrons, small-signal traveling-wave tubes, backwardwave oscillators, magnetron oscillators and magnetron amplifiers. Lecures and laboratory.

287. **Special Topics in Microwave Circuits and Tubes Seminar.** *Prerequisite: Elec. Eng. 286 or permission of instructor.* (*3*).
Effect of magnetic field on space-charge wave propagation, electric and magnetic lenses, periodic magnetic focusing, Harris flow, electrolytic tanks; linear and nonlinear carcinotron theory; large-signal traveling-wave tubes, magnetron amplifiers and oscillators; Omega-Beta diagrams, periodically loaded waveguides; Masers; linear accelerators; energy theorems for electron streams. Lectures.

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.

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.* 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; demonstrations 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 I.** *Prerequisite: Eng. Mech. 1 or 5 and Math. 54.* I and II. (*3*).
The basic principles of mechanics are applied to liquid and gaseous fluids. Continuity, momentum, and energy relations are derived for typical problems. 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.** *Prerequisite: 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.* (*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 jets 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 4 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.*

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.*

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.*

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. 2 and 3, and Math. 103 and 150. (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. 2, Math. 103 and 150. (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 and 3. (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. 2, Math. 103 and 150.* (*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. 124.* (*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, Math. 103 and 150.* (*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. 124 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.* (*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. 3, Math. 103 or 104, or permission of instructor.* I. (*2*).
General theory; rate gyros, freely gimbaled gyros, rate of turn gyros; gyro-stabilization, 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.

141. Mechanics of Inviscid Fluids I. *Prerequisite: Eng. Mech. 4 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 or 150.* (*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 and Math. 150; Eng. Mech. 141 is desirable.*
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. 124, 114, 142.* (*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, Math. 152 and 155.* (*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. 124 and 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. 200.* (*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. 131, 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.

241. **Mechanics of Inviscid Fluids II.** *Prerequisite: Eng. Mech. 141 and 142; others by special permission.* (*2*).

Stream functions for general three-dimensional flows, 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, waves in flowing water; 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 in general co-ordinates. Navier-Stokes equations in general co-ordinates by tensor methods, solutions of Navier-Stokes equations; 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 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.

136. Technical Report. *Open to seniors and graduate students only.* (*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 Dar-

win'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, Kellum, Landes, Stumm, and Turneaure; Associate Professors Belknap, Briggs, Kesling, and Zumberge; Assistant Professors Dorr, Eschman, and Kelly; Dr. 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 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.

*College of Literature, Science, and the Arts

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. Lectures, recitations, and problems.

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 laboratory.

123. 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, problems, and laboratory.

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.

126. Human Engineering Problems. *Prerequisite: Ind. Eng. 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.

*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.

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.* 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.

151. 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.

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.

200. 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*).
Individual or group study, design, or laboratory research is in 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.
Permission of the individual instructor should be obtained before classification. The course may be elected in more than one semester with approval of the adviser.

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 manage-

*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.

ment. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A laboratory 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 laboratory fee is required.

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.

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.

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.

INSTRUMENTATION ENGINEERING

170. **Seminar on Electronic Analog Computers (formerly Aero. Eng. 170).** *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.

172. **Introduction to Instrument Dynamics (formerly Aero. Eng. 172).** *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5, and a course in differential equations.* (*2*).
Treatment of instrument response and errors including static, steady-state, and transient behavior; gyros, accelerometers, seismic instruments, and other measuring devices. Dynamic and steady-state response of first, second, and *n*th order linear systems. Laboratory experiments with physical systems; application of the electronic differential analyzer to the solution of instrumentation problems. Lecture and laboratory.

174. **Principles of Automatic Control (formerly Aero. Eng. 174).** *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 Instr. Eng. 174. Use of the electronic differential analyzer for simulation and as a design tool.

175. **Applications of the Electronic Differential Analyzer I (formerly Aero. Eng. 175).** *Prerequisite: a course in differential equations.* (*2*).

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 (formerly Aero. Eng. 177).** *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 (formerly Aero. Eng. 178).** *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 (formerly offered under Aero. Eng. 181).** (*To be arranged*).

Individual study of specialized aspects of instrumentation engineering.

184. **Research (formerly offered under Aero. Eng. 182).** (*To be arranged*).

Specialized individual or group problems of research or design instrumentation supervised by a member of the staff.

210. **Advanced Engineering Measurements (formerly Aero. Eng. 210).** *Prerequisite: Instr. Eng. 172 and 177, Elec. Eng. 108, and Math. 148.* (*3*).

Transfer functions and impulse response characteristics of linear systems; synthesis and analysis by the Fourier transform; power spectra and correlation functions of signal and noise; effects of nonlinear components; modern information theory used in analyzing instrumentation and the design of experiments; the role of calculating machines in the treatment of experimental data.

214. **Information Theory and Radio Telemetry (formerly Aero. Eng. 214).** *Prerequisite: Instr. Eng. 172 and 177, Elec. Eng. 120, 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 (formerly Aero. Eng. 215).** *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 (formerly Aero. Eng. 248). *Prerequisite: Instr. Eng. 174 or Elec. Eng. 255 or equivalent, and Math. 148. (3).*

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 (formerly Aero. Eng. 250). *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 (formerly Aero. Eng. 251). *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 (formerly Aero. Eng. 252). *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 (formerly Aero. Eng. 273). *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 the electronic differential analyzer for the solution of problems is demonstrated.

275. Applications of the Differential Analyzer II (formerly Aero. Eng. 275). *Prerequisite: Instr. Eng. 175 or equivalent. (2).*

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; behavoir 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.

385. **Seminar.** (*To be arranged*).

MATHEMATICS*

Professor Hay; Professors Bartels, Bott, Carver, Churchill, Coburn, Copeland, Craig, Dwyer, Fischer, Jones, Kaplan, Moise, Nesbitt, Piranian, Rainville, Rothe, Samuelson, Thrall, Wilder, and Young; Associate Professors Darling, Dolph, Dushnik, LeVeque, Lohwater, Lyndon, McLaughlin, Reade, and Wendel; Assistant Professors Addison, Clarke, Dickson, Galler, Gehring, E. L. Griffin, Harary, Higman, Kazarinoff, Kruskal, Leisenring, Livingstone, Mayerson, Remmert, Ritt, Shields, Titus, Ullman, and Wesler; Mr. Bedient, Mr. Brooks, Dr. Davison, Mr. Deal, Mr. Finney, Dr. Goldman, Dr. Greenstein, Dr. J. S. Griffin, Dr. Halpern, Dr. Hicks, Mr. Klein, Mr. Korfhage, Mr. Lazerson, Dr. Low, Dr. Palermo, Mr. Stampfli, Mr. Woolf; Lecturers, Dr. Albrecht, Mr. Bell, Dr. Evans, Dr. Karrer, Dr. Kincaid, Dr. Nagao, and Dr. Weil.

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.

*College of Literature, Science, and the Arts

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.

20. Introduction to Air Navigation. I. (*3*).

Graphical and numerical methods of solving geometrical problems arising in air navigation; solution of wind diagrams, and drift on two headings; plane, Mercator, and great circle flyings; radius of action and intercept problems; bearing and fixes.

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.

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 integrals; introduction to differential equations.

55. Analytic Geometry and Calculus III. *Prerequisite: Math. 34.* I. (*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.

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; solutions 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 1959–60.]

[142. **Theoretical Mechanics II.** Omitted in 1959–60.]

[145. **Celestial Mechanics.** Omitted in 1959–60.]

147. Modern 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, transient 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.* 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.

[154. **Advanced Calculus II.** Omitted in 1959–60.]

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 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 principle; 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 1959–60.]

173. **Methods in High-Speed Computations I (Computer Algorithms).** *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, differential equations, linear programing, etc. Laboratory work in programing and operating the IBM Type 650 and Type 704 digital computers.

174. **Methods in High-Speed Computation II (Numerical Analysis).** *Prerequisite: Math. 103 or 104, and 113, and 173, or equivalent.* **I and II.** (*3*).
The mathematics used with high-speed electronic computing machines. Presents attacks on: integration of ordinary differential equations, solutions of large-scale linear systems, determination of eigenvalues and eigenvectors, inte-

gration 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.** *Prerequisite: Math. 150 or 151.* II. *(3).*
Newtonian attraction, Newtonian and logarithmic potentials, the equations of Laplace and Poisson, harmonic functions, principle of Dirichlet, the problems of Dirichlet and Neumann, the Green's function.

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.** *Prerequisite: permission of instructor.* I. *(2).*
Problems illustrating methods used in analyzing transient and steady diffusion in solids. The use of Fourier and generalized Fourier series and integrals, integral transforms, Green's functions, conformal mapping, similarity transformations in the resolution of problems; properties of flow.

[243. **Mathematical Theory of Turbulence.** Omitted in 1959–60.]

[244. **Compressible Fluid Flows.** Omitted in 1959–60.]

[245. **Advanced Mechanics.** Omitted in 1959–60.]

[246. **Hydrodynamics.** Omitted in 1959–60.]

247. **Mathematical Elasticity.** I. *(3).*
Analysis of stress, equations of equilibrium, analysis of strain, equations of compatibility, stress-strain relations, elastic energy, extension, torsion, and flexure of homogeneous beams. Plane stress; plane strain; Airy's stress function and the biharmonic equation; thin plates and shells.

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. **Topics in Mathematical Physics.** *Prerequisite: Math. 150 and 152.* I. *(3).*
Boundary value problems and initial value problems; elliptic, hyperbolic, and parabolic equations; method of integral equations, expansion in characteristic function, Green's function; variational methods.

[251. **Modern Topics in Mathematical Physics.** Omitted in 1959–60.]

[252. **Advanced Fourier Analysis.** Omitted in 1959–60.]

[255. **Direct Methods in Calculus of Variations.** Omitted in 1959–60.]

[256. **Nonlinear Differential Equations.** Omitted in 1959–60.]

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.** II. *(3).*
Definition of tensors; tests for tensor character; manifolds; geodesics; absolute derivatives, covariant and contravariant 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.* 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; mechanical properties of nonmetals such as cement and plastics. 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. 53.* 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 mechanisms 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, and preceded or accompanied by Eng. Mech. 2.* (*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. Considers a variety of processes in the areas of machining, plastic-working, foundry and welding. Three recitations and one two-hour demonstration.

33. **Manufacturing Processes II.** *Prerequisite: Mech. Eng. 31.* (*3*).

Capabilities of manufacturing processes. Design features obtainable in terms of dimensional accuracy, surface finish, and economy. The interrelation of materials, process, and design.

80. **Dynamics of Machinery.** *Prerequisite: Eng. Mech. 2 and 3, Eng. Draw. 2 or 12.* I and II. (*2*).

Application of dynamics to machinery. Analysis of velocities, accelerations, and forces in machines; vibration analysis and balancing. Two two-hour periods.

82. **Machine Design I.** *Prerequisite: Eng. Mech. 2, and preceded or accompanied by Chem.-Met Eng. 107 and Mech. Eng. 32.* 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 fluids machinery.

105. **Thermodynamics I.** *Prerequisite: Physics 45 and Math. 53.* 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. 54.* I and II. (*3*).
Continuation of Mech. Eng. 105. Systems involving chemical reactions, with emphasis on combustion; power and refrigeration cycles; flow through nozzles and blade passages; general thermodynamic relations, equations of state, and compressibility factors; gaseous dissociation.

107. **Applied Energy Conversion.** *Prerequisite: Mech. Eng. 106 or equivalent.* II only. (*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, atomic energy, power plant economics, load curves, energy rates. Selected power plant problems are assigned.

108. **Mechanical Engineering Laboratory.** *Prerequisite: Mech. Eng. 17.* I and II. (*3*).
Experimental study of a steam turbo-electric plant, C.F.R. engine, fan, steam injector, air compressor, air conditioning and refrigerating plant, Unaflow steam engine, centrifugal pump, and impulse water turbine. Laboratory, computations, and reports. One four-hour laboratory.

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. Spectrographic analysis. Optical methods for combustion studies. Otto, diesel, gas turbine, and rocket combustion.

113. **Steam Turbines.** *Prerequisite: Mech. Eng. 106.* I. (*3*).
Application of the laws of thermodynamics, fluid flow, and kinetic effects to the steam turbine; various types and forms of turbines; applications, including electric generation and marine propulsion; general principles of governing.

114. **Internal-Combustion Engines.** *Prerequisite: Mech. Eng. 106.* I and II. (*3*).
Thermodynamic analysis of various internal-combustion engine cycles as used by both piston and turbine type engines; fuels, combustion, detonation; fuel systems, superchargers, and other auxiliaries as they apply to these 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.

120. Refrigeration and Air Conditioning. *Prerequisite: Mech. Eng. 106.* II. (*3*).
Theory, design, and construction of refrigerating and air-conditioning equipment; characteristics of various refrigerants; the application of refrigeration to cold storage, ice making, and air-conditioning.

122. Plastic Working of Metals. *Prerequisite: Mech. Eng. 32, Eng. Mech. 2 and accompanied by Mech. Eng. 186 or Eng. Mech. 123, or permission of instructor.* I and II. (*3*).
Study of the plastic deformation of metals in relation to their mechanical properties and metallurgical aspects; true stress, true strain analysis, criteria of yielding and fracture, strength theory, in extrusion, ideal plastics, strain hardening; analysis of piercing, pressing, forging, rolling, drawing; friction, slip line method.

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.

132. Manufacturing Engineering. *Prerequisite: Mech. Eng. 32.* I and II. (*3*).
Application of fundamental principles to problems arising in manufacturing. Particular attention is devoted to planning operations, designing special equipment, operations research, 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.

134. Plastics Fabrication. *Prerequisite: Mech. Eng. 31 or 32 and Eng. Mech. 4.* I. (*2*).
Principles underlying the design of products manufactured from plastic materials; correlation of properties of materials and process limitations with the functional requirements of the product, followed by problems and cost studies. Two lectures and one two-hour design period.

135. Die Casting and Powder Metallurgy. *Prerequisite: Chem.-Met. Eng. 13 and 125, or Chem.-Met. Eng. 107 and 11 or 12.* II. (*2*).
Development of die-casting alloys and practice; modern alloys, machines, alloying, casting, machining, and finishing practice; elements of the die and product

design for the economical utilization of die castings; costs of die castings; underlying theoretical principles of powder metallurgy; characteristics, preparation, and treatment of metal powders, compacting and sintering, and equipment. One lecture, one recitation, and one two-hour design period.

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.

143. **Design of Pumping Machinery.** *Prerequisite: Mech. Eng. 82 and 104 or equivalent and Mech. Eng. 142.* II. (*3*).
Calculations and drawings for a centrifugal or reciprocating pump. Special attention is given to the design of runners, casings, and valves.

150. **Automobiles and Motor Trucks.** *Not open to students below senior level except by permission of instructor.* I and II. (*3*).
Fundamental principles of construction, operation; application in current practice; engine cycle, details of construction, cooling, lubrication, carburetion, electrical systems, clutch, transmission, axle, differential, steering, springs, brakes; engine and car testing, performance curves, operations and control. Lectures, recitations, and laboratory demonstrations.

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 and 150, or permission of instructor.* 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. 150 or permission of instructor.* 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 or 150.* I and II. (*3*).
Experimental study of automobile and aircraft engines, including horsepower, fuel economy, thermal efficiency, mechanical efficiency, heat 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. 150 or permission of instructor.* II. (*3*).
Frames, bodies, and cabs in automobiles, trucks, and tractors; unit-body versus 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.

161. Aircraft Power Plants — Experimental Tests. *Prerequisite: Mech. Eng. 17 and 114.* I and II. (*3*).

Experimental study of aircraft engines, test apparatus, and methods, and the determination of their characteristic performance, including speed, timing, mixture ratios, compression ratio, and fuels.

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.

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 one-hour recitations and one three-hour laboratory.

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. **Production Factors in Product Design.** *Prerequisite: Mech. Eng. 82.* II. (*3*).
Correlation between functional specifications and process influence. Case studies in operation routing. Machine tools, accessories, inspection instruments and cutting fluids, speeds, feeds, operation time, handling time for various sequences of operation.

183. **Wear Consideration in Design.** *Prerequisite: Mech. Eng. 82 or 83.* 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 equivalent.* 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.

200. **Study or Research in Selected Mechanical Engineering Topics.** *Prerequisite: senior or 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.
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.

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.

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.

327. **Air Conditioning 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.

355. **Automotive 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.

METEOROLOGY

4. **Weather, Climate, and Life (formerly Civ. Eng. 92).** *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 (formerly Civ. Eng. 90). *Prerequisite: preceded or accompanied by Math. 7 or equivalent.* Credit will not be 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 (formerly Civ. Eng. 91). *Prerequisite: Meteor. 4 or 104.* Credit will not be 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 (formerly Civ. Eng. 501). *Prerequisite: upperclass or graduate standing or permission of instructor. Not open to engineering students. (2–3).*

Lectures and discussions on elementary meteorology, combined with workshop on problems of introducing meteorology into individual school programs; survey of material sources, demonstration methods, laboratory and field exercises and equipment design. For science teachers of all levels.

115. Micrometeorology I (formerly Civ. Eng. 194). *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.

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 (formerly Civ. Eng. 191). *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 (formerly Civ. Eng. 192). *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).*

Methods of weather observation; the systematic dissemination of meteorological information; meteorological symbols and their use in graphical presentation; introductory analysis of weather patterns.

136. Laboratory in Synoptic Meteorology II (formerly Civ. Eng. 193). *Prerequisite: Meteor. 135.* II. *(3).*

Application of air mass analysis principles to the preparation of weather maps at various levels in the atmosphere; the use of thermodynamic diagrams in forecasting problems; the construction of prognostic pressure charts and atmospheric cross-sections; practice weather forecasts and their 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 (formerly Civ. Eng. 195). *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 (formerly Civ. Eng. 198). *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 (formerly Civ. Eng. 199). *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.

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, 126, 153, and 162 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 (formerly Civ. Eng. 294). *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 (formerly Civ. Eng. 296). *Prerequisite: Meteor. 182 and 186 or equivalent.* I. (*3*).
Realistic interpretation of climatic information; space and time interpolation and exterpolation of climatic factors; combined effects of weather elements; methods of determining the specific applications of climatic knowledge. Lectures and the analysis of practical examples.

293. **Meteorological Research** (formerly Civ. Eng. 295). *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.

297. **Interdepartmental Seminar on Applied Meteorology** (formerly Civ. Eng. 297). *Prerequisite: permission of instructor.* I and II. (*1–3*).

Reading, preparation of term papers, and seminar discussion on various areas of applied meteorology. Course credit assigned each student at 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. Draw. 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.** (*To be arranged*).

127. **Stress Analysis of Structures in Ship Design.** *Prerequisite: Eng. Mech. 126.* (*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.* (*2*).

The motion of ships at sea, rolling, pitching, sea-keeping qualities; steering and maneuvering.

132. Ship Design I. *Prerequisite: senior standing.* (*2*).

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.* (*3*).

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.* (*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 commercial 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.

141. Marine Propulsion Machinery. *Prerequisite: Mech. Eng. 105 and preceded or accompanied by Eng. Mech. 4.* I. (*2*).

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. (*2*).

Piping systems; electrical distribution; engine room auxiliaries; deck machinery; steering gear; and emergency apparatus.

151. **Resistance, Power, Propellers.** *Prerequisite: Nav. Arch. 12.* II. (*3*).
All items affecting the resistance and propulsion of various ships' forms, investigation of the theory and practice involved in the design of propellers, and methods of conducting trial trips, etc.

152. **Ship Model Theory.** *Prerequisite: Eng. Mech. 4 and Nav. Arch. 12.* I and II. (*3*).
Theory of model testing, with particular attention to surface vessels; methods of estimating speed, power, and revolutions. A model is towed in the tank, and resistance, trim, wake, and other data are worked up.

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 fields 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: preceded by 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: Nuclear Eng. 191 or permission of instructor.* 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. **Applications of Nuclear Radiations.** *Prerequisite: preceded or accompanied by 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.

291. Interaction of Radiation and Matter. *Prerequisite: Nuclear Eng. 191 or permission of instructor.* (*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 attentuation, shield optimization, heat generation and removal in shields, and other related problems.

294. Wave Mechanics in Nuclear Engineering. *Prerequisite: Nuclear Eng. 191.* (*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 interaction.

295. Theory of Nuclear Reactors. *Prerequisite: Nuclear Eng. 191 and Math. 150.* (*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 design, reactor control, shielding, fluid flow, turbomachinery, heat transfer, and stress analysis parameters to over-all nuclear powerplant design. Connections between these various fields and their interrelations are examined.

298. Nuclear Reactor Laboratory. *Prerequisite: Nuclear Eng. 192 and 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 sessions.

299. Directed Research in Nuclear Engineering. (*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.

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 multigroup 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.

PHYSICS*

Professor Dennison; Professors Case, Crane, Glaser, Hazen, Laporte, Parkinson, Pidd, Sawyer, Uhlenbeck, Wiedenbeck, Wolfe; Associate Professors Hough, Katz, Krimm, McCormick; Assistant Professors Chagnon, Ford, Franken, Hecht, Jones, Lewis, Meecham, Meyer, Perl, Peters, Sands, Sherman, Terwilliger, Trilling; Instructors Brown, Fregeau, Kadyk, Nelson, Sinclair, Vander Velde.

45. **Mechanics, Sound, and Heat.** I and II. *(5).*

Calculus should be elected concurrently. 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.* 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.

*College of Literature, Science, and the Arts

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.

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. (*3*).

The characteristics of electron tubes and transistors, and their functions in electric circuits such as amplifiers and oscillators. Two 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. (*2*).

The Navier-Stokes equation is developed and is used to treat several classical problems. The student is introduced to elementary aspects of turbulence, shock waves, and hydromagnetics.

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.* Sec. A, I and II; Sec. B, I, for Science Engineering program.
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 applications 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. Experimental 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 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 (formerly 2001). *Prerequisite: Math. 55 and Chem. 14.* (*4*).
Introduction to thermodynamics.

112. Rate Processes. *Prerequisite: Eng. Mech. 14, Math. 56, and a course in thermodynamics.* (*4*).
A unified study of heat, mass, momentum transfer, and chemical reaction kinetics, with emphasis upon the background of existing theories and applications to the design of equipment.

Committees and Faculty*

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ex officio

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M. J. SINNOTT, term, 1956–60
†J. G. TARBOUX, term, 1957–61
L. M. LEGATSKI, term, 1958–62

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*Listed for the academic year, 1958–59.
†Deceased, February 6, 1959.

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*Effective July 1, 1959.

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Movses Jeremy Kaldjian, M.S., *Instructor in Engineering Mechanics*

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Walter Ralph Debler, M.S., *Instructor in Engineering Mechanics*

Richard Christian Wilson, M.S., *Instructor in Engineering Mechanics and in Industrial Engineering*

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*

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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*

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W. HARRY MACK, A.M., *Assistant Professor Emeritus of English, College of Engineering*
EDMUND PENDLETON DANDRIDGE, JR., A.M., *Instructor in 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*

INDUSTRIAL ENGINEERING

WYETH ALLEN, B.M.E., D.Eng., *Professor of Industrial Engineering and Chairman of the Department of Industrial Engineering*
EDWARD LEERDRUP ERIKSEN, B.C.E., *Professor Emeritus of Engineering Mechanics and Lecturer in Industrial Engineering*
CHARLES BURTON GORDY, Ph.D., *Professor Emeritus of Industrial Engineering*
MERRILL MEEKS FLOOD, Ph.D., *Professor of Industrial Engineering*
ROBERT MCDOWELL THRALL, Ph.D., *Professor of Operations Analysis, Department of Industrial Engineering, and Professor of Mathematics, College of Literature, Science, and the Arts*

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*

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.), *Associate Professor of Industrial Engineering*

William D. McIlvaine, M.S., *Associate Professor of Industrial Engineering and Assistant to the Dean, College of Engineering*

James A. Gage, M.S. (M.E.), *Associate Professor of Industrial Engineering*

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, A.B., *Assistant Professor of Industrial Engineering*

Richard Christian Wilson, M.S., *Instructor in Industrial Engineering and in Engineering Mechanics*

Richard Virdin Evans, D.Eng., *Instructor in Industrial Engineering and Lecturer in Mathematics, College of Literature, Science, and the Arts*

Donald A. Gordon, Ph.D., *Lecturer in Industrial Engineering and Associate Research Psychologist, Willow Run Laboratories*

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*

MECHANICAL ENGINEERING

Gordon John Van Wylen, Sc.D., *Professor of Mechanical Engineering and Chairman of the Department of Mechanical Engineering*

Walter Edwin Lay, B.M.E., *Professor of Mechanical Engineering.* On retirement furlough, 1958–59

Hugh Edward Keeler, M.S.E., M.E., *Professor of Mechanical Engineering.* On retirement furlough, 1958–59

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*

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*

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 DATSKO, M.S.E., *Associate Professor of Mechanical Engineering*

JOSEPH EDWARD SHIGLEY, M.S.E., *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*

HAROLD RHYS LLOYD, M.A., *Associate Professor Emeritus of Mechanical Engineering*

LESLIE E. WAGNER, M.A., *Assistant Professor of Mechanical Engineering*

HOWARD REX COLBY, M.S.E., *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*

KARL ERNST HANS MOLTRECHT, M.S.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*

ROBERT MACORMAC CADDELL, M.S.E., *Assistant Professor of Mechanical Engineering*

LELAND JAMES QUACKENBUSH, M.S.E., *Assistant Professor of Mechanical Engineering*

JULIAN ROSS FREDERICK, Ph.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*

FREDERICK KENT BOUTWELL, M.S.E., *Instructor in 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*

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*

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*

HARRY BELL BENFORD, B.S.E. (Nav. Arch. and Mar.E.), *Associate Professor of Naval Architecture and Marine Engineering*

GEORGE LAUMAN WEST, JR., B.S.E. (Nav. Arch. and Mar.E.), *Assistant Professor of Naval Architecture and Marine Engineering and of Nuclear Engineering*

FINN CHRISTIAN MICHELSEN, M.S.E., *Instructor 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 Assistant Director, Michigan Memorial–Phoenix Project*

WILLIAM KERR, Ph.D., *Professor of Nuclear Engineering and of Electrical Engineering*

LLOYD EARL BROWNELL, Ph.D., *Professor of Nuclear Engineering and of Chemical and Metallurgical Engineering*

RICHARD KENT OSBORN, Ph.D., *Associate Professor of Nuclear Engineering*

FREDERICK GNICHTEL HAMMITT, Ph.D., *Associate Professor of Nuclear Engineering and of Mechanical Engineering*
PAUL FREDERICK ZWEIFEL, Ph.D., *Associate Professor of Nuclear 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*
GEORGE LAUMAN WEST, JR., B.S.E., *Assistant Professor of Nuclear Engineering and of Naval Architecture and Marine Engineering*
CHARLES WILLIAM RICKER, M.S., *Instructor in Nuclear Engineering and Acting Reactor Supervisor, Phoenix Project No. 110*
RICHARD EARL BALZHISER, M.S.E., *Instructor in Nuclear Engineering and in Chemical Engineering*
ARDATH H. EMMONS, M.S., *Lecturer in Nuclear Engineering and Laboratory Supervisor, Phoenix Project No. 110*
JEAN MICHEL PLANEIX, Ph.D., *Lecturer in Nuclear Engineering*

Rules and Procedures

COUNSELING

Counseling services of many types are available. Those who are uncertain concerning procedures or who have special problems may seek advice from the Assistant Dean, 255 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, the taking of a photograph for the student identification card, the adjustment of transfer credit from other colleges, consultation with academic advisers, selection of courses, and payment of fees.

A student with standing above that of freshman should consult with the adviser of the degree program in which he is enrolled, or with his representative who is called a classifier, for advice with respect to academic matters, such as changes in objectives or in his subject electives (see Elections of Courses).

As soon as possible after the opening of a semester, all freshmen are placed in groups of ten to twelve students, each under a faculty counselor. Each group is formed of students living in a single unit of the residence halls.

Freshmen are urged to call on their counselors at their offices, and 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.

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.

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.*

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.*

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.

PLACEMENT MEETINGS

The College conducts a series of placement meetings which includes discussion of a variety of placement and professional subjects, such as the considerations for selecting an engineering position, the techniques for employment interviewing, legal registration of engineers, personal career management, continued education, and so forth.

Although these meetings are planned to be of primary concern to upperclassmen who will soon be starting their careers, they are open to all interested students in the College.

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

ELECTION OF STUDIES

1. Each classifier has the responsibility for the proper election of courses by the student. The classifier 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 classifier 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 Secretary, 263 West Engineering Building. A course may be dropped without record during the first eight weeks of the semester with the consent of the classifier 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 freshman, a course dropped will carry the grade of E.

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 classifier or the Assistant Dean concerning a revision of his elections.

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 classifier 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. 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 nontechni-

cal 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 is possible only in accordance with the rules of the Committee on Curriculum.

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 average semester grade and the general 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 a general average grade below 2.0 in the courses elected in this College may be graduated. A student whose general average or semester average falls below 2.0 should consult with his 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 whose average for the following semester or summer session is 2.0 or better shall be restored to good standing, provided his general 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 general 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 a semester or summer session.

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 reinstated on probation to elect a program in another school or college of this University must obtain permission to classify from the Committee on Scholastic Standing each semester as long as he is registered in the College of Engineering. This provision, in the case of such a student, supersedes paragraphs 5, 6, 7, 8, 9, 10, and 11.

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

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.

Leave of absence will be granted to those who expect to return before the end of the year.

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. (The written approval of parent or guardian is generally required.) This permission must be obtained from the Assistant Dean.

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, drawing, 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.

The credit hours of work required at the University to earn the degree depend upon the quality and extent of the student's preparation. Those who possess average ability and present the admission units as stated under Admission as a Freshman should complete the requirements as any one of the degree programs with 140 hours of credit. Significant acceleration is possible in the cases of those students who are able to achieve earlier the basic level of attainment through the medium of a planned program of preparation in high school or at another college.

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.

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

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, 1959–60

WEDNESDAY, SEPTEMBER 16, 1959

A.M.			P.M.		
8:00– 8:10	Grj	—Gum	1:00–1:10	Joh	—Jones, J.
8:10– 8:20	Gun	—Had	1:10–1:20	Jones, K.	—Kam
8:20– 8:30	Hae	—Hall, Q.	1:20–1:30	Kan	—Kea
8:30– 8:40	Hall, R.	—Ham	1:30–1:40	Keb	—Ker
8:40– 8:50	Han	—Harde	1:40–1:50	Kes	—Kiq
8:50– 9:00	Hardf	—Harrisn	1:50–2:00	Kir	—Kni
9:00– 9:10	Harriso	—Hat	2:00–2:10	Knj	—Koth
9:10– 9:20	Hau	—Hd	2:10–2:20	Koti	—Krug
9:20– 9:30	Hea	—Hei	2:20–2:30	Kruh	—Lami
9:30– 9:40	Hej	—Henl	2:30–2:40	Lamj	—Lawre
9:40– 9:50	Henm	—Her	2:40–2:50	Lawrf	—Leis
9:50–10:00	Hes	—Hile	2:50–3:00	Leit	—Lewi
10:00–10:10	Hilf	—Hoc	3:00–3:10	Lewj	—Lit
10:10–10:20	Hod	—Holl	3:10–3:20	Liu	—Luca
10:20–10:30	Holm	—Hors	3:20–3:30	Lucb	—M(a)cClel
10:30–10:40	Hort	—How	3:30–3:40	M(a)cClem	—M(a)cGi
10:40–10:50	Hox	—Hui	3:40–3:50	M(a)cGj	—M(a)cMa
10:50–11:00	Huj	—Hur	3:50–4:00	M(a)cMb	—Mall
11:00–11:10	Hus	—Irl	4:00–4:10	Malm	—Marsg
11:10–11:20	Irm	—Jack	4:10–4:20	Marsh	—Mat
11:20–11:30	Jacl	—Jog	4:20–4:30	Mau	—Mere

THURSDAY, SEPTEMBER 17, 1959

A.M.			P.M.		
8:00– 8:10	Merf	—Miller, E.	1:00–1:10	Sa	—Sarg
8:10– 8:20	Miller, F.	—Miz	1:10–1:20	Sarh	—Schl
8:20– 8:30	Mj	—Moro	1:20–1:30	Schm	—Schwartz,R.
8:30– 8:40	Morp	—Munm	1:30–1:40	Schwartz, S.	—Send
8:40– 8:50	Munn	—Nax	1:40–1:50	Sene	—Shel
8:50– 9:00	Nay	—Ne	1:50–2:00	Shem	—Siel
9:00– 9:10	Nf	—Nz	2:00–2:10	Siem	—Sk
9:10– 9:20	Oa	—Opa	2:10–2:20	Sl	—Smith, L.
9:20– 9:30	Opb	—Pak	2:20–2:30	Smith, M.	—Sol
9:30– 9:40	Pal	—Pats	2:30–2:40	Som	—Stah
9:40– 9:50	Patt	—Pere	2:40–2:50	Stai	—Steu
9:50–10:00	Perf	—Pick	2:50–3:00	Stev	—Sto
10:00–10:10	Picl	—Pop	3:00–3:10	Stp	—Sup
10:10–10:20	Poq	—Pri	3:10–3:20	Suq	—Tas
10:20–10:30	Prj	—Ram	3:20–3:30	Tat	—Thomp
10:30–10:40	Ran	—Reid, S.	3:30–3:40	Thomq	—Toml
10:40–10:50	Reid, T.	—Richa	3:40–3:50	Tomm	—Tup
10:50–11:00	Richb	—Robertsn	3:50–4:00	Tuq	—Vandeq
11:00–11:10	Robertso	—Rop	4:00–4:10	Vander	—Ver
11:10–11:20	Roq	—Rot	4:10–4:20	Ves	—Walc
11:20–11:30	Rou	—Rz	4:20–4:30	Wald	—Wark

FRIDAY, SEPTEMBER 18, 1959

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	—Cro
9:40– 9:50	Andersf	—Ark	2:40–2:50	Crp	—Daz
9:50–10:00	Arl	—Bab	2:50–3:00	Db	—Din
10:00–10:10	Bac	—Baq	3:00–3:10	Dio	—Dup
10:10–10:20	Bar	—Bas	3:10–3:20	Duq	—En
10:20–10:30	Bat	—Bec	3:20–3:30	Eo	—Fil
10:30–10:40	Bed	—Benr	3:30–3:40	Fim	—Fran
10:40–10:50	Bens	—Bes	3:40–4:00	Frao	—Gau
10:50–11:00	Bet	—Blac	4:00–4:10	Gav	—Goldl
11:00–11:10	Blad	—Boe	4:10–4:20	Goldm	—Gri
11:10–11:20	Bof	—Bot			
11:20–11:30	Bou	—Bra			

SATURDAY, SEPTEMBER 19, 1959

Any student may register from 8:00 to 10:30 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, 1959–60

WEDNESDAY, FEBRUARY 3, 1960

A.M.			P.M.		
8:00– 8:10	Lawrf	—Leis	1:00–1:10	Patt	—Pere
8:10– 8:20	Leit	—Lewi	1:10–1:20	Perf	—Pick
8:20– 8:30	Lewj	—Lit	1:20–1:30	Picl	—Pop
8:30– 8:40	Liu	—Luca	1:30–1:40	Poq	—Pri
8:40– 8:50	Lucb	—M(a)cClel	1:40–1:50	Prj	—Ram
8:50– 9:00	M(a)cClem	—M(a)cGi	1:50–2:00	Ran	—Reid, S.
9:00– 9:10	M(a)cGj	—M(a)cMa	2:00–2:10	Reid, T.	—Richa
9:10– 9:20	M(a)cMb	—Mall	2:10–2:20	Richb	—Robertsn
9:20– 9:30	Malm	—Marsg	2:20–2:30	Robertso	—Rop
9:30– 9:40	Marsh	—Mat	2:30–2:40	Roq	—Rot
9:40– 9:50	Mau	—Mere	2:40–2:50	Rou	—Rz
9:50–10:00	Merf	—Miller, E.	2:50–3:00	Sa	—Sarg
10:00–10:10	Miller, F.	—Miz	3:00–3:10	Sarh	—Schl
10:10–10:20	Mj	—Moro	3:10–3:20	Schm	—Schwartz,R.
10:20–10:30	Morp	—Munm	3:20–3:30	Schwartz, S.	—Send
10:30–10:40	Munn	—Nax	3:30–3:40	Sene	—Shel
10:40–10:50	Nay	—Ne	3:40–3:50	Shem	—Siel
10:50–11:00	Nf	—Nz	3:50–4:00	Siem	—Sk
11:00–11:10	Oa	—Opa	4:00–4:10	Sl	—Smith, L.
11:10–11:20	Opb	—Pak	4:10–4:20	Smith, M.	—Sol
11:20–11:30	Pal	—Pats	4:20–4:30	Som	—Stah

THURSDAY, FEBRUARY 4, 1960

A.M.			P.M.		
8:00– 8:10	Stai	—Steu	1:00–1:10	Andersf	—Ark
8:10– 8:20	Stev	—Sto	1:10–1:20	Arl	—Bab
8:20– 8:30	Stp	—Sup	1:20–1:30	Bac	—Baq
8:30– 8:40	Suq	—Tas	1:30–1:40	Bar	—Bas
8:40– 8:50	Tat	—Thomp	1:40–1:50	Bat	—Bec
8:50– 9:00	Thomq	—Toml	1:50–2:00	Bed	—Benr
9:00– 9:10	Tomm	—Tup	2:00–2:10	Bens	—Bes
9:10– 9:20	Tuq	—Vandeq	2:10–2:20	Bet	—Blac
9:20– 9:30	Vander	—Ver	2:20–2:30	Blad	—Boe
9:30– 9:40	Ves	—Walc	2:30–2:40	Bof	—Bot
9:40– 9:50	Wald	—Wark	2:40–2:50	Bou	—Bra
9:50–10:00	Warl	—Webe	2:50–3:00	Brb	—Brown, F.
10:00–10:10	Webf	—Wer	3:00–3:10	Brown, G.	—Buc
10:10–10:20	Wes	—Wh	3:10–3:20	Bud	—Bur
10:20–10:30	Wi	—Willi	3:20–3:30	Bus	—Cam
10:30–10:40	Willj	—Wolc	3:30–3:40	Can	—Car
10:40–10:50	Wold	—Wre	3:40–3:50	Cas	—Cha
10:50–11:00	Wrf	—Yz	3:50–4:00	Chb	—Ci
11:00–11:10	Za	—Zz	4:00–4:10	Cj	—Cohe
11:10–11:20	Aa	—Alc	4:10–4:20	Cohf	—Con
11:20–11:30	Ald	—Anderse	4:20–4:30	Coo	—Cou

FRIDAY, FEBRUARY 5, 1960

A.M.			P.M.		
8:00– 8:10	Cov	—Cro	1:00–1:10	Han	—Harrisn
8:10– 8:20	Crp	—Dam	1:10–1:20	Harriso	—Hd
8:20– 8:30	Dan	—Daz	1:20–1:30	Hea	—Henl
8:30– 8:40	Db	—Deng	1:30–1:40	Henm	—Hile
8:40– 8:50	Denh	—Din	1:40–1:50	Hilf	—Holl
8:50– 9:00	Dio	—Dou	1:50–2:00	Holm	—How
9:00– 9:10	Dov	—Dup	2:00–2:10	Hox	—Hur
9:10– 9:20	Duq	—Eg	2:10–2:20	Hus	—Jack
9:20– 9:30	Eh	—En	2:20–2:30	Jacl	—Jog
9:30– 9:40	Eo	—Fan	2:30–2:40	Joh	—Jones, J.
9:40– 9:50	Fao	—Fil	2:40–2:50	Jones, K.	—Kam
9:50–10:00	Fim	—Foc	2:50–3:00	Kan	—Kea
10:00–10:10	Fod	—Fran	3:00–3:10	Keb	—Ker
10:10–10:20	Frao	—Fz	3:10–3:20	Kes	—Kiq
10:20–10:30	Ga	—Gau	3:20–3:30	Kir	—Kni
10:30–10:40	Gav	—Gill	3:30–3:40	Knj	—Koth
10:40–10:50	Gilm	—Goldl	3:40–4:00	Koti	—Krug
10:50–11:00	Goldm	—Grah	4:00–4:10	Kruh	—Lami
11:00–11:10	Grai	—Gri	4:10–4:20	Lamj	—Lawre
11:10–11:20	Grj	—Had			
11:20–11:30	Hae	—Ham			

SATURDAY, FEBRUARY 6, 1960

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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:

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The prospective student should have, in addition to a copy of the bulletin of 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.

Bulletin of General Information

Announcements:

- Architecture and Design, College of
- Business Administration, School of
  - Graduate
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- Dentistry, School of
- Education, School of
- Engineering, College of
- Flint College
- Graduate Dentistry, W. K. Kellogg Foundation Institute
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- Public Administration, Institute of
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