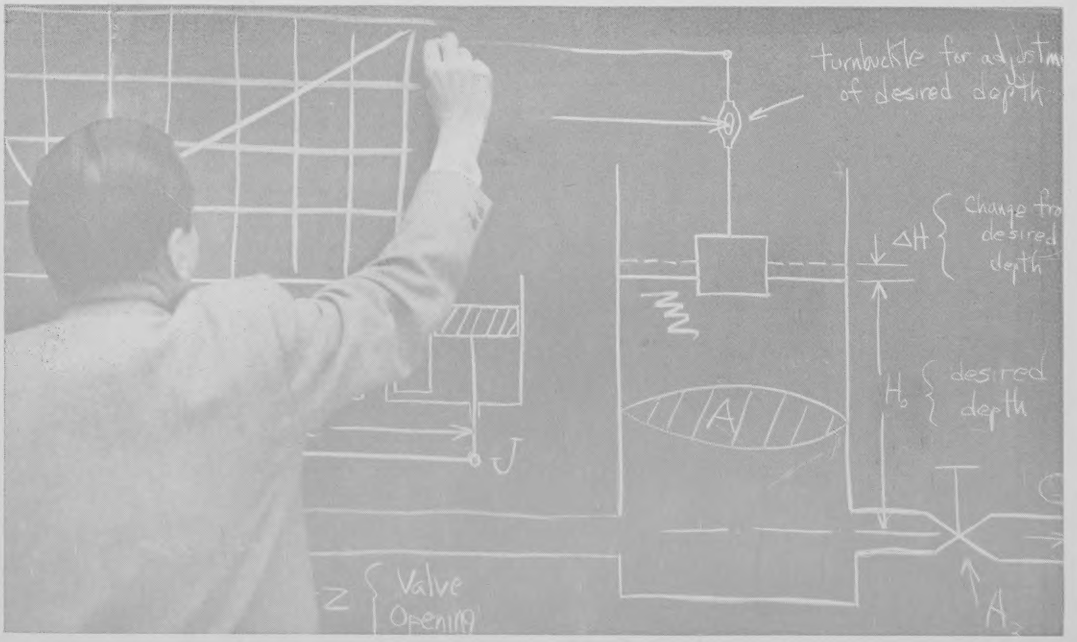
ANNOUNCEMENT

1956/1957

COLLEGE OF ENGINEERING

University of Michigan

OFFICIAL PUBLICATION



Vol. 57 No. 67, January 3, 1956

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

University of Michigan Official Publication

College of Engineering

1956-1957

Announcement

Published by the University Ann Arbor

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Study period ....January 17, Thursday
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* For registration schedules, see pages 160–161.

COLLEGE OF ENGINEERING

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

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

GEORGE GRANGER BROWN, Ph.D., Ch.E., Eng.D., *Dean of the College of Engineering*

WALTER JOHNSON EMMONS, B.S., A.M., *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 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 the 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 Engineering 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 and high school principals.

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; one division of the engineering libraries; 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; the transportation and other libraries; and the highway and soil mechanics laboratory. The EAST ENGINEERING ADDITION (1947) contains two subsonic wind tunnels, a 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, some 375 acres north of the Huron River, also includes 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 Phoenix–Memorial Laboratory and accompanying Ford nuclear reactor, which provide 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 WITH 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 College 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 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 these 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 26 and 30.

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

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 College conducts a weekly seminar during the first semester of the academic year. See page 152.

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, sport 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 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.

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 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
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 Architecture and Marine Engineering
SAILING CLUB, an organization for dinghy sailing, iceboating, intercollegiate competition
SCABBARD AND BLADE, national ROTC honor fraternity
SIGMA XI, a national society devoted to the encouragement of research
SOCIETY OF AUTOMOTIVE ENGINEERS, student branch
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 bulletins, *University Scholarships, Fellowships, and Prizes,* and *Student Loan Funds,* which are available upon request.

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

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

Detailed information regarding registration and payment of fees, also directions for classification, may be obtained from the Secretary of the College.

Semester fees:	**Michigan students . . . . .**	**$100**
	Non-Michigan students	**235**

The semester fees must be paid before classification, and no student can enter upon his work until after such payment.

Students are urged to provide themselves with money orders or travelers' checks 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 travelers' checks. 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 of *General Information,* which should be consulted for further information.

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, College of Engineering.

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

	UNITS
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 possible.

College credit is not given for work done in the high-school course, but adjustments in the work required for graduation from the University are made in accordance with a student's preparation and ability. Some acceleration is possible 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, or may be satisfied by examination. When conditions warrant such action, provisional admission may be granted if not more than two units are lacking.

Candidates for admission who have passed College Board, New York Regents, or Canadian Matriculation examinations with satisfactory grades will be excused from further examinations in the subjects covered. All applications for examination by the College Entrance Examination Board must be addressed to its secretary, Box 592, Princeton, New Jersey, and must be made on a blank form which may be obtained from its secretary.

ADMISSION BY CERTIFICATE

Only those applicants are admitted by certificate who are officially recommended graduates of accredited high schools and who have completed in a standard 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 junior 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

* A bulletin containing a list of the accredited schools in the state of Michigan will be sent upon request to the Bureau of School Services, University of Michigan.

his satisfactory completion of the secondary school program and the passing of a medical examination at the time of registration.

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, and, for admission without deficiencies, he must satisfy the requirements for admission from high school as stated on pages 12 and 13.

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 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.

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 by fulfilling the regular requirements for admission. See pages 12 and 13.

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

Students entering without deficiencies have the choice of two schedules of studies for the first year as stated below. 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. 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. In Schedule S, calculus, 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 mathematics and science for four semesters.

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 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, physics, and materials equivalent, respectively, to the satisfactory completion of the following courses: English 12 and 21, Drawing 2, Mathematics 54 or 56, Chemistry 5E or 15, Physics 46 or 54 and Chemical and Metallurgical Engineering 1. 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.

FIRST SEMESTER	HOURS		SECOND SEMESTER	HOURS	
Schedule	*T*	*S*	*Schedule*	*T*	*S*
Math. 13 (or 17)........	4	–	Math. 14 (or 18)	4	–
Math. 33	–	4	Math. 34	–	4
English 11	3	3	English 12	2	2
English 21	1	1	English 1, Group II	2	0
Drawing 1 or 1x	3	3	Drawing 2 or 2x	3	3
Chem. 5E (or 1 or 3) or Ch.-Met. Eng. 1	5 or 4	–	Ch.-Met. Eng. 1 or Chem. 5E (or 4 or 6) ..	5 or 4	–
Physics 53	–	4	Chemistry 14	–	4
Assembly	0	0	Eng. Mech. 11	–	3
Phys. Ed.*	0	0	Phys. Ed.*	0	0
	16 or 15	15		16 or 15	16
Mil. Sci.*	2		Air Sci.*	2	
Nav. Sci.*	3		Mil. Sci.*	2	
Air Sci.*	2		Nav. Sci.*	3	

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

Modifications in the first-year schedules are necessary for those who enter with deficiencies in preparation. Changes are also made as seem desirable in accordance with the ability of the individual student. These schedules assume that at least 1½ units of algebra, solid geometry, and trigonometry have been accepted as entrance credits.

The tabulation on page 19 indicates the required courses at the University for those entering with various degrees of preparation and ability in mathematics and chemistry. Proficiency tests are given during the orientation period which precedes registration.

As indicated, it is clearly to the advantage of the high-school 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.

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.

Students planning to take chemical and materials engineering may facilitate their progress by electing Chemistry 5E, five hours, in the first semester and Chemistry 20, three hours, instead of English, Group II, in the second semester. They must then take, at a later time, English, Group II. An alternate procedure is to elect Chemistry 3 and 8 during the first year for a total of nine hours. This program makes it possible to elect Chemistry 41 during the first semester of the second year and to elect subsequent courses marked "x" at an earlier semester than is indicated.

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 in air, military, and naval science will be recorded as stated above.

The classifier 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.

* See statement concerning Reserve Officers' Training Corps, page 53.

Units Presented				Mathematics Courses to Be Elected (See course descriptions pages 117–118.)	
Group	Alg.	Geom.	Trig.	Courses	Hours
1	1	1	0	Math. 6, 7, — 13, 14, 53, 54	22
2	1	1½	0	Math. — 7, — 13, 14, 53, 54	20
3	2	1	0	Math. 6, — 8, 13, 14, 53, 54	20
4	1½	1½	0	Math. — — 8, 13, 14, 53, 54, or — — 8, 33, 34, 55, 56	18
5	2	1½	0	Math. — — 8, 13, 14, 53, 54, or — — 8, 33, 34, 55, 56	18
6	2	1	½	Math. 6, — — 13, 14, 53, 54, or 6, — — 33, 34, 55, 56	18
7	1½	1½	½	Math. — — — 13, 14, 53, 54, or — — — 33, 34, 55, 56	16
8	2	1½	½	Math. — — — 13, 14, 53, 54, or — — — 33, 34, 55, 56	16

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 13 or 33 in the first semester.

Group 8: Math. 17, 18, 54 in place of Math. 13, 14, 53, 54, a saving of 4 credit hours in Schedule T.

Chemistry 5E, in place of two 4-hour courses, a saving of 3 credit hours in Schedule T.

UNDERGRADUATE DEGREE PROGRAMS

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

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 includes subjects in certain basic areas common 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, 13, 14, 53, 54	12–18	–
Math. 8, 33, 34, 55, 56	–	16–18
Chemi. 5E, or two 4-hour courses	5 or 8	–
Chem. 14, 15	–	8
Drawing 1, 2, or 1x, 2x	6	6
Ch. and Met. Eng. 1, or equivalent	5	4
Physics 45, 46	10	–
Physics 53, 54	–	8
	44–53	48–50

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 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 Nelson

The design of modern aircraft 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 aircraft structure courses. Studies in the field of instrumentation include principles of measurements, data transmission, automatic control, and systems 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 aircraft are treated from the dynamic 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, or instrumentation.

Students are encouraged to take employment in the aeronautical or allied industries during the summer periods.

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 20)	44-53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Econ. 53, 54, General Economics, *or*	
Econ. 153 and 173, General Economics and Accounting	6*
Math. 103 or Math. 148, Differential Equations	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity of Materials	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	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	4
Aero. Eng. 131, Aircraft Structures II	3
Aero. Eng. 141, Mechanics of Flight I	3
Aero. Eng. 142, Mechanics of Flight II	3
Aero. Eng. 143, Aircraft Control Systems	3
Aero. Eng. 163, Basic Aircraft Propulsion	3
Aero. Eng. 164, Aircraft Propulsion Systems	3
Nontechnical electives	9
Group options and electives	10
Total, professional subjects and electives	87

*Econ. 153 and 3 hours additional of nontechnical electives also will satisfy this requirement.

SUGGESTED SCHEDULE

For common first-year schedule see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 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	Eng. Mech. 4	3
	16		17

SUMMER SESSION	
Elective	3
Elec. Eng. 5	4
	7

FIFTH SEMESTER		SIXTH SEMESTER	
Math. 103	3	Aero. Eng. 130	3
Aero. Eng. 110	4	Aero. Eng. 114	4
Eng. Mech. 3	3	Econ. 54 or nontech. elec.	3
Mech. Eng. 105	3	Aero. Eng. 163	3
Econ. 53 or 153	3	Elective	3
	16		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Aero. Eng. 131	4	Aero. Eng. 143	3
Aero. Eng. 164	3	Aero. Eng. 101	3
Aero. Eng. 141	3	Electives	7
Aero. Eng. 142	3	Engl., Group III	2
Elective	3		15
	16		

CHEMICAL ENGINEERING

Program Adviser: Associate Professor Williams

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 20)	44-53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Chemistry 20, 41, Introductory Analytical	7
Chemistry 61, 161R, Organic	8
Chemistry 182, 183, Physical	6
Ch. and Met. Eng. 2, Engineering Calculations	3
Ch. and Met. Eng. 16, Measurements Laboratory	3
Ch. and Met. Eng. 111, Thermodynamics	3
Ch. and Met. Eng. 113, Unit Operations	4
Ch. and Met. Eng. 115, Unit Operations Design	3
Ch. and Met. Eng. 117, Metals and Alloys	3
Ch. and Met. Eng. 118, Structure of Solids	3
Ch. and Met. Eng. 121, Design of Process Equipment	3
Ch. and Met. Eng. 129, Engineering Operations Laboratory	3
Ch. and Met. Eng. 130, Chemical Process Design, or equivalent	3
Nontechnical electives	6
Group options and electives*	8
Total, professional subjects and electives	87

* Advanced courses in air, military, or naval science approved by the program adviser may be used as option electives, but the basic courses (100 or 200 series) will not be accepted.

SUGGESTED SCHEDULE*

For common first-year schedule see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Ch. and Met. Eng. 2	3
xChem. 20	3	Physics 46	5
Elective	3	xChem. 41	4
	15		16

SUMMER SESSION	
Eng. Mech. 5	4
Chem. 182	3
	7

FIFTH SEMESTER		SIXTH SEMESTER	
xChem. 61	6	xChem. 161R	2
Ch. and Met. Eng. 16	3	Ch. and Met. Eng. 113	4
Ch. and Met. Eng. 111	3	Ch. and Met. Eng. 118	3
Chem. 183	3	Econ. 173	3
		Eng. Mech. 3	3
	15	Electives	3
			18

SEVENTH SEMESTER		EIGHTH SEMESTER	
Ch. and Met. Eng. 117	3	Ch. and Met. Eng. 129	3
Ch. and Met. Eng. 115	3	Ch. and Met. Eng. 121	3
Elec. Eng. 5	4	Ch. and Met. Eng. 130	3
Econ. 153	3	English, Group III	2
Electives	3	Electives	5
	16		16

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 Ch.-Met. Eng. 13, 119, and 124, and elect Ch.-Met. Eng. 127 and 128 rather than Ch.-Met. Eng. 117 for a total of thirteen hours for additional courses. Students in the

* 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. 17, 18, 54 sequence to reduce the total hours. Also the election of Chem. 20 during the first year will permit advancing the courses marked x by one semester.

metallurgical program who desire to earn a degree in chemical engineering as well must elect Chem. 41, Chem. 61 and 161R instead of 61R; Ch.-Met. Eng. 113 and 115 instead of Ch.-Met. Eng. 114; and Ch.-Met. Eng. 130 in addition for a total of fourteen extra hours.

CHEMICAL ENGINEERING AND CHEMISTRY

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

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 industry and of students 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		18
English 1, 2	6	
German 1, 2, 35	12	
If any of this German is satisfied by entrance credits, an equivalent amount of work in foreign language must be substituted.		
MATHEMATICS AND SCIENCE GROUP		61 (to 69)
Chemistry 3, 8, (or 3, 4, 20), 41 (4 or 5 hrs), 61, 141 (4 or 5 hrs), 161, 182, 183, 185, 186, 191	39 (to 43)	
Physics 45, 46	10	
Math. 13, 14, 53, 54; or 17, 18, 54	16 (or 12)	
SOCIAL SCIENCES GROUP*		12
Econ. 53, 54, 173	9	
Electives	3	
ENGINEERING COURSES		53
Eng. Mech. 3, 5	7	
Elec. Eng. 5	4	
Drawing 1, 2	6	

* Econ. 173 and 153 may be substituted; in this case electives in social sciences will total six hours.

	HOURS	HOURS
Ch. and Met. Eng. 1, 2, 111, 113, 115, 117, 118, 121, 129, 130	33	
Elective in engineering or mathematics	3	
ELECTIVES*		9
Not more than 44 hours of courses in the Department of Chemistry may be counted toward the degree.		
Total		153 (to 161)

CIVIL ENGINEERING

Program Adviser: Professor Boyce

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 special work in one of the following fields:

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.

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

HIGHWAY 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.

HYDRAULIC. The application of the fundamental principles of hydraulics and hydrology to the development of water power, flood control, drainage, the improvement of rivers and harbors, and other hydraulic structures.

* Econ. 173 and 153 may be substituted; in this case electives in social sciences will total six hours.

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.

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; and principles and standards of ventilation.

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.

GROUP OPTIONS AND ELECTIVES. As early as practicable the student should select that field of civil engineering in which he may have a major interest and confer with the adviser for that option relative to the completion of his program.

REQUIREMENTS

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

	HOURS
A. SUBJECTS TO BE ELECTED OR EQUIVALENT PROFICIENCIES TO BE DEMONSTRATED	
Total normally (see page 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Civ. Eng. 1, 2, 3, Surveying	11
English, Group II and Group III	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	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, Heat Engines	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. 50, Fundamentals of Sanitary Engineering	2
Civ. Eng. 60, Highway Engineering	2

	HOURS
Civ. Eng. 70, Railroad Engineering	2
Civ. Eng. 121, Reinforced Concrete	3
Civ. Eng. 140, Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 151, Water Supply and Sewerage	3
Civ. Eng. 180, Specifications and Contracts	2
Geol. 98	4
Econ. 153, 173*	6
Nontechnical electives	2
Group options and electives	10
Total, professional subjects and electives	87

One of the following groups, each including a design course, should be selected by the student. Substitution for any other than the design course and the selection of courses to complete the elective group are subject to the approval of the program adviser.

	HOURS
1. CONSTRUCTION Adviser: Associate Professor Alt	
Civ. Eng. 131, Cost Analysis and Estimating	2
Civ. Eng. 132, Construction Methods and Equipment	3
Choice of a civil engineering design course	3
2. HIGHWAY TRAFFIC Adviser: Professor Kohl	
Civ. Eng. 165, Highway Traffic Engineering	2
Civ. Eng. 166, Highway Traffic Surveys	2
Civ. Eng. 169, Highway Design	3
3. HIGHWAY Adviser: Assistant Professor Cortright	
Civ. Eng. 161, Highway Materials	3
Civ. Eng. 167, Highway Economics	2
Civ. Eng. 169, Highway Design	3
4. HYDRAULIC Adviser: Professor Brater	
Civ. Eng. 143, Advanced Hydraulics	3
Civ. Eng. 146, Hydraulic Engineering Design	3
Choice of either:	
Civ. Eng. 142, Water Power Engineering	2
Civ. Eng. 144, Hydraulic Structures	3
5. RAILROAD Adviser: Professor Sadler	
Civ. Eng. 172, Railroad Maintenance	3
Civ. Eng. 173, Terminal Design	3
Civ. Eng. 176, Economics of Railroad Construction and Operation	2
6. SANITARY Adviser: Associate Professor Borchardt	
Bacteriology 51 or 111E	4
Civ. Eng. 154, Sanitary Engineering Design	3
Civ. Eng. 156, Sanitary Engineering Laboratory	2
7. STRUCTURAL Adviser: Professor Maugh	
Civ. Eng. 122, Advanced Theory of Structures	3
Civ. Eng. 123, Design of Structures	3

* Econ. 53 and 54 may be elected instead of Econ. 153 and 173.

Choice of either:	HOURS
Civ. Eng. 124, Rigid Frame Structures	3
Civ. Eng. 135, Applied Soil Mechanics	3

Specialization in soil mechanics is possible under the structural option.

SUGGESTED SCHEDULE

For common first-year schedule see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Civ. Eng. 1	3	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Civ. Eng. 20	2	Civ. Eng. 2	4
	17		18

SUMMER SESSION (at Camp Davis)	
Civ. Eng. 3	4
Geol. 98	4
	8

FIFTH SEMESTER		SIXTH SEMESTER	
Civ. Eng. 30	1	Civ. Eng. 50	2
Eng. Mech. 3	3	Econ. 173	3
Eng. Mech. 4	3	Civ. Eng. 121	3
Civ. Eng. 22	3	Civ. Eng. 23	3
Civ. Eng. 60	2	Civ. Eng. 140	3
Civ. Eng. 70	2	Electives	3
Electives	3		17
	17		

SEVENTH SEMESTER		EIGHTH SEMESTER	
Civ. Eng. 151	3	Civ. Eng. 180	2
Civ. Eng. 141	2	Mech. Eng. 13	4
Elec. Eng. 5	4	Engl. 136	2
Econ. 153	3	Electives	6
Electives	5		14
	17		

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

Advisers: College of Literature, Science, and the Arts, Assistant Dean Robertson; College of Engineering, Assistant Professor Harris.

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.

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 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 171 semester hours 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.

In addition to the courses required for the program in civil engineering shown on pages 28 and 29, the combined curriculum requires the successful completion of the following courses:

	HOURS
A foreign language group or literature group	16
Philosophy	6
Fine arts or history	5
American literature	3
Economics	3
History, geology, philosophy, fine arts, political science	3

ELECTRICAL ENGINEERING

Program Adviser: Professor Attwood

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 diversity of the work done by electrical engineers and the specialization required within the profession have led to the establishment of two options within the basic program: one centered in electrical power production and machinery, the other in electronics and communications. A student may achieve, by a careful selection of elective courses, a measure of specialization even within the basic undergraduate program. Extensive specialization, however, should be reserved for graduate study.

Course requirements are identical for the first three years but, before beginning his senior year, a student must decide which of the two options he wishes to select. Thereafter he may change his option only with the consent of the program adviser.

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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Math. 57	2
English, Group II and Group III	4
Econ. 53, 54	6*
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 13, Heat Engines	4
Mech. Eng. 82, Elements of Machine Design	3
Elec. Eng. 3, Circuits I	4
Elec. Eng. 4, D.C. Machinery	2
Elec. Eng. 10, Principles of Electricity and Magnetism	4
Elec. Eng. 100, Circuits II	4
Elec. Eng. 130, Electrical Measurements	3
Elec. Eng. 150, A.C. Apparatus	4
Elec. Eng. 160, Fundamentals of Electrical Design	4
Elec. Eng. 180, Electronics and Electron Tubes I	4
Nontechnical electives	6
Group options and electives	19
Total, professional subjects and electives	87

One of the following groups should be selected by the student before beginning his senior year and thereafter he may change only with the consent of the program adviser.

* Econ. 153 and 173 or Econ. 153 and three hours additional of nontechnical electives also will satisfy this requirement.

1. MACHINERY-POWER Adviser: Associate Professor Carey

	HOURS
Civ. Eng. 21, Theory of Structures	3
Mech. Eng. 14, Laboratory	1
Elec. Eng. 140, Power Plants, Transmission, and Distribution, or 181, Industrial Electronics	3 or 4
Elec. Eng. 141, Economic Applications in Electrical Engineering	2
Elec. Eng. 155, Automatic Control Systems	4
Elec. Eng. 170, Illumination and Photometry	2
Electives	4–3

2. ELECTRONICS-COMMUNICATIONS Adviser: Professor Holland

	HOURS
Elec. Eng. 101, Networks and Lines	3
Elec. Eng. 120, Radio Communications I	4
Elec. Eng. 121, Radio Communications II or 181, Industrial Electronics or 189, Electron Tubes II	4
Elec. Eng. 141, Economic Applications in Electrical Engineering	2
Electives	6

SUGGESTED SCHEDULE

For common first-year schedule, see page 17.

THIRD SEMESTER	HOURS
Math. 53	4
Physics 45	5
Eng. Mech. 1	3
Electives	3
	15

FOURTH SEMESTER	HOURS
Math. 54	4
Physics 46	5
Elec. Eng. 3	4
Electives	3
	16

FIFTH SEMESTER	
Elec. Eng. 4	2
Elec. Eng. 10	4
Elec. Eng. 100	4
Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Math. 57	2
	17

SIXTH SEMESTER	
Elec. Eng. 150	4
Elec. Eng. 180	4
Eng. Mech. 3	3
Mech. Eng. 82	3
Eng. Mech. 4	3
	17

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

SEVENTH SEMESTER	HOURS Option 1	2
English, Group III	2	2
Econ. 53	3	3
Elec. Eng. 181	4	–
Elec. Eng. 141	2	–
Mech. Eng. 14	1	–
Elec. Eng. 120	–	4
Elec. Eng. 101	–	3
Elective	3 or 4	3
	15 or 16	15

EIGHTH SEMESTER	HOURS Option 1	2
Elec. Eng. 140 or 155	3 or 4	–
Elec. Eng. 160	4	–
Elec. Eng. 170	2	–
Civ. Eng. 21	3	–
Econ. 54	3	3
Elec. Eng. 121 or 181 or 189	–	4
Elec. Eng. 141	–	2
Elec. Eng. 160	–	4
Elective	–	3
	15 or 16	16

ENGINEERING MECHANICS

Program Adviser: Professor Dodge

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 20)	44-53

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Group II and Group III	4
Math. 103, Differential Equations	3
Math. 147, Modern Operational Mathematics	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 or Aero. Eng. 172	3
Mech. Eng. 105, Thermodynamics	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, 2*a*, Strength and Elasticity	5
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 124, Theory of Elasticity I	3
Eng. Mech. 131, Fundamental Vibration Analysis	3
Eng. Mech. 141, Advanced Fluid Mechanics I	3
Eng. Mech., approved advanced courses	7
Economics 153	3
Nontechnical electives	5
Group options and electives	23
Total, professional subjects and electives	87

Every student is required to take a complete design sequence from some other program in the College of Engineering. This is to enable him to correlate his theoretical training with engineering practice in that field. The sequences consist of twelve to fourteen hours of the twenty-three hours listed. Up to six hours of advanced air, military, or naval science may be used as electives. Suggested group options are:

Aerodynamics	Instrumentation
Aeromechanics	Internal Combustion
Chemical Engineering	Metallurgy
Electrical Power	Naval Architecture
Electronics	Nuclear Engineering
Hydraulics	Structures

Details of these can be obtained from the Program Adviser. Options in other areas can be arranged in conference with the Program Adviser.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Allen

The industrial engineer is primarily interested in the structure of business problems as an adviser to major management. His principal task is the establishment of an uninterrupted flow of production at the lowest cost. He may be called upon to devise entire plans for management control systems; and, through a consideration of cost, quality, and quantity elements, to evaluate existing systems against predetermined standards. When to take corrective action, and to what extent such action should be taken as results vary from the standards established, must be determined by an analysis of the human, the economic, and the mechanical elements of the management control plan. He may be called upon to devise alternate plans as resources used in the business vary in their availability.

Operating elements in the planning and control functions of management are many. The industrial engineer may be asked to devise means which will ensure quality in the product; to evaluate wage rates and production standards; to establish economical methods for the layout of processes and the handling of material; to determine inventory policies; to develop adequate production control plans for loading the plant effectively; to devise adequate means of communication between management and the working force. These are examples of the elements with which the industrial engineer must be concerned in over-all systems design. Preparation for proficiency in this area involves familiarity with the basic sciences, with technical engineering, with business administration, and with the techniques of industrial engineering.

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 20)	44-53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Draw. 3	2
English, Group II and Group III	4
Econ. 153*	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Ch. and Met. Eng. 11, Cast Metals	2
Ch. and Met. Eng. 107, Metals and Alloys	2
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 13, Heat Engines	4
Mech. Eng. 14, Laboratory	1
Mech. Eng. 32, Machining I	3
Mech. Eng. 80, Mechanism	2

* Students planning to enroll in the School of Business Administration as candidates for the M.B.A. may elect Econ. 53 and 54 and Bus. Ad. 11 and 12. The electives may be chosen to apply to the 60-hour requirement for the M.B.A. Some of the engineering courses may be accepted by the School of Business Administration to apply to this 60-hour requirement.

	HOURS
Mech. Eng. 82, Machine Design	3
Mech. Eng. 86, Advanced Machine Design	3
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 132, Machining II	3
Ind. Eng. 100, Industrial Management	3
Ind. Eng. 110, Plant Layout and Materials Handling	3
Ind. Eng. 120, Motion and Time Study	3
Ind. Eng. 130, Wage Incentives and Job Evaluation	2
Ind. Eng. 140, Production Control	2
Ind. Eng. 150, Engineering Economy	2
Bus. Ad. 11, 14, Cost Accounting	6
Bus. Ad. 124, or Math. 161, Statistical Methods for Engineers	3
Bus. Ad. 142, Personnel Administration	3
Nontechnical electives	2
Group options and electives*	9
Total, professional subjects and electives	87

SUGGESTED SCHEDULES

For common first-year schedule, see page 17.

THIRD SEMESTER	HOURS
Math. 53	4
Phys. 45	5
Draw. 3	2
Eng. Mech. 1	3
Elective	2
	16

FOURTH SEMESTER	HOURS
Math. 54	4
Phys. 46	5
Ch. and Met. Eng. 107	2
Eng. Mech. 2	4
	15

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

FIFTH SEMESTER	
Mech. Eng. 14	1
Mech. Eng. 32	3
Mech. Eng. 80	2
Mech. Eng. 82	3
Bus. Ad. 11	3
Ind. Eng. 100	3
	15

SIXTH SEMESTER	
Mech. Eng. 86	3
Mech. Eng. 104	3
Ch. and Met. Eng. 107	2
Bus. Ad. 14	3
Ind. Eng. 110	3
Ind. Eng. 120	3
	17

* A maximum of six hours of advanced air, military, or naval science (300 and 400 series), approved by the program adviser, may be used as electives.

SEVENTH SEMESTER	HOURS
Bus. Ad. 124 or Math. 161	3
Econ. 153	3
Engl., Group III	2
Mech. Eng. 132	3
Ind. Eng. 130	2
Electives	3
	16

EIGHTH SEMESTER	HOURS
Bus. Ad. 142	3
Elec. Eng. 5	4
Ind. Eng. 140	2
Ind. Eng. 150	2
Electives	6
	17

MATERIALS ENGINEERING

Program Adviser: Associate Professor Van Vlack

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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Econ. 153 and 173	6
Eng. Mech. 3, Dynamics	3
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 126, Advanced Stress Analysis	2
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Mech. Eng. 82, Machine Design	3

	HOURS
Chem. 20, Introductory Analytical	3
Chem. 61, Organic	6
Chem. 182, 183, Physical	6
Ch. and Met. Eng. 2, Engineering Calculations	3
Ch. and Met. Eng. 13, Processing of Cast Metals	2
Ch. and Met. Eng. 16, Measurements Laboratory	3
Ch. and Met. Eng. 111, Thermodynamics	3
Ch. and Met. Eng. 114, Unit Operations	4
Ch. and Met. Eng. 117, Metals and Alloys	3
Ch. and Met. Eng. 118, Structure of Solids	3
Ch. and Met. Eng. 121, Design of Process Equipment	3
Ch. and Met. Eng. 122, Refractory and Abrasive Materials	2
Ch. and Met. Eng. 124, X-ray Studies of Engineering Materials	3
Ch. and Met. Eng. 125, Organic Materials	4
Ch. and Met. Eng. 126, Glass and Vitreous Materials	2
Ch. and Met. Eng. 136, Protective Coatings	3
Nontechnical electives	5
Group options and electives*	3
Total, professional subjects and electives	87

SUGGESTED SCHEDULE†

For common first-year schedule, see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Phys. 45	5	Phys. 46	5
xChem. 20	3	xChem. 61	6
Econ. 173	3	xCh. and Met. Eng. 2	3
	15		18

SUMMER SESSION	
xChem. 182	3
xEng. Mech. 5	4
	7

FIFTH SEMESTER		SIXTH SEMESTER	
Chem. 183	3	Eng. Mech. 126	2
Eng. Mech. 3	3	Ch. and Met. Eng. 16	3
Ch. and Met. Eng. 111	3	Ch. and Met. Eng. 118	3
Ch. and Met. Eng. 114	4	Mech. Eng. 82	3
Elec. Eng. 5	4	Ch. and Met. Eng. 13	2
		Econ. 153	3
	17		16

* Advanced courses in air, military, or naval science may be used as option electives but the basic courses (100 or 200 series) will not be accepted.

† 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. 17, 18, 54 sequence to reduce the total hours. Also the election of Chem. 5E and 20 during the first year will permit advancing the courses marked x by one semester.

SEVENTH SEMESTER	HOURS
Ch. and Met. Eng. 117	3
Ch. and Met. Eng. 121	3
Ch. and Met. Eng. 125	4
Electives	5
	15

EIGHTH SEMESTER	HOURS
Ch. and Met. Eng. 122	2
Ch. and Met. Eng. 124	3
Ch. and Met. Eng. 126	2
Ch. and Met. Eng. 136	3
English, Group III	2
Electives	3
	15

MATHEMATICS

Program Adviser: Associate Professor Hay

With the widespread advance in science and its application in development engineering and research, engineers so engaged find it necessary to rely to an increasing extent upon higher mathematics. Frequently these positions may be filled by men trained primarily in mathematics. The mathematics program in the College of Engineering provides the student an opportunity to become acquainted with engineering language and methods. Many students who are candidates for degrees in engineering programs elect additional courses and qualify for the award of a degree in mathematics as well. See Requirements for Graduation, page 157.

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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Groups II and III	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Eng. Mech. 142, or Ch. and Met. Eng. 111, or Mech. and Ind. Eng. 105, Thermodynamics	2 or 3
Electives in mathematics	12

	HOURS
Electives in engineering analysis and design	15
Electives in science, engineering science	15
Nontechnical electives	6
Electives	19 or 18
Total, professional subjects and electives	87

Students in chemical engineering or in metallurgical engineering who become candidates for degrees in chemical engineering and mathematics or in metallurgical engineering and mathematics are permitted to substitute three hours of chemistry (beyond 5E) for Eng. Mech. 1, and Eng. Mech. 5 for Eng. Mech. 2.

All students who are candidates for the degree in mathematics must consult with and have their elections approved by the program adviser.

MECHANICAL ENGINEERING

Program Adviser: Professor Vincent

The mechanical engineer is responsible for the design, operation, and development of machines of all types for the generation and use of power, together with the equipment, dies, and tools used by all industries, such as electrical, chemical, aeronautical, etc., in the manufacture of their products.

The primary fields of interest include refrigeration, heating, air conditioning, power plants for central stations, and today's transportation needs of all types, as well as most modern home conveniences.

The mechanical engineer is also concerned with manufacturing processes and their integration into an efficient organization. This field includes the development, operation, and control of such processes as casting, forging, rolling, die-casting, machining, and the selection of the equipment, jigs, fixtures, tools, dies, etc., involved in the manufacture of any product.

The course material is designed to give a broad foundation of engineering sciences needed by the mechanical engineer, whether in power generation or in manufacturing. Some specialization can be accomplished by suitable choice of electives.

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 20)	44–53

B. PROFESSIONAL SUBJECTS AND ELECTIVES	HOURS
English, Group II and Group III	4
Econ. 153	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Math. 103, Differential Equations	3
Mech. Eng. 17, Laboratory, first course	2
Mech. Eng. 31, Machining I*a*	2
Mech. Eng. 80, Mechanism	2
Mech. Eng. 82, Machine Design	3
Mech. Eng. 86, Advanced Machine Design	3
Mech. Eng. 104, Fundamentals of Fluids Machinery	3
Mech. Eng. 105, Thermodynamics I	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 111, Fundamentals of Heat Transfer	2
Mech. Eng. 114, Internal Combustion Engines	3
Mech. Eng. 125, Heating and Air Conditioning	3
Civ. Eng. 21, Theory of Structures	3
Elec. Eng. 5, D. C. and A. C. Apparatus and Circuits	4
Elec. Eng. 7, Motor Control and Electronics	4
Ch. and Met. Eng. 10, Utilization of Fuels	1
Ch. and Met. Eng. 11, Cast Metals	2
Ch. and Met. Eng. 107, Metals and Alloys	2
Nontechnical electives	6
Group options and electives	12
Total, professional subjects and electives	87

The group option requirement will be satisfied by the election of three hours of advanced laboratory, three hours of advanced theory or design, and six hours of electives. With the approval of the adviser, six hours of advanced air, military, or naval science may be used as the electives.

Groupings of courses which meet the group option requirement, together with appropriate additional electives, are available in the following fields:

1. Air Conditioning and Refrigeration—Adviser: Professor Marin
2. Automotive Engineering—Adviser: Professor Lay
3. Heat-Power Engineering—Adviser: Professor Schwartz
4. Fluids Engineering—Adviser: Professor Edmonson
5. Machine Design—Adviser: Associate Professor Hall
6. Production Engineering—Adviser: Professor Boston

Other combinations can be formulated and approved by the program adviser in accordance with the special interest of the student.

SUGGESTED SCHEDULE

For common first-year schedule, see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Ch. and Met. Eng. 11	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Nontechnical electives	3	Mech. Eng. 31	2
	17		16

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

FIFTH SEMESTER		SIXTH SEMESTER	
Mech. Eng. 17	2	Mech. Eng. 104	3
Mech. Eng. 80	2	Mech. Eng. 111	2
Mech. Eng. 82	3	Mech. Eng. 125	3
Mech. Eng. 106	3	Elec. Eng. 5	4
Eng. Mech. 4	3	Ch. and Met. Eng. 10	1
Ch. and Met. Eng. 107	2	Math. 103	3
	15		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Mech. Eng. 86	3	Civ. Eng. 21	3
Mech. Eng. 114	3	Econ. 153	3
Elec. Eng. 7	4	English, Group III	2
Electives	6	Nontechnical electives	3
		Electives	6
	16		17

METALLURGICAL ENGINEERING

Program Adviser: Professor Flinn

Metals and alloys possessing carefully defined properties are required by manufacturers of electronic equipment, aircraft, reactors, as well as 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 combination of metals which possess specified qualities such as higher strength, increased resistance to extreme temperatures, 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 other metallurgical operations. The nature and control of metal structures are studied by modern methods, such as X-ray defraction 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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, Group II and Group III	4
Economics 153, 173	6
Eng. Mech. 5, Statics, Strength, and Elasticity	4
Eng. Mech. 3, Dynamics	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Mech. Eng. 82, Machine Design	3
Chemistry 23, Analytical	4
Chemistry 61R, Organic	4
Chemistry 182, 183, Physical	6
Ch. and Met. Eng. 2, Engineering Calculations	3
Ch. and Met. Eng. 13, Processing of Cast Metals	2
Ch. and Met. Eng. 16, Measurements Laboratory	3
Ch. and Met. Eng. 111, Thermodynamics	3
Ch. and Met. Eng. 114, Unit Operations	4
Ch. and Met. Eng. 118, Structure of Solids	3
Ch. and Met. Eng. 119, Metallurgical Process Design	4
Ch. and Met. Eng. 121, Design of Process Equipment	3
Ch. and Met. Eng. 124, X-ray Studies of Engineering Material	3
Ch. and Met. Eng. 127, Physical Metallurgy I	4
Ch. and Met. Eng. 128, Physical Metallurgy II	3
Ch. and Met. Eng. 129, Engineering Operations Laboratory	3
Nontechnical electives	6
Group options and electives*	5
Total, professional subjects and electives	87

* Advanced courses in air, military, or naval science approved by the program adviser may be used as option electives but the basic courses (100 or 200 series) will not be accepted.

SUGGESTED SCHEDULE*

For common first-year schedule see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Ch. and Met. Eng 2	3
Chem. 23	4	Physics 46	5
Econ. 173	3	Eng. Mech. 5	4
	16		16

SUMMER SESSION	
Chem. 182	3
Eng. Mech. 3	3
Electives	2
	8

FIFTH SEMESTER		SIXTH SEMESTER	
Chem. and Met. Eng. 114	4	Chem. 61R	4
Chem. 183	3	Chem. and Met. Eng. 127	4
Chem. and Met. Eng. 16	3	Chem. and Met. Eng. 13	2
Chem. and Met. Eng. 111	3	Mech. Eng. 82	3
Chem. and Met. Eng. 118	3	Electives	3
	16		16

SEVENTH SEMESTER		EIGHTH SEMESTER	
Chem. and Met. Eng. 128	3	Chem. and Met. Eng. 121	3
Chem. and Met. Eng. 119	4	Chem. and Met. Eng. 129	3
Elec. Eng. 5	4	Engl., Group III	2
Econ. 153	3	Chem. and Met. Eng. 124	3
Electives	2	Electives	4
	16		15

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Baier

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

* The program may be completed in eight semesters if 17-18 hour semester schedules can be carried successfully and the sequences are carefully planned.

propelling machinery, such as steam-reciprocating, 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 year. 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 naval tank or experimental model basin, which is unique in this institution.

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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
Draw. 3	2
Math. 57	2
English, Group II and Group III	4
Econ. 153	3
Civ. Eng. 4, Surveying	2
Eng. Mech. 1, Statics	3

	HOURS
Eng. Mech. 2, Strength and Elasticity of Materials	4
Eng. Mech. 2*a*, Laboratory—Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 136, Vibration of Ship Structures	3
Mech. Eng. 17, Mechanical Engineering Laboratory	2
Mech. Eng. 80, Mechanism	2
Mech. Eng. 82, Machine Design	3
Mech. Eng. 105, Thermodynamics I	3
Elec. Eng. 5, D.C. and A.C. Apparatus and Circuits	4
Nav. Arch. 11, Introduction to Practice	2
Nav. Arch 12, Form Calculations I	3
Nav. Arch. 21, Structural Design I	3
Nav. Arch. 141, Marine Propulsion Machinery	2
Nav. Arch. 147, Marine Auxiliary Machinery	2
Nav. Arch. 151, Resistance, Power, and Propellers	3
Nontechnical electives	5
Group options and electives	23
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:

Eng. Mech. 127, Theory of Structures in Ship Design	4
Nav. Arch. 13, Form Calculations II	3
Nav. Arch. 22, Structural Design II	2
Nav. Arch. 131, Ship Design I	3
Nav. Arch. 132, Ship Design II	4
Nav. Arch. 137, Contracts, Specifications, and General Arrangements of Vessels	3
Nav. Arch. 152, Naval Tank	2
Electives	2

2. MARINE ENGINEERING Adviser: Assistant Professor Maddocks

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

Ch. and Met. Eng. 10, Fuels	1
Civ. Eng. 21, Theory of Structures	3
Mech. Eng. 104, Hydraulic Machinery	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 108, Mechanical Engineering Laboratory	3
Mech. Eng. 113, Steam Turbines	3
Nav. Arch. 144, Design of Marine Power Plant	3
Nav. Arch. 146, Analysis of Marine Machinery	2
Electives	2

SUGGESTED SCHEDULE

For common first-year schedule, see page 17.

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

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

SUMMER SESSION	
Eng. Mech. 3	3
Mech. Eng. 105	3
Math. 57	2
	8

FIFTH SEMESTER	*Option 1*	*Option 2*
Nav. Arch. 21	3	3
Nav. Arch. 141	2	2
Eng. Mech. 4	3	3
Mech. Eng. 17	2	2
Mech. Eng. 80	2	2
Nav. Arch. 13	3	–
Mech. Eng. 106	–	3
Civ. Eng. 4	2	2
	17	17

SIXTH SEMESTER	*Option 1*	*Option 2*
Nav. Arch. 22	2	–
Mech. Eng. 82	3	3
Civ. Eng. 21	–	3
Nav. Arch. 147	2	2
Elec. Eng. 5	4	4
Nav. Arch. 152	2	–
Mech. Eng. 104	–	3
Eng. Mech. 136	3	3
Electives	2	–
	18	18

SEVENTH SEMESTER	*Option 1*	*Option 2*
Nav. Arch. 131	3	–
Nav. Arch. 137	3	–
Econ. 153	3	3
Nav. Arch. 146	–	2
Ch. and Met. Eng. 10	–	1
Mech. Eng. 113	–	3
Mech. Eng. 108	–	3
Eng. Mech. 127	4	–
Electives	2	3
	15	15

EIGHTH SEMESTER	*Option 1*	*Option 2*
English, Group III	2	2
Nav. Arch. 151	3	3
Nav. Arch. 132	4	–
Nav. Arch. 144	–	3
Electives	3	4
	12	12

PHYSICS

Program Adviser: Professor Wolfe

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, page 157.

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 20)	44–53
B. PROFESSIONAL SUBJECTS AND ELECTIVES	
English, one course each from Group II and Group III	4
Modern language (preferably German or French)	8
Chem. 23, General and Analytical	4
Chem. 188, Physical	4
Math. 103, Differential Equations	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Elec. Eng. 3, Circuits I	4
Elec. Eng. 100, Circuits II	4
Physics 147, Electrical Measurements	4
Physics 165, Electron Tubes	3
Physics 196, Atomic and Molecular Structure	3
Group options and electives	39
Total, professional subjects and electives	87

Group options and electives are to be selected with the advice and consent of the program adviser as indicated in the following list:

Physics	13
Chemistry	3
Engineering	10
Mathematics	3
From economics, geography, history, philosophy, political science, sociology	6
Electives	4

SCIENCE

Program Adviser: Professor White

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. However, any student enrolled in the science engineering program can transfer into one of the specialized programs at the end of the fourth semester (second year) if such interests develop.

All entering students interested in the science engineering program should make their desires known to the Assistant Dean as soon as possible and well in advance of registration, as only a limited number can be enrolled in 1956.

REQUIREMENTS

The degree of Bachelor of Science in Engineering (Science) will be granted to those candidates who fulfill the following requirements:

	HOURS
A. The level of attainment in English, drawing, mathematics, chemistry, and physics described on page 20. It is expected that usually a high school graduate will fulfill this requirement by completing a group of University courses totaling	42
B. Professional subjects and electives:	
1. Nontechnical courses	13
2. Advanced mathematics including calculus, differential equations	9
3. Engineering science including the following subject areas: statics, dynamics, strength and elasticity, electricity and magnetism, electrical circuits and machinery, electronics, fluid mechanics, engineering materials, thermodynamics, modern physics, and rate processes	42
4. Group options and electives. The student will be encouraged to formulate his own sequence of courses, including a number of integrated courses covering an area of particular interest to him, with the advice and approval of the program adviser	27

SUGGESTED SCHEDULE FOR SECOND YEAR

For first year schedule see page 17.

THIRD SEMESTER	HOURS	FOURTH SEMESTER	HOURS
Math. 55	4	Math. 56	4
Physics 54	4	Chemistry 15	4
Eng. Mech. 12	4	Eng. Mech. 14	4
Eng. Mech. 13	3	Elec. Eng. 1	4
English 12	2	Elective (nontechnical)	2
	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. Some of these special fields have been specifically mentioned under the various degree programs. Information regarding these fields and others in which the student may be interested will be made available upon request. Program advisers will assist any student in preparing a program to fit his particular desires.

INSTRUMENTATION ENGINEERING

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 page 63.)

Undergraduate students may start these special studies by electing one or more of the following courses: Aero. Eng. 172, Engineering Measurements and Instrumentation (*3*); Elec. Eng. 108, Networks and Electron Tube Circuits (*4*), or 128, Electronics and Radio Communication (*4*), Mathematics 148, Operational Methods for Systems Analysis (*4*).

METEOROLOGY

The importance of weather and climate as factors in human life and activities has become increasingly apparent. There has been a corresponding demand for education in meteorology and its applications. The program of teaching and research emphasizes not only engineering meteorology, but also applied phases in such fields as medicine, public health, forestry, botany, etc. A bachelor's degree in any field, with basic physics and mathematics through calculus, is required preparation for specialization in meteorology and its applications at the graduate level. Recommended courses for those who wish to start studies in meteorology while undergraduates are: Civ. Eng. 80, Introductory Meteorology (*3*); Civ. Eng. 185, Physical Meteorology (*2*); and Civ. Eng. 187, Weather Map Analysis and Forecasting Laboratory (*2*). See Graduate School *Announcement* for advanced degree program.

NUCLEAR ENGINEERING

The new developments in atomic or nuclear energy have required engineers to design, construct, and operate the essential facilities. The implications and effects of atomic energy demand the attention of engineers in all fields and a special undergraduate or B.S.E. degree program in this field is not considered desirable at this time. Such specialization is offered at the graduate level. (See page 65.) Undergraduates desiring only a one semester course of nuclear engineering should elect Nuclear Engineering 190, Elements of Nuclear Engineering. Seniors who wish to start on the advanced program should elect Nuclear Engineering 191, Introduction to Nuclear Engineering.

OPPORTUNITIES FOR SPECIALIZATION

THE ENGINEERING RESEARCH INSTITUTE offers excellent opportunity for the student to assist in research and development work and to gain actual research experience in one of a wide variety of special fields. The Institute offers no courses of instruction but conducts a large volume of research in many branches of engineering under contract with government agencies and industrial organizations. These projects are supervised by experienced faculty members or full-time research engineers and scientists. Part-time employment may be obtained by advanced students who are thereby afforded an opportunity to gain valuable experience while earning.

In AERONAUTICAL ENGINEERING the following three group options are suggested: aerodynamics, structures and design, and aircraft propulsion. A special program in guided missiles, at the graduate level, has also been developed at the request of the Air Force. Many of the courses in this program are open to civilian students.

CHEMICAL ENGINEERING is well equipped to offer work in food processing, process design, petroleum refining, petroleum production, protective coatings, plastics, polymers, and pulp and paper.

CIVIL ENGINEERING is prepared to offer special work in soil mechanics and surveying, and in the following seven options: construction, highway, highway traffic, hydraulic, railroad, sanitary, and structural.

ELECTRICAL ENGINEERING offers two main options: one in machinery and power and the other in electronics and communications, and suggests well-rounded programs in illumination, design, measurement, industrial electronics, electron tubes, and industrial-electrical engineering.

Within the MECHANICAL ENGINEERING program students may follow their special interests in automotive, aircraft power, air conditioning, heat-power, refrigeration, machine design, or production.

In METALLURGICAL ENGINEERING the two main fields of physical metallurgy and process metallurgy are provided.

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 minor 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 Parkhill, Assistant Professors Callis, Callow, DuBois, Heckman, Knapp, Middlebrook, Nixon, and Schatz. Instructors Angus, Brown, Clark, Ivey, Lodigiani, Morton, and Smith.

The Department of Air Science offers a four-year generalized course of study designed to develop in selected engineering students those attributes of character, personality, and leadership which are essential to a commissioned offier of the USAF, and to provide the students with a broad knowledge and understanding of national and international defense structures in relation to the global mission of the USAF. A qualified student who is selected for the AFROTC program and who successfully completes a four-year program with an engineering major acceptable to the USAF will, upon graduation from the University, be considered for a commission as second lieutenant in the USAF Reserve. No specific major is required for students desiring flight training. A limited number of commissions will be granted to students who qualify for nonflying engineering specialties. Throughout the program both the theoretical and the practical phases of modern air power are emphasized. The course of study is so organized and developed that the student acquires an understanding of strategic and tactical air power, air operations, aerodynamics and propulsion, aerial navigation, meteorology, administration and logistics, principles of leadership, personnel management, international tensions and security organizations, instruments of national military security, elements of aerial warfare, applied air science, communications process and Air Force correspondence, military aviation and the art of war, and military aspects of world political geography.

Pay and allowances are offered to students who are formally enrolled in the advanced course (third and fourth years), approximating $275 for each of these two years. An additional amount of approximately $75, plus all expenses and life insurance, is earned while at summer camp.

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

Students who are commissioned will be required to serve on active duty for three years.

The Department of Air Science sponsors a rifle team, drill team, newspaper, 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 the Scabbard and Blade and Pershing Rifles.

COURSES OFFERED IN AIR SCIENCE

101, 102 Airplane and the Air Age. (*2*).
201, 202 Elements and Potentials of Air Power. (*2*).
301, 302 Air Force Officer in the Air Age. (*3*).
401, 402 Leadership and Air Power Concepts. (*3*).

MILITARY SCIENCE AND TACTICS

Professor Land; Assistant Professors Wayne, Dover, and Reidy. 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 are offered 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 by higher Army Headquarters 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	40
Map and Aerial Photograph Reading	20
School of the Soldier	30
ADVANCED COURSE	
Military Science III	
Small Unit Tactics and Communications	60
Organization, Function, and Mission of Arms and Services	30
Military Teaching Methods	20
Leadership	10
Exercise of Command	30
Military Science IV	
Logistics	20
Operations	55
Military Administration and Personnel Management	25
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's Corps, Army Security, Chemical, Corps of Engineers, Finance Corps, Medical Service Corps, Military Intelligence, Military Police Corps, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. Completion of the ROTC course does not lead to commissions in: Medical Corps, Dental Corps, Chaplains' Corps, Judge Advocate General's Corps, or Veterinary Corps.

PAY AND ALLOWANCES 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.

For information as to credit allowed for previous military training or service, 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 Zern; Associate Professor McClain; Assistant Professors Briggs, Gunckel, Lambert, Mitchell, Shafer, and Van Malsen; Instructors Boydston, Fleming, Mite, Moshgat, O'Brien, and Petty.

THE MISSION of the Naval Reserve Officers' Training Corps is to provide a source, by a permanent system of training and instruction in essential naval subjects at civil educational institutions, from which qualified officers may be obtained for the Navy, the Marine Corps, the Naval Reserve, and the Marine Corps Reserve.

THE OBJECTIVES of the Department of Naval Science in carrying out the above mission at the University of Michigan follow:

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 of the NROTC are of two types: (*a*) Regular NROTC students. These students, after selection by nation-wide competitive examinations, are appointed Midshipmen, USNR, and are granted 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 and during summer training cruises. Regular students are obligated to serve three years on active duty after commissioning as ensigns, United States Navy, or second lieutenants, United States Marine Corps, unless sooner released 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, but are issued uniforms and the textbooks and equipment required for Naval Science courses. During their third and fourth years of NROTC training, they receive a subsistence allowance (currently about $30 per month). 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 commissioning as ensigns, United States Naval Reserve, or second lieutenants, United States Marine Corps Reserve, they are obligated to serve two years on active duty unless sooner released by the Secretary of the Navy.

All candidates must pass the Navy physical examination before being accepted for enrollment. Physical requirements are high. Vision must be 20/20 uncorrected by glasses; height must be between 64 and 78 inches; and students must be between seventeen and twenty-one years of age (in special cases, contract students sixteen years of age may be enrolled). All candidates must remain unmarried until commissioned.

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 college year. In addition, Regular NROTC students must complete one year of college physics by the end of their sophomore college year.

Options. 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 commissions in the Supply Corps complete four semesters of general naval science subjects and four semesters of naval supply corps subjects.

COURSES OFFERED IN NAVAL SCIENCE

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

101. Naval Orientation. I. *(3).*
A preliminary course presenting naval history, concepts of sea power, and customs and traditions of the Navy.

102. Naval Orientation. II. *(3).*
A general indoctrination in the various components of the United States Navy; shipboard organization and duties.

201. Naval Weapons. I. *(3).*
A familiarization course in modern naval weapons and the purpose of each.

202. Naval Weapons. II. *(3).*
Instruction in the general nature, basic principles of employment, and control of naval weapons, including radar and sonar. Employment of the Combat Information Center in ship organization. Fundamental operation and principles of guided missiles.

301. Naval Engineering. I. *(3).*
Provides a broad general concept of the fundamentals of naval engineering installations including steam, diesel and auxiliary plants, and ship stability.

301S. Navy Supply. I. *(3).*
A study of naval science and naval accounting methods. For Naval Supply Corps candidates only.

301M. The Evolution of the Art of War. I. *(3).*
The development of tactics and materials by a study of specific European battles. For Marine Corps candidates only.

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 Naval Supply Corps candidates only. A study of supply organization and administration afloat.

302M. Modern Basic Strategy and Tactics. II *(3).*
For Marine Corps candidates only. The development of the United States military policy. Individual battles analyzed.

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. Navy Supply. I. *(3).*
For Naval Supply Corps candidates only. Procurement, distribution, and storage with emphasis on ships' store and clothing problems.

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 military law.

402S. Navy Supply. II. *(3).*
For Naval Supply Corps candidates only. Procurement, distribution, and storage of provisions. Fifteen sessions only; remaining thirty sessions combined with NS402 in study of Naval Justice and Leadership.

402M. Amphibious Warfare. II. *(3).*
For Marine Corps candidates only. The history, development, and techniques of amphibious warfare. Fifteen sessions only; remaining thirty sessions combined with NS402 in study of Naval Justice and 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. 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 ENGINEERING

Advisory Committee: Professors Kuethe and Peery, Associate Professors Broadwell and Howe.

A candidate for this degree may, through suitable selection of courses, specialize in any of the following fields: aerodynamics, structures, propulsion, design, 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 Flinn and Siebert, Associate Professors Banchero, Churchill and Martin.

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, 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: Professor Holland and Associate Professor Macnee

A candidate for this degree must have satisfactorily completed the undergraduate electrical engineering program of the University of Michigan 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. 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 MECHANICS

Advisory Committee: Professors Dodge, Hansen, McNown, Naghdi, and Ormondroyd.

The following courses are prerequisite to all courses in engineering mechanics numbered 100 or above: Engineering Mechanics, 1, 2, 3, and 4, Physics 45 and 46, and Mathematics 103.

The master's degree program must include Engineering Mechanics 124, 129, 131, 132, 141, 142 and Mathematics 152, 155, and 157, or their equivalents as approved by the advisory committee. If so approved, a master's thesis may be substituted for part of the course work.

INDUSTRIAL ENGINEERING

Program Adviser: Professor Gordy

A candidate for this degree must have completed satisfactorily the undergraduate industrial engineering program of this College, or its equivalent, and twelve hours of graduate work in mathematics, industrial engineering problems, or appraisal of management, twelve hours of approved cognate work, and six hours in the furtherance of specific objectives developed by the student in consultation with his adviser.

INSTRUMENTATION ENGINEERING

Advisory Committee: Professor Rauch, and Associate Professors Kaplan, Macnee, Parkinson, and Williams

Candidates may be admitted to the degree program from any of the undergraduate engineering curriculums if accepted by the advisory committee. The requirements for the degree include Mathematics 148, Electrical Engineering 108 or 128, Aeronautical Engineering 171 and 172 and other courses approved by the advisory committee. The systems-engineering concept is emphasized throughout the program.

MECHANICAL ENGINEERING

Program Adviser: Professor Porter

The course selections necessary for this degree are rather flexible but it is expected that approximately fifteen hours of course study will be in one of the areas such as heat-power, automotive, heating, air-conditioning and refrigeration, hydromechanical or machine design, and most of the remaining hours in well-selected subjects of a cognate character. At least one course in advanced design and one course in mechanical engineering laboratory must be included, and at least two advanced courses in engineering mechanics, or in some other branch of engineering are required.

METALLURGICAL ENGINEERING

Advisory Committee: Professors Flinn and Siebert, Associate Professors Banchero, Churchill, and Martin.

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

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

MUNICIPAL ENGINEERING ADMINISTRATION

Program Adviser: Professor Boyce

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

NAVAL ARCHITECTURE AND MARINE ENGINEERING

Program Adviser: Professor Adams

A candidate for this degree must have completed the equivalent engineering courses for the degree Bachelor of Science in Engineering (Naval Architecture and Marine Engineering) or, if he has had practical experience in the subject matter covered by these courses, pass an examination in them. The requirements for a Master of Science in Engineering (Naval Architecture and Marine Engineering) degree usually include Naval Architecture 123, 135, 153, and 145 or 154.

NUCLEAR ENGINEERING

Advisory Committee: Professors Gomberg, Ohlgren, Rauch, and Schwartz, Associate Professor Borchardt and Assistant Professor Kerr.

Candidates may be admitted to the program from any of the undergraduate engineering curriculums if accepted by the advisory committee. The requirements for the degree include nineteen hours of course work in the nuclear engineering field (see pp. 133-34) plus electives which meet with the approval of the committee, and the preparation of a thesis.

Opportunities for thesis work are provided by the Ford nuclear reactor in the Phoenix Memorial Laboratory. The University is well equipped for work in tracers, radiation effects, instrumentation, and associated fields.

SANITARY ENGINEERING

Advisory Committee: Professor Boyce and 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 fifteen hours in the field of sanitary engineering and a number of courses in environmental health and public health statistics offered by the School of Public Health.

PROFESSIONAL DEGREES

The following professional degrees may be awarded to qualified candidates:

AERONAUTICAL ENGINEER—Ae.E.
CHEMICAL ENGINEER—Ch.E.
CIVIL ENGINEER—C.E.
ELECTRICAL ENGINEER—E.E.
INDUSTRIAL ENGINEER—I.E.
MARINE ENGINEER—Mar.E.
MECHANICAL ENGINEER—M.E.
METALLURGICAL ENGINEER—Met.E.
PUBLIC HEALTH ENGINEER—P.H.E.
NAVAL ARCHITECT—Nav. Arch.

These advanced degrees will be conferred upon persons who have proved their ability to plan and direct professional work or to conduct original investigation in applied science.

Graduates of the University of Michigan will be required to register during the semester in which they obtain their degrees. Such applicants may register *in absentia.*

Graduates from other institutions of recognized standing who have not been in residence at any time at the University of Michigan must satisfy the standard residence requirement of two semesters of full-time work before receiving the degree.

An applicant for any of these degrees must have received a bachelor's degree from an approved college at least seven years before registration for the advanced degree. He must have been engaged in professional work for a period of seven years, in responsible charge of the same for at least three years, and must present at the time of registration a detailed account of his professional experience up to that time.

Upon admission to candidacy for the degree, a committee will be appointed to supervise the preparation of a thesis, which, with the candidate's professional record, must demonstrate beyond doubt that he is a competent professional engineer capable of taking responsible charge of important engineering work. This thesis may not be a mere description of engineering work of a usual character nor a digest of existing literature, but should be a distinct contribution to engineering science. If the thesis has been previously completed it must be approved by the committee in charge.

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.

APPLICANT FOR THE DOCTORATE. 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.

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 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 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*).

Preliminary design of an airplane from the aerodynamic and structural standpoints, including three-view layout, weight and balance calculations, and preliminary performance estimations. Lectures and drawing.

102. Pilotless Aircraft Design II. (*To be arranged.*)

Primarily for graduates.

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.

109. Aerodynamics I. *Prerequisite: preceded or accompanied by Math. 150 and Eng. Mech. 3.* I. (*3*).

Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Calculation of the forces and moments acting on wings and bodies in incompressible inviscid flow and comparison with experiment. (Differs from Aero. 110 in that in this course an adequate background in mathematics is assumed.)

110. Aerodynamics I. *Prerequisite: preceded or accompanied by Eng. Mech. 3 and Math. 54.* I and II. *(4).*
Development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Calculation of the forces and moments acting on wings and bodies in incompressible inviscid flow and comparison with experiment.

114. Aerodynamics II. *Prerequisite: Aero. Eng. 109 or 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, experiments, and demonstrations.

115. Theory of Thin Airfoils. *Prerequisite: Aero. Eng. 110 or equivalent. (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.

116. Applied Fluid Mechanics. *Prerequisite: Eng. Mech. 4 or equivalent. (3).*
The physical aspects of various problems of viscosity and compressibility and their application in aeronautical and other branches of engineering. Not open to students who have elected Aero. 114.

117. Theory of Propellers and Fans. *Prerequisite: Aero. Eng. 109 or 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 Math. 150. (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. Theoretical aspects of subject are stressed.

121. Turbulence and Diffusion. *Prerequisite: Math. 150, 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.

130. Aircraft Structures I. *Prerequisite: Eng. Mech. 2, and preceded or accompanied by Eng. Mech. 3. (3).*
Fundamentals of aircraft structural design and stress analysis. Application of statics, dynamics, and properties of materials to simple aircraft structures.

131. Aircraft Structures II. *Prerequisite: Aero. Eng. 130 or by special arrangement for students from other departments. (4).*
The investigation and development of methods of analysis for stressed-skin airplane structures, the behavior of thin sheet and stiffened panels at and above the critical buckling stresses. Laboratory experiments cover tests on columns, tubes, shear webs, torsion of open and closed sections, combined loadings, compression of flat plates, and other special topics.

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. Materials and Structures. *Prerequisite: Aero. Eng. 130. (To be arranged).*
Materials likely to be used in the construction of pilotless aircraft, with particular reference to their physical properties at normal and elevated temperatures. Analysis of monocoque structures is reviewed and the effect of dynamic loads considered.

141. Mechanics of Flight I. *Prerequisite: Aero. Eng. 114 and Math. 103, and preceded or accompanied by Aero. Eng. 164 and Eng. Mech. 3. (3).*
Ballistics studies, trajectories in a vacuum and in the atmosphere, solution of equations for simplified cases. 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 or accompanied by Aero. Eng. 131 and 141 or equivalent. (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. Methods in Airplane Dynamics. *Prerequisite: preceded or accompanied by Aero. Eng. 142. (3).*
Stability derivatives. Routh-Hurwitz and Nyquist stability criteria. Airplane transfer functions. Auto-pilots with proportional, derivative, and integral control. Stability of systems with auto-pilot. Detailed investigation of linearized equations with free and automatically operated surfaces on the analog computer. Solution of the equations by the Laplace transformation. Two lectures and one laboratory.

144. Aeroelasticity in Airplane Dynamics. *Prerequisite: Aero. Eng. 142. (3).*
Unsteady aerodynamic transfer functions and indicial admittances at all speeds. Approximate methods for the determination of frequencies and mode shapes for flexible airplanes. Matrix iteration. Solution of flutter and aeroelastic response problems. Laboratory experiments on dynamics of systems with many degrees of freedom. Two lectures and one laboratory.

150. Rotary Wing Aircraft. *Prerequisite: Aero. Eng. 114, and preceded or accompanied by Aero. Eng. 141. (3).*

Rotating-wing aircraft development. Performance analysis, rotor blade stall, stability, vibration.

160. Seminar. I and II. *(To be arranged).*
Open only to graduates and seniors who receive special permission. Reading and reports on selected aerodynamical and aeronautical problems. A reading knowledge of French and German is desirable.

161. Research. I and II. *(To be arranged).*
Continuation of Aero. Eng. 118. Offers an opportunity for students to pursue experimental investigations.

162. Analytical Research. *(To be arranged).*
Theoretical investigation of problems in aeronautical engineering particularly suited to treatment by analytical and mathematical methods.

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. (3).*
Performance and analysis of aircraft propulsion systems including the reciprocating engine-propeller, reciprocating engine-rotor, turboprop, turbojet, ramjet, pulse-jet, and rocket.

165. Introduction to Aircraft Propulsion. *Prerequisite: Mech. Eng. 105, 106, or equivalent. (3).*
Review of those phases of thermodynamics used in the analysis of compressible flow and propulsion systems; turbojet and ramjet; and aeropulse.

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 aeropulse, turbojet, 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.

170. Seminar on Electronic Analog Computers. *Open only to graduates and seniors who receive special permission. (To be arranged).*
Study of selected topics in design and application of electronic analog computers.

171. Principles of Automatic Control. *Prerequisite: preceded or accompanied by 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 and attenuation methods. Use of the electronic differential analyzer in the laboratory for simulation and as a design tool. Lecture and laboratory.

172. Engineering Measurements and Instrumentation. *Prerequisite: Eng. Mech. 3, Elec. Eng. 3 or 5. (3).*
Treatment of instrument response and errors; static, transient, and steady state behavior together with the statistical basis of measurement; altimeters, gyros, thermocouples, seismic instruments, strain gages, and vibration isolation; the concept of the general response of a linear system with simple types of nonlinear damping; use of the electronic differential analyzer to solve and illustrate various physical systems over a wide range of parameters. Lectures and laboratory.

173. Fundamentals of Aeronautical Instruments and Research Techniques. *Prerequisite: Aero. Eng. 172. (3).*
Study of the role of schlieren, shadow, X-ray, and interferometric techniques in aerodynamic research and a comparison of their relative accuracy and effect in data reduction; temperature measurement in combustion chambers and jets; wind tunnel balances; analysis of problems encountered in flight research, including methods of data multiplexing and data recovery; comparison of wind tunnels versus instrumental flight in aerodynamic and systems research.

175. Applications of the Electronic Differential Analyzer I. *Prerequisite: differential equations. (2).*
Basic theory and principles of operation of electronic differential analyzers. Application to heat flow, wave propagation, static and dynamic structural problems, automatic control systems; simulation of physical systems. One lecture and one three-hour laboratory a week. Laboratory consists of the solution of problems on the electronic differential analyzers of the Department of Aeronautical Engineering.

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.

178. Design of Electronic Analog Computers. *Prerequisite: Elec. Eng. 108 or equivalent. (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.

179. Gyrokinetics. *Prerequisite: Math. 104 or equivalent. (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.

201. Dynamics of Viscous Fluids. *Prerequisite: Aero. Eng. 119 or permission of instructor.*
Effect of viscosity in fluid flows. Laminar and turbulent boundary layers in theory and experiment; flow through tubes; flow separation; turbulence theories.

202. Dynamics of Compressible Fluids. *Prerequisite: Aero. Eng. 119. (3).*
Advanced study of the mechanics of high-speed flows; subsonic and supersonic flow through nozzles and diffusers, normal and oblique shock waves, effects of viscosity, flow past wedges, cones, and around corners, transonic and supersonic airfoil theory.

210. Advanced Engineering Measurements. *Prerequisite: Aero. Eng. 172, Elec. Eng. 100 and 180, 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. Lectures and problems.

212. Control and Guidance of Pilotless Aircraft. *Prerequisite: Aero. Eng. 171 or Elec. Eng. 255, Elec. Eng. 120 and 220, Math. 148. (3).*

General analysis of the stability of linear closed-loop systems; relations between control and propulsion and guidance and fuel consumption; beam rider, command guidance, and homing methods together with their relation to collision courses. Demonstrations are made with the electronic differential analyzer and missile simulator. Lectures, problems, and laboratory.

214. Information Theory and Radio Telemetry. *Prerequisite: Aero. Eng. 172, Elec. Eng. 120, Math. 148. (2).*

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; end instruments and various methods of data recording. Lectures and problems.

215. Radio Telemetry Laboratory. *Prerequisite: to be taken concurrently with or following Aero. Eng. 214. (1).*

Laboratory experiments involving the various modulation and multiplex methods and associated instrumentation described in Aero. Eng. 214.

248. Feedback Control. *Prerequisite: Aero. Eng. 171 or Elec. Eng. 255 or equivalent. (3).*

Review of linear system theory; analysis and synthesis of a.c. carrier systems. Operational amplifiers as control elements. Analysis and synthesis of elementary nonlinear control systems and systems with pulsed inputs. Behavior of linear systems in the presence of noise; introduction to autocorrelation methods; the Wiener-Hopf equation for optimum linear system design. Lecture and laboratory.

250. Theory of Oscillation of Nonlinear Systems. *Prerequisite: Math. 104 and a knowledge of elementary matrix theory. (2).*

Principally considered are autonomous (unforced) systems with large nonlinearities and a finite number of degrees of freedom as represented by systems of nonlinear ordinary differential equations without explicit appearance of the independent variable. The concept of phase space is introduced to redevelopment of linear ordinary differential equations in this framework. Conservative nonlinear systems are treated although the main emphasis is on nonconservative nonlinear systems with detailed treatment of second order systems including many physical examples. Use of the electronic differential analyzer for the solution of problems is demonstrated.

251. Theory of Nonlinear System Response. *Prerequisite: Aero. Eng. 250. (2).*

Principally considered are forced systems with large 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 synchronization and entrainment of oscillatory systems are considered. The response of dynamical systems with nonlinear elements to functions of time is treated with particular reference to the improvement of feedback control system performance by the use of nonlinear elements. Use of the electronic differential analyzer for the solution of problems is demonstrated.

252. Seminar on Simulation and Solution of Nonlinear Systems. *Prerequisite: Aero. Eng. 175 and 250, or permission of instructor. (1).*
Supervised work on assigned problems and problems of interest to the student of the types treated in Aero. Eng. 250 and 251. The principal tool used is the electronic differential analyzer.

261. Gas Dynamics. *Prerequisite: Aero. Eng. 119 or permission of instructor. (3).*
Unsteady flow with heat addition; shock, detonation, and deflagration waves, wave interactions; diffuser and nozzle flow; applications to internal flow in engines.

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.

275. Applications of the Differential Analyzer II. *Prerequisite: Aero. 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 eigen-value and difference techniques. Error analysis of differential analyzer solutions. Lecture and laboratory.

BACTERIOLOGY*

Professor Nungester, Associate Professor Kempe; Assistant Professors Gerhardt, Halvorson, Merchant, Preston, and Wheeler; Instructors Garrison, Johnson, and Rajam.

109. Bacteriology for Engineers. *Prerequisite: Org. Chem. 61.* 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 I. *(4-2).*
Lectures and laboratory. Study of the composition and function of bacterial cells.

* Medical School.

156. Bacterial Metabolism. *Prerequisite: Bact. 151.* I. *(4-2).*
Lectures and laboratory. Presentation of principles and methods for study of bacterial metabolism.

160. Industrial Bacteriology. *Prerequisite: Bact. 109.* II. *(4-2).*
Lectures and laboratory to illustrate the applications of microbiology in industry.

BUSINESS ADMINISTRATION*

Professors Davisson, Eiteman, Woodworth, Moore, Riegel, Waterman, Dixon, Schlatter, Schmidt, Dykstra, Assistant Professor Gardner, and others.

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.
2. Juniors may elect courses numbered 1 to 99, inclusive, and seniors may elect any course numbered 1 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:

11. Principles of Accounting. *(3).*
12. Principles of Accounting. *(4).*
14. Industrial Cost Accounting. *(3).*
61. Money and Banking. *(3).*
62. Financial Principles. *(3).*
105. Business Law. *(3).*
106. Business Law. *(3).*
124. Industrial Statistics. *(3).*
141. Production Management. *(3).*
142. Personnel Administration. *(3).*
151. Marketing Principles and Policies. *(3).*

CHEMICAL AND METALLURGICAL ENGINEERING

1. Engineering Materials and Processes. *Prerequisite: an acceptable high school course in chemistry or Chem. 3. (5).*
An introductory course of study of materials and processes. Covers the influence of basic considerations which affects the properties and uses of metals, alloys, cement, clay products, protective coatings, plastics, fuels, and water.

* School of Business Administration.

The influence of the processes of plastic working, casting, joining, machining, and heat treatment on production methods and economics as well as properties are considered in the lecture and recitation and are illustrated in the laboratory experiments. Required of all engineering students. Two lectures, three recitations, and three hours of laboratory a week.

2. Engineering Calculations. *Prerequisite: general chemistry and Phys. 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 (formerly Prod. Eng. 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 period a week.

12 (formerly Prod. Eng. 12). Processing of Cast Metals. *Prerequisite: preceded or accompanied by Math. 54. (3).*

For students in other than metallurgical engineering. Quantitative study of the operations of melting, molding, cleaning, as well as exercises in quality control. Melting experiments include investigations of gases in metals and refining slags; also operation of the cupola, induction, and arc furnaces. Molding instruction covers sand ceramics, gating and risering, in addition to the use of a variety of standard molding machines. Precision casting methods, radiographic and magnaflux inspection of castings, and rapid chemical control procedures are also reviewed. Two lectures and one three-hour laboratory period a week.

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 period a week.

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: Ch. and 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.

103 (formerly Prod. Eng. 113). Research in Cast Metals and Foundry Processes. *Prerequisite: Ch. and Met. Eng. 11, 12, or 13. (3).*
Affords an opportunity for the student to participate in research in problems of importance to the cast metals industry. Both short individual investigations as well as parts of long-range projects are available. These problems include experimental determination of equilibrium constants for slag-metal couples, machinability of cast metals, experimental cupola design and operation, new precision casting processes. Progress is reported at a weekly seminar for the benefit and criticism of the group.

105. Fuels and Chemical Equilibrium in Combustion. *Prerequisite: Mech. Eng. 105 or Ch. and 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: Ch. and Met. Eng. 1 and preceded or accompanied by Mech. Eng. 82. (2).*
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 Ch. and Met. Eng. 107. One laboratory period of three hours.

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

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

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

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

117. Metals and Alloys. *Prerequisite: Ch. and 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: Ch. and 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 Ch. and Met. Eng. 115 or 119. (3).*
The student designs and estimates cost of selected equipment. Lectures, reports, and design.

122. Refractory and Abrasive Materials. *Prerequisite: physical chemistry or permission of instructor. (2).*
Thermochemistry, microstructures, and physical properties of refractory, abrasive, and related industrial minerals. Engineering applications and service behavior of mineral products. Recitation 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: Ch. and 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. Glass and Vitreous Materials. *Prerequisite: physical chemistry and Ch. and Met. Eng. 118. (2).*
Structures and properties of glasses and ceramics as related to composition and thermal treatment.

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

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

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

136. Protective Coating—Pigments. *Prerequisite: Chem. 61R and 183.* II. *(3).*
Pigments, stains, and dyes, their manufacture, properties, and use in protective coatings.

137. Protective Coatings—Vehicles and Driers. *Prerequisite: Chem. 61 and 183.* I. *(3).*
Production, properties, and uses of natural and synthetic oils, thinners, and diluents.

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.

202. Advanced Chemical Engineering Calculations. *Prerequisite: Ch. and 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: Ch. and 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: Ch. and 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: Ch. and 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: Ch. and 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: Ch. and 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: Ch. and Met. Eng. 111. (3).*
Principles of the laws of energy as applied to chemical and metallurgical engineering problems.

212. Equilibrium Stage Operations. *Prerequisite: Ch. and Met. Eng. 115, preceded or accompanied by Ch. and 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: Ch. and Met. Eng. 115. (4).*
Chemical reactions, transport of material, heat transfer, mass transfer, and momentum transfer.

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

216. Engineering Experiments and Their Design. *Prerequisite: Ch. and Met. Eng. 129. (3).*
Economical design of experiments, analysis of experimental data, errors of measurement, limitations of equipment. Subjects considered involve procedures of particular interest to chemical and metallurgical engineers, such as optical and electron microscopy, determination of properties of high polymers, particle size measurements, micro-hardness tests, pyrometry, endurance, chemical and spectroscopic analysis. Lecture, recitation, laboratory.

217. Corrosion and High-Temperature Resistance of Metals. *Prerequisite: Ch. and 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: Ch. and 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: Ch. and Met. Eng. 107 or 127. (3).*
Rolling, forging, extrusion, piercing, drawing, and straightening.

220. Chemical Plants, Design, Operations, and Production Control. *Prerequisite: Ch. and Met. Eng. 130 or by special permission. (3).*
The evaluation of research and development data, integration, and selection of optimum unit operations for chemical plants, preparation of equipment design calculations. Design data, utilities requirements, plant operating instructions, plant startup, operation and shutdown, and engineered control of production costs. Lectures, problems, and recitations.

221. Equipment Design for Advanced Engineering Students. *Prerequisite: Ch. and 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.

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

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

231. Explosives. *Prerequisite: Chem. 161R and Ch. and Met. Eng. 130. (3).*
Manufacture of commercial and military explosives and pyrotechnic materials, their properties and uses.

232. Cellulose Industries. *Prerequisite: Chem. 183 and 161R.* II. *(3).*
Manufacture of pulp and paper, cellulose fibers, and plastics; their properties and uses.

235. Petroleum Engineering. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 130.* I. *(3).*
Properties of petroleum gases and liquid under pressure, the production and processing of natural gas and crude oil.

237. Synthetic Resins and Emulsions. *Prerequisite: Ch. and Met. Eng. 137. (4).*
Manufacture, properties, and uses.

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 Ch. and Met. Eng. 115 or permission of instructor. (3).*
Chemistry of food and food processing methods. Lectures, seminars, and field trips.

240. Metal Reactions in Melting and Refining. *Prerequisite: Chem. 183, Ch. and 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: Ch. and 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: Ch. and Met. Eng. 128. (3).*
Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel. Lecture and recitations.

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

244. Cast Metals in Engineering Design. *Prerequisite: Ch. and Met. Eng. 11, 12, 13, 107, 117 or 127. (2).*
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 period a week.

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

254. Heavy Chemicals. *Prerequisite: Ch. and 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 Ch. and Met. Eng. 211. (4).*
Designs and economic studies of selected petrochemical and refining processes.

256. Small Particles and Suspensions. *Prerequisite: Ch. and Met. Eng. 113 or 123, or Eng. Mech. 4, or permission of instructor. (3).*
Physical and chemical properties of small particles, properties and flow of suspensions, and engineering principles of equipment for handling such material. Includes measurement techniques, conveying and separation equipment, sprays, and dusts.

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

266. Paint, Varnish, and Lacquer Laboratory. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 136 or 137.* I. *(4).*
Analysis, physical testing, and manufacture. Conferences and laboratory.

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

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

328. Physical Metallurgy Seminar. *Prerequisite: Ch. and Met. Eng. 228. (2).*

336. Paint, Varnish, and Lacquer Formulation. *Prerequisite: Ch. and Met. Eng. 237. (5).*
Economic formulation, manufacture, and uses.

337. Varnish. *Prerequisite: Ch. and Met. Eng. 237.* I. *(3).*
Formulation, manufacture, and uses of natural and synthetic resin, varnish, and wax.

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

355. Petroleum Seminar. *Prerequisite: Ch. and 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: Ch. and Met. Eng. 213. (2).*

365. Mass Transfer Seminar. *Prerequisite: Ch. and Met. Eng. 213. (2).*

CHEMISTRY*

Professors Anderson, Brockway, Elderfield, Elving, Fajans, and Halford; Associate Professors Case, Hodges, Parry, Rulfs, Smith, Soule, Vaughan, and Westrum; Assistant Professors Bernstein, Meinke, Rondestvedt, Tamres, Taylor, and Weatherill; Dr. Nordman, Dr. O'Rourke, and Dr. Stiles.

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

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 work.

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).*

* College of Literature, Science, and the Arts.

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 work.

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 work.

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 work.

14. Unified Chem. I. *Prerequisite: Physics 53.* *(4).*
The properties of matter discussed from the viewpoint of dynamics: discussions of thermodynamic functions, kinetic theory, and chemical kinetics. Lectures, recitations, laboratory.

15. Unified Chem. II. *Prerequisite: Physics 54.* *(4).*
Properties of matter from the viewpoint of atomic structure, including periodic relationships; organic and inorganic chemistry. Lectures, recitations, 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.* 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. 3 and 4, or 5E and 20, or 8.* I and II. *(6).*
Survey of the whole field of organic chemistry. Four lectures, one recitation, and seven hours of laboratory.

61R. Organic Chemistry. *Prerequisite: Chem. 3 and 4, or 5E and 20, or 8.* I and II. *(4).*
Same as 61 but without laboratory work.

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, 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.* I and II. *(3).*
Atomic concepts of matter and energy, nature of the gaseous, liquid, solid states, thermochemistry and thermodynamics. Lecture.

183. Physical Chemistry. *Prerequisite: Chem. 182.* I and II. *(3).*
Homogeneous and heterogeneous equilibria, kinetics, electrochemistry, solution theory, photochemistry, and colloids. Lecture.

185, 186. Physicochemical Measurements. *Prerequisite: preceded or accompanied by Chem. 41 and 182.* 185, I and II; 186, I and II. *(2 each).*
Measurements of molecular weights, properties of pure liquids and solutions, thermochemical data, equilibria, kinetics, atomic and molecular properties, and electrochemical data.

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.

234. Physicochemical Methods in Quantitative Analysis. *Prerequisite: Chem. 141 and 183.* II. *(2–3).*
Lectures and laboratory work.

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. Surveying. *Prerequisite: Math. 14.* I and II. *(3).*
Care and use of surveying instruments and equipment; differential and profile leveling, establishing grade, vertical curves, traverse surveys and computations; circular curves. Theory, problems, and field exercises.

2. Surveying. *Prerequisite: Civ. Eng. 1.* I and II. *(4).*
Principles of triangulation, topographic mapping, use of plane table and stadia; U. S. land subdivision, property surveys; map projections and co-ordinate systems; earthwork computations including mass diagram; controlled planimetric map from aerial photographs; map making; theory of instrument adjustment. Problems and field exercises.

3. Surveying. *Prerequisite: Civ. Eng. 1 and 2.* Camp Davis. S.S. *(4).*
Field adjustment of instruments, triangulation and base line measurements, establishment of vertical and horizontal controls; route surveys with application of vertical and horizontal curves to location; land surveys; construction surveys (including setting grade and slope stakes, excavation batter boards, etc.). Field problems.

4. Surveying. *Prerequisite: Math. 14.* I and II. (*2*).
For noncivil engineering students. Care and use of surveying instruments and equipment; differential and profile leveling; establishing grade; traverse surveys and computations. Theory, problems, and field exercises.

12. Surveying. *Prerequisite: Math. 13.* (*3*).
Similar to Civ. Eng. 1. Designed for forestry students. Theory, problems, and field exercises.

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. Lectures, text, and drawing room practice.

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

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. Lectures, text, and home problems.

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 and drawing work.

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, laboratory.

50. Fundamentals of Sanitary Engineering. I and II. (*2*).
Environmental factors affecting public health that may be controlled through the application of engineering knowledge. Principles of public sanitation as applied to community problems of water supply, sewerage, housing, and ventilation, and to the technical problems of other sanitation activities. Open to juniors and seniors.

60. Highway Engineering. *Prerequisite: Civ. Eng. 1 or 4.* I and II. (*2*).
General course covering the planning, design, construction, maintenance, economics, and financing of highways.

70. Railroad Engineering. *Prerequisite: Civ. Eng. 1 or 4.* I and II. (*2*).
Regulation and valuation of railways; elements of the location, design, construction, and maintenance of roadway and equipment; the analysis of operating problems. Open to juniors and seniors.

80 (formerly 75). Introductory Meteorology. (*3*).
The atmosphere, its composition and properties; construction and interpretation of the weather map; atmospheric heat gains and losses; wind and storm

systems; cloud, fog, and precipitation; elements of climate; influence of climate on man.

101. Geodesy. *Prerequisite: Civ. Eng. 3.* *(3).*
Introductory course; history; elements of modern practice and its application to several branches of surveying. Lectures, text, recitation.

102. Geodesy. *Prerequisite: Civ. Eng. 101.* *(2).*
Methods employed and field covered by the United States Coast and Geodetic Survey. Lectures, reference work.

105. Least Squares. *Prerequisite: Math. 54.* *(2).*
Theory of least squares; adjustment and comparison of data. Lectures, text, problems, and recitations.

106. Advanced Surveying. S.S. *(2–8).*
Special advanced work can be provided for those who have received credit in Civ. Eng. 3. Given only at Camp Davis.

107. Municipal Surveying. *Prerequisite: Civ. Eng. 3.* *(2).*
Surveys for streets, grades, paving, sewers, property lines, subdivisions. Lectures, text, drawing, field period.

109. Railway Surveying. *Prerequisite: Civ. Eng. 3.* *(2).*
Text, field, track problems. One recitation and one four-hour field period.

111. Photography—Basic Course. *Prerequisite: elementary chemistry and physics.* I and II. *(3).*
Fundamental theory and practice. Lectures, reference work, and laboratory period.

113. Aerial Photography and Mapping. *(2).*
Map projections and map making from aerial photographs. Lectures, reference work, recitations, problems, and laboratory.

114. Registration of Land Titles. *Prerequisite: Civ. Eng. 3.* *(3).*
Torrens Act of Australia and modifications as adapted to conditions of other countries. Lectures, reference work.

115. Boundary Surveys. *Prerequisite: Civ. Eng. 3.* *(3).*
Problems relating to the establishment of boundaries. Lectures, reference work.

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, laboratory.

121. Reinforced Concrete. *Prerequisite: Civ. Eng. 22.* I and II. *(3).*
Properties of materials; analysis of stresses in plain and reinforced concrete structures.

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. Lectures, texts, problems.

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

126. Sanitary Engineering Structural Design. *Prerequisite: Civ. Eng. 23, 121, 151.* (*2*).
Structural design problems encountered in the field of sanitary engineering. Lectures, computations, drafting.

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

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, 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. Lectures, references, problems.

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

135. Applied Soil Mechanics. *Prerequisite: Civ. Eng. 121, should be accompanied by Civ. Eng. 136.* 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; problems in highway and airport construction. Lectures, references, and problems.

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. Laboratory exercises, field trips, lectures, and references.

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 problems.

141. Hydraulics. *Prerequisite: Eng. Mech. 4.* I and II. *(2).*
Hydrostatics; flow in pipes and pipe fittings; pipe orifices, Venturi meters; siphons; pump characteristics; flow in open channels; spillways; control meters. Lectures, demonstrations, and laboratory exercises.

142. Water-Power Engineering. *Prerequisite: Eng. Mech. 4.* II. *(2).*
Hydraulics of turbines and fundamental principles of water-power development; characteristics and uses of different types of turbines; effect of load upon selection; storage and pondage; turbine testing; speed regulation. Lectures and problems.

143. Advanced Hydraulics. *Prerequisite: Civ. Eng. 141 or equivalent.* I and II. *(3).*
Flow in open channels; nonuniform flow; critical depth; hydraulic jump channels of varying width; waves; flow in the laminar and transition regions in pipes and open channels; dimensional analysis; hydraulic similitude; hydraulic models.

144. Hydraulic Structures. *Prerequisite: Civ. Eng. 140 and 141, preceded or accompanied by Civ. Eng. 143.* I. *(3).*
Dams, head gates, canals, flumes, pipelines, surge tanks, revetments, breakwaters, and other structures with special reference to the hydraulic problems encountered in connection with their design. Lectures and problems.

145. Seminar in Hydraulic Engineering. *Prerequisite: Civ. Eng. 140 and 141.*
Lecturers, assigned reading, and student reports on problems dealing with theoretical hydraulics, hydrology, hydraulic models, hydraulic structures, hydroelectric power, or multipurpose projects.

146. Hydraulic Engineering Design. *Prerequisite: Civ. Eng. 121, 140, and 141; 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. Lectures, computations, and design.

151. Water Supply and Sewerage. *Prerequisite: Eng. Mech. 4 and Civ. Eng. 50.* I and II. *(3).*
Sources of public water supply, quality and quantity requirements; design of works for the collection, purification, and distribution of water for municipal use; requirements for municipal sewerage systems; fundamentals of design of sewage treatment plants. Lectures, problems.

152. Water Purification and Treatment. *Prerequisite: Civ. Eng. 151 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. 151 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. 121 and 151. (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. Lectures, library reading.

156. Sanitary Engineering Laboratory. *Prerequisite: Civ. Eng. 151 and Bact. 51 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 225, or consent 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. 60.* 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. 60.* I. *(3).*
Sources, production, and testing of highway materials; specifications; minor research problems. Lectures, text, laboratory.

162. Bituminous Materials and Pavements. *Prerequisite: Civ. Eng. 60.* II. *(2).*
Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods. Lectures, text, laboratory.

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 material surveys. Lectures, references, and design problems.

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 Engineering. I. *(2).*
Causes of and remedies for street traffic congestion and accidents.

166. Highway Traffic Surveys. *Prerequisite: Civ. Eng. 165 or permission of instructor.* II. *(2).*
Traffic studies for highway planning and for the facilitation and safeguarding of traffic flow. Assigned reading and field work.

167. Highway Economics. *Prerequisite: Civ. Eng. 60.* II. *(2).*
Open to seniors and graduates. Economics of highway location, construction, and operation; highway finance; effect on cost of grades, curves, and distance.

169. Highway Design. *Prerequisite: Civ. Eng. 60.* I and II. *(3).*
Studies of highway capacity, alignment, profiles, intersections, interchanges, and grade separations. Problems and drawing work.

170. Railway Location Design. *Prerequisite: Civ. Eng. 70. (3).*
Field and office practice of location and construction. Computation and design.

171. Advanced Railroad Location. *Prerequisite: Civ. Eng. 170.* I and II. *(3).*
Design of a railroad division, including paper location, selection of rolling stock, operating schedules, and appropriate facilities.

172. Railroad Maintenance. *Prerequisite: Civ. Eng. 70.* 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. 70. (3).*
Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities. Text, problems, and design.

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. Lectures and seminar.

175. Advanced Terminal Design. *Prerequisite: Civ. Eng. 173. (3).*
Technical studies of metropolitan terminals, including details of car retarder, hump-yard computations, multiple-switch installations, and provisions for improved efficiency in the movement and transfer of passengers and freight.

176. Economics of Railroad Construction and Operation. *Prerequisite: Civ. Eng. 70.* 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. Lectures, text, problems.

177. Railroad Administration. *Prerequisite: Civ. Eng. 70. (3).*
Nature of the railroad organization; the various departmental and divisional functions; employee relationships; public relations; intercarrier traffic agreements.

178. Transportation. I. *(3).*
Transportation facilities, services, and policies, with emphasis on comparative performance of the various agencies of transport. Lectures, library research, seminar. Open to seniors and graduate students.

179. Railroad Engineering Seminar. I and II. *(1).*
Preparation and presentation of reports covering assigned topics.

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

183. Public Utility Problems. II. *(2).*

Nature of public service corporations; organization; ownership; valuation; depreciation; accounting; regulations; taxation; rates. Lectures, library reading.

184. Micrometeorology I. *Prerequisite: restricted to senior and graduate students.* II. *(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.

185 (formerly 147). Physical Meteorology. *Prerequisite: Math. 54 and Phys. 26 or equivalent.* I. *(2).*

The distribution of temperature, pressure, and wind over the earth; composition of the atmosphere; atmospheric statics; thermodynamics of dry and moist air, stability, fog, cloud, and precipitation; wind and turbulence; air masses; pressure systems. Lectures and problems.

186 (formerly 148). Applied Meteorology. *Prerequisite: Civ. Eng. 80 or 185.* II. *(2).*

Topics in applied meteorology, selected in accordance with the requirements of the class. Representative topics: meteorological aspects of atmospheric pollution; wind and snow loading of buildings and bridges; weather and climate as elements in plant, animal, and human ecology; weather in business and industry.

187. Weather Map Analysis and Forecasting Laboratory. *Prerequisite: preceded or accompanied by Civ. Eng. 80 or 185.* *(2).*

The assembly of simultaneous weather observations to form weather maps. The analysis of weather maps: drawing isobars and contours; frontal analysis; isallobars, designation of air masses and of various important weather phenomena, the relation of clouds and cloud systems to pressure systems, fronts, and the transport of moist and dry air. Forecasting: the preparation of forecast maps; the prediction of pressure configuration, frontal locations, and intensities; forecasts for specified stations of pressure, temperature, wind speed and direction, cloud cover, precipitation, fog, thunderstorms, and upper level phenomena. Laboratory instructions and exercises. One lecture and three laboratory hours.

188. Dynamic Meteorology. *Prerequisite: Math. 54 and Physics 46 or equivalent.* *(3).*

Atmospheric structure; altimetry; thermodynamics of dry and moist air; cloud, precipitation, and icing processes; atmospheric turbulence and diffusion; general dynamics of air motions; dynamics of storms; vorticity; weather prediction by high-speed electronic computing methods; the jet stream; the high atmosphere. Lectures, problems, and selected reading.

189. Meteorological Instrumentation. *Prerequisite: Physics 26 or its equivalent. Restricted to seniors and graduate students.* I. *(2).*
Principles of meteorological instruments; methods of measurement of pressure, temperature, humidity, precipitation, evaporation, and wind. Lectures and laboratory exercises.

210. Geodesy and Surveying Research. *Prerequisite: Civ. Eng. 101, 102. (To be arranged).*
Assigned work in geodesy, with emphasis on research development in methods of trilateralation.

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. Advanced Theory of Reinforced Concrete. *Prerequisite: Civ. Eng. 121. (3).*
Design and analysis of special types of reinforced concrete structures. Lectures, text, problems.

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. Lectures and problems.

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, 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. Lectures, recitations, and problems.

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

226. Metal Structures. II. *(3).*
Yield, fracture, and fatigue failure of metals. Plastic or "limit" analysis and design of metal structures. Local buckling and the design of compression plate elements and stiffeners of columns and girders.

227. Bridge Engineering. *Prerequisite: Civ. Eng. 123.* I. *(2).*
History of bridges; selection of the proper bridge structure for a given location with regard to economics, underclearance, site, foundation, erection, maintenance, aesthetics, safety, and financing.

228. Bridge Design. *Prerequisite: Civ. Eng. 123. (3).*
Design of reinforced concrete and steel highway or railway bridges. Lectures, computations, 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.

230. Precast and Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 30 and 123.* II. *(2).*
Shrinkage, plastic flow, bond, precast beams, cast-in-place floors forming T beams, and prestressed reinforced concrete, precast members.

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 in 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. By appointment.

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.

252. State Health Department Engineering Practice. II. *(2).*
Critical and analytical study of the jurisdiction, functions, standards, and activities of engineering divisions of state departments of health.

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 and Highway Transport Research. I and II. *(To be arranged).*
Assigned work in the fields of highway engineering, highway transport, or highway traffic control.

262. Advanced Bituminous Materials and Flexible Pavement Design. *Prerequisite: Civ. Eng. 162. (To be arranged).*
Conferences and special problems on new developments in bituminous materials, bituminous mixture design, and flexible pavement design for highways and airports. Conferences, assigned reading, laboratory investigations, reports.

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. Railroad Engineering Research. I and II. *(To be arranged).*
Assigned work in the field of railroad engineering. To obtain credit a thesis must be prepared which would be acceptable for publication.

280. Civil Engineering Research. I and II. *(To be arranged).*
Assigned work in the fields of transportation, public utilities, or engineering relations and ethics. To obtain credit a thesis must be prepared which would be acceptable for publication.

284. Micrometeorology II. *Prerequisite: Civ. Eng. 184 and 185 or permission of instructor.* I. *(3).*
Laminar and turbulent flow in the atmosphere; transfer of matter, momentum, and heat; eddy diffusion; evaporation from natural surfaces. Lectures and problems.

285 (formerly 247). Meteorological Research. *(To be arranged).*
Assigned work in meteorological research; may include field measurements, analysis of data, development in physical or applied meteorology.

286. Interdepartmental Seminar on Applied Meteorology. *Prerequisite: Civ. Eng. 80 or 185, 186, or permission of instructor. (1).*
Preparation of two term papers on applied meteorology: one on current topics, and one covering an investigation on some special subject. Reading, preparation of papers, and class discussions.

501. Meteorology for Teachers. *Prerequisite: upperclass or graduate standing or permission of instructor. Not open to engineering students. (2).*
Lectures, discussions, and workshop in the introduction and organization of meteorology subject matter in the science curriculum. Emphasis will be on the place of meteorology in the total school program, the interrelationships with other subject-matter fields and the planning of courses, units, and projects to fit into various individual programs. Included will be a survey of the type and sources of supplementary materials and the designing and equipping of facilities for projects, demonstrations, and laboratory and field exercises.

DRAWING (ENGINEERING)

The first-year requirements in engineering drawing may be fulfilled by Drawing 1 and 2 or by Drawing 1x and 2x. The student will elect whichever sequence is advised by the classifier.

1. Elementary 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.

1x. Elementary Engineering Drawing. *Prerequisite: solid geometry.* I. *(3).*
Use of instruments, lettering, geometric constructions, multiview drawings, auxiliary views, basic principles of descriptive geometry, intersection and development of surfaces. Three two-hour periods.

2. Descriptive Geometry. *Prerequisite: solid geometry and Eng. Draw. 1.* I and II. *(3).*
The course is outlined and problems are chosen to develop facility in solving the five basic geometrical problems of engineering; determination of all problems of distances, angles, intersection of any line with any surface, intersection of surfaces, plane dimensions, areas, and patterns of developable surfaces. Three two-hour periods.

2x. Engineering Drawing. *Prerequisite: Eng. Draw. 1x.* II. *(3).*
Pictorial drawings, sectional views and conventions, fasteners, dimensioning and tolerances, detail and assembly drawings, simple structural details; piping, process, and circuit diagrams; freehand sketching. Three two-hour periods.

3. Advanced Engineering Drawing. *Prerequisite: Eng. Draw. 1 and 2 or equivalent.* I and II. *(2).*
Advanced work in orthographic and pictorial representation including: engineering sketching, working drawings both detail and assembly with emphasis on auxiliary views, sectioning, tolerance dimensioning, piping and structural layouts.

11. Engineering Drawing. II. *(1).*
Elementary drawing for forestry students. 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. One three-hour period a week.

12. Graphical Presentation and Computation. *Prerequisite: Eng. Draw 1, 2, and 3.* 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. Two-hour period to be arranged.

15. Production Illustration. *Prerequisite: Eng. Draw. 1 or its equivalent. (2).*
Various methods of making the pictorial drawings being used today by engineers and draftsmen; use of production illustrations, lettering, orthographic projection, axinometric projection, oblique projection, perspective projection, sectional views, exploded views, and assembly views to more clearly show how things are to appear when manufactured.

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.

ECONOMICS*

Professor Ackley; Professors Boulding, Dickinson, Ford, Haber, Katona, Klein, Musgrave, Paton, Peterson, Remer, Stolper, and Watkins; Associate Professors Morgan, Palmer, Levinson, and Suits; Assistant Professor Peck; Mr. Adams, Mr. Liebhafsky, Mr. Mandelstamm, Mr. Reher, Mr. Anderson, Mr. Buckberg, Mr. Hutchinson, Mr. Runyon, and Mr. Yohe.

Department office, 107 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.

* College of Literature, Science, and the Arts.

71, 72. Accounting. *Prerequisite: Econ. 71 is prerequisite to Econ. 72.* 71, I and II *(3);* 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 war and postwar 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.

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.

173. Fundamentals of Accounting. I and II. *(3).*

Not open to students who have had Economics 71. Emphasizes cost determination and financial statements.

175. Elementary Economic Statistics. *Prerequisite: Econ. 53 and 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. 54. (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 period.

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 a week.

5. Direct- and Alternating-Current Apparatus and Circuits. *Prerequisite: Math. 54 and Physics 46. (4).*
Electric circuits; characteristics of direct- and alternating-current motors and generators; problem work. Not open to electrical engineering students. Three lectures and one three-hour laboratory period.

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 period.

8. Circuits. *(4).*
Review of direct-current and alternating-current circuits and machinery. A special course for the guided-missile program. Not open to electrical engineering students.

10. Principles of Electricity and Magnetism. *Prerequisite: Math. 54 and Physics 46. (4).*
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; combined electric and magnetic fields; Maxwell's equations. Three lectures and one three-hour computing period.

79 (formerly 199). 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.

100. Circuits II. *Prerequisite: Elec. Eng. 3. (4).*
Analysis of complex alternating-current waves; average and effective values; power factor; the method of the complex variable in a.c. problems; solutions of simple transients and oscillatory circuits; use of hyperbolic functions in solving the general equation of a circuit containing distributed inductance, capacitance, resistance, and leakage. Lectures and problems.

101. Networks and Lines. *Prerequisite: Elec. Eng. 100. (3).*
General network analysis; artificial lines, attenuators, filters, equalizers; trans-

mission of electric waves on lines; reflections at terminals. Lectures and problems.

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. Lectures, recitations, and problems.

103. Electroacoustics and Ultrasonics. *Prerequisite: Math. 57 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 Electron Tube Circuits. *Prerequisite: Elec. Eng. 5 or equivalent. (4).*
Network analysis; vacuum tube circuits; amplifiers, mixers, modulators, and detectors. Not open to electrical engineering students. Lectures and laboratory.

120. Radio Communications I. *Prerequisite: Elec. Eng. 100 and 180 or Physics 165. (4).*
Circuit theory with special emphasis on resonant circuits; audio-frequency and radio-frequency amplification; modulation and detection; transmitting and receiving circuits. Lectures and laboratory.

121. Radio 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.

126. Telephone Communications. *Prerequisite: preceded or accompanied by Elec. Eng. 101. (4).*
Telephone circuits, networks, and apparatus. Lectures and laboratory.

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 period.

131. Technical Electrical Measurements. *Prerequisite: Elec. Eng. 130 or equivalent. (2).*

Selected topics in technical electrical measurements; dielectric measurements by Schering bridge methods, watthour meter calibration, magnetic measurements. One lecture and one three-hour laboratory period.

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. Lectures, demonstrations, and 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 period.

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. Lectures and recitations.

150. Alternating-Current Machinery. *Prerequisite: Elec. Eng. 3. (4).*
Theory and operating characteristics of transformers, polyphase synchronous and induction machines; various types of single-phase motors, selsyn devices. Lectures and laboratory.

151. Design of Induction Motors. *Prerequisite: Elec. Eng. 150. (3).*
Design and performance of polyphase and single-phase machines, especially induction motors. Lectures and computing period.

155. Automatic Control Systems. *Prerequisite: Elec. Eng. 150 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.

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. Recitation and problems.

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 period.

172. Electrical Lighting and Distribution. *(2).*
For students of architecture particularly; students of electrical engineering cannot receive credit for this course. Lectures and problems.

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. Lectures, problems, and surveys.

176. Residence Lighting. *Prerequisite: preceded by Elec. Eng. 170 or Elec. Eng. 172. (2).*
For students of architecture and engineering. Co-ordination of architecture with illumination as applied to residence lighting. Problems and lectures supplemented by illustrated talks.

180. Electronics and Electron Tubes I. *Prerequisite: Elec. Eng. 3 or 5; preceded or accompanied by Elec. Eng. 10. (4).*
Electron ballistics and space-charge flow in cathode-ray and grid-controlled vacuum tubes; thermionic emission, gaseous conduction devices; electron tube characteristics; amplifiers, rectifiers, photosensitive devices; energy-level diagrams for atoms, metals, and semiconductors. 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 work.

189. Electron Tubes II. *Prerequisite: Elec. Eng. 180, or permission of instructor. (4).*
Conformal analysis of fields in space-charge control tubes; transit time loading, electron transit phase delay, and induced current effects in ultra-high frequency small-signal and large-signal triodes and tetrodes; electron optics of

cathode-ray focusing; secondary emission and photoelectric phenomena in television pickup and memory storage tubes; initiation of current in thyratrons, ignitrons, glow tubes, and circuit breakers; Paschen's law; radiation counter tubes. Lectures and laboratory.

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

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. (2).*
Synthesis for prescribed transfer functions; the approximation problem; synthesis for a prescribed time response; feedback amplifier design.

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. *Prerequisite: Elec. Eng. 3 and 10. (3).*
Advanced theory and problems in electric and magnetic fields, using elementary vector methods which are introduced as required. Maxwell's equations, waves, and propagation of energy.

211. Applications of Electromagnetic Field Theory. *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. 180 and 210. (3).*
Electric and magnetic properties of gaseous, liquid, and solid materials used in electrical engineering. Lectures and recitations.

220. Microwave Engineering. *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. 120. (3).*
Fundamental theory; simple antennas, arrays, and reflecting systems; ionosphere; reflection, refraction, and diffraction; tropospheric propagation. Lectures.

225. Television. *Prerequisite: preceded or accompanied by Elec. Eng. 121. (2).*
Basic principles, cathode-ray scanning devices, and television receivers and transmitters. Lectures.

228. Microwaves, Radiation, and Propagation. *Prerequisite: Elec. Eng. 128. (4).*
Transmission lines, standing waves, impedance transformation; Maxwell's equations, waves, waveguides, cavity resonators; antennas, arrays, radiation pat-

terns; tropospheric and ionospheric propagation, radar equation, ducts. A special course for the guided-missile program. Not open to electrical engineering students.

232. **Analog and Digital Computer Technology.** *Prerequisite: Math. 57 or 103; 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.

234. **Theory of Networks of Switching Elements.** *Prerequisite: Elec. Eng. 100 and Math. 57. (3).*
Analysis and synthesis of switching networks for performing counting, coding, computing, and similar functions. Lectures and laboratory.

235. **Digital Computer Design Principles.** *Prerequisite: Elec. Eng. 232. (2).*
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 Michigan Digital Automatic Computer (MIDAC). Open only to USAF officers.

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. Lectures and recitations.

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. Lectures.

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-state 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 synchronous 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. Attenuation 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 nonsalient 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. Laboratory work on the analysis of several control systems and their simulation on the differential analyzer. Two lectures and one four-hour laboratory period.

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.

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; management; 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 (formerly 299). 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 period a week.

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 period a week.

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 formation, 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. Introduction to Noise and Information Theory. *Prerequisite: Elec. Eng. 100, Math. 57, and preceded or accompanied by Math. 152, or permission of instructor. (3).*
Elementary probability and random processes. Inverse probabilities, sampling, and detectability of signals in noise. Generalization of harmonic analysis. Sources and properties of random noise in systems of communication and control. Smoothing and prediction. Entropy and redundancy of languages and codes. Optimum rate of transmission of information through communication channels.

286. Microwave Electron Tubes. *Prerequisite: Elec. Eng. 210 or permission of instructor. (3).*
Energy conversion in electron devices, klystrons and velocity modulation principles, waves on electron streams, traveling wave tubes, double stream amplifiers, backward wave oscillators, magnetron traveling wave amplifiers, magnetron oscillators, particle accelerators. Lectures and laboratory.

288. Semiconductors, Ferromagnetic and Ferroelectric Materials. *Prerequisite: Elec. Eng. 180 and Math. 57. (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. 53 and Phys. 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. Recitations, lectures, problems.

2. Strength and Elasticity 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. Recitations, lectures, and problems.

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 and Math. 54.* I and II. *(3).*
Motion of a particle, dynamics of moving bodies. Newton's laws, simple harmonic motion, elementary vibration problems, balancing, pendulums, impulse and momentum, work and energy. Recitations, lectures, problems.

3a. Experimental Dynamics. *Prerequisite: preceded or accompanied by Eng. Mech. 3. (1).*
Experiments with acceleration, vibration, balancing, critical speeds, and gyroscopics. One laboratory period, with report, each week.

4. Fluid Mechanics I. *Prerequisite: Eng. Mech. 1 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 conducts. Recitation, lectures, and laboratory demonstrations.

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 of orifices; flow nozzles, Venturi meters, weirs; hydraulic jump and critical depth; resistance to flow, boundary layer, transition. Experiments, demonstrations, reports.

5. Statics and Stresses. *Prerequisite: Phys. 45 and Math. 54. For chemical engineering students only. (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. Recitations, lectures, and problems.

11. Statics. *Prerequisite: Phys. 51, 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. 55. (3).*
Kinematics, rectilinear and curvilinear motion, rotational kinematics, relative motion, Coriolis' acceleration, kinetics of particles and rigid bodies, d'Alembert's principle, momentum principle, conservation of energy, conservative and nonconservative systems, thermodynamical considerations, applition to impact, dynamic stresses, propulsion; free and forced vibrations of rigid bodies, vibration of distributed masses, damping, 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 in 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).*

103. Experimental Mechanics. *Prerequisite: Eng. Mech. 2, 3, and 4 and Elec. Eng. 5. (3).*
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. Lectures, laboratories, and problems.

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, structures, and materials.

122. Photoelasticity. *Prerequisite: Eng. Mech. 2 and Math. 57. (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.

123. Theory of Strength. *Prerequisite: Eng. Mech. 2. (3).*
Review of plane state of stress and strain; criteria of material failure; derivation of energy principles and application to statically indeterminate problems; bending of curved beams; torsion of thin-walled open and closed sections; fundamentals of elastic instability; beam-columns; basic concepts of limit design.

124. Theory of Elasticity I. *Prerequisite: Eng. Mech. 2 and 3, and Math. 103 and 150. (3).*
Fundamentals of the theory of elasticity; three-dimenional 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, 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, and Math. 103. Not open to students in the engineering mechanics program. (2).*
Motion of stress and strain, theories of failure, concept of plastic flow and yield criteria; problems of tension, bending, and torsion beyond elastic limit; stresses in thick-walled cylinders and rotating disks; elementary analysis of plates and thin-walled pressure vessels, including the thermal effect; design of members subjected to static, impact, vibrational and fatigue stresses.

127. Theory of Structures in Ship Design. *Prerequisite: Eng. Mech. 2. Not open to students in the engineering mechanics program. (4).*
Statically indeterminate structures in general; reciprocal theorem; internal deformation and strain energy; deflection of beams and trusses; Castigliano's theorems; continuous beams and frames; moment distribution method; elementary theory of thin plates on continuous and elastic supports.

128. Stability of Elastic Structures. *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.

131. Fundamental Vibration Analysis. *Prerequisite: Eng. Mech. 3, Math. 57, 103, or 104. (3).*
Theory of vibration of single and multiple mass systems with or without damping in translation and rotation; the impedance of mobility methods in analysis of complex vibratory systems; vibration of distributed mass systems (strings, beams, and shaft; self-induced vibration, stability).

132. Advanced Dynamics. *Prerequisite: Eng. Mech. 131, 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 work of Tycho Brahe and Kepler, 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. 131. (3).*
Dynamic balancing of rotors and crankshafts; torsion and vibration analysis of equivalent masses and shaft systems in engines; 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 131, or permission of instructor. (3).*
Fundamental equations of motion of strings, bars, shafts, and beams. Problems in free and forced vibrations with various end conditions and types of loading; effect of damping on the motion; application of the methods of Rayleigh, Ritz, Holzer, Trefftz, and Stodola 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; gyrostabilization, gyro control, and other selected topics.

140. Research in Flow of Fluids. *(To be arranged).*
Special problems in the laboratory or research in literature, such as hydraulic roughness, flow of solid suspensions, boundary layer studies, turbulence, photoviscosity, secondary flow in conduits and channels, stability of modes of fluid flow.

141. Fluid Mechanics II. *Prerequisite: Eng. Mech. 4 and Math. 150. (3).*
Equations of motion of nonviscous fluids, continuity, potential flow relations, conformal transformations, vortex motion; equations of motion of viscous fluids, dimensional analysis; velocity distribution, boundary layer, lubrication, turbulence.

142. Thermodynamics. *Prerequisite: Math. 103 or 150. (2).*
Fundamental concepts; first and second laws of thermodynamics; equilibrium of homogeneous systems; applications to elastic deformations and fluid dynamics.

144. Selected Topics in Fluid Mechanics. *Prerequisite: Eng. Mech. 141, Civ. Eng. 143, or Aero. Eng. 110. (2).*
Theory, dimensional analysis, and experiment are combined in the analysis of selected topics in fluid mechanics, such as unsteady flow in conduits, water hammer, and flow with spatially variable discharge. General methods of analysis are emphasized and laboratory results and current publications are utilized.

200. Theory of a Continuous Medium. *Prerequisite: Eng. Mech. 124, 141, 142. (3).*
General theory of a continuous medium and its specialization to the theories of elasticity, fluid mechanics, and plasticity; 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.

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, 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. Fluid Mechanics III. *Prerequisite: Eng. Mech. 141 and 142; others by special permission. (2).*
Equations of motion and energy for viscous liquids and viscous gases; some simple flows of each; energy dissipation, vorticity, and circulation in liquids and gases; boundary layers; shock waves in gases; turbulent flow of liquids and gases; practical application of potential theory to the flow of liquids and gases at low speeds; approximate methods for high-speed flow of inviscid gases; calculating transsonic flows.

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

Normally, English 11, 21 and 12 are required of all engineering students. English 11 and 21 should be taken in the student's first semester; English 12 in his second semester. The student who, in the opinion of the department, needs further preparatory work before taking English 11 may be required to elect English 10; the student with demonstrated superior ability may be excused from one or more courses in Group I.

10. Preparatory Composition. *(3).*
A practice course in composition and reading, designed for those in need of further preparatory training. Study and drill in diction, spelling, grammar, punctuation; the structure of the sentence, paragraph, and short essay; and in the techniques of reading.

11. Theme Writing. I and II. *(3).*
An introdutory course in composition and the study of literature. Practice in writing of prepared and impromptu themes and in the reading and analysis of essays, prose, fiction, drama, and poetry.

12. Expository Writing. *Prerequisite: English 11; to be preceded or accompanied by English 21.* I and II. *(2).*
A continuation of English 11 with special emphasis on the longer composition.

21. Oral Exposition. I and II. *(1).*
A practice course in speaking, both prepared and extemporaneous, normally taken with English 11. Two hours of classwork.

GROUP II

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. Three to five papers, besides impromptus, are required. *Prerequisite: English 11 and 21; to be preceded or accompanied by English 12.*

31. Advanced Composition. *(2).*
For students who desire special practice in the various forms of composition.

41. Public Speaking for Engineers. *(2).*
Preparation and delivery of persuasive speeches. Frequent opportunity for practice and class criticism.

46. Scientific and Technical Lecture. *(2).*
Preparation and delivery of lectures on scientific subjects intended for scientific societies or for popular assemblies. Emphasis on demonstration methods.

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

To satisfy the Group III requirement the student must either elect one of these courses, which are open only to juniors, seniors, and graduate students, or present a satisfactory equivalent. The courses in this group may also be taken for credit as nontechnical electives. With the exception of English 141, all courses in the group may be taken for graduate credit, provided that the student has the approval of his program adviser and that he completes additional work. A considerable amount of written work is required in all these courses. *Prerequisite: English 11, 12, 21, and one course in Group II.*

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.

156. Professional Student and His Reading. *(2).*

Studies in literature in relation to philosophy and the social sciences.

158. Literature of Science. *(2).*

Review of the writings of eminent scientists—ancient, modern, and contemporary.

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).*

Works of exceptional merit in the various literary forms.

GEOLOGY*

Professor Goddard; Professors Arnold, Ehlers, Hibbard, Hussey, Kellum, Landes, Turneaure, and Wilson; Associate Professors Belknap, Kesling, Senstius, Stumm, and Zumberge; Assistant Professors Briggs and Dorr; Dr. Eschman.

11. Introductory Geology. I and II. *(4).*
Principles of physical and structural geology. Lectures, recitations, laboratory, and excursions.

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. I. *(4).*
Geological processes and their effect on civilization.

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, Historical Geology, 131, Soil Geology, 90, Minerals and World Affairs, and 127, Ground Water Geology, are especially useful for engineering students.

INDUSTRIAL ENGINEERING

100 (formerly Mech. and Ind. Eng. 135). Factory Management. 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. Not open to students below junior year.

110 (formerly Mech. and Ind. Eng. 130). 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 (formerly Mech. and Ind. Eng. 136). Motion and Time Study. *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.

130 (formerly Mech. and Ind. Eng. 137). Wage Incentives and Job Evaluation. *Prerequisite: Ind. Eng. 120.* I and II. *(2).*
Principles of major types of wage incentive systems and their evaluation.

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Appraisal of various job evaluating systems and use of job evaluation in developing equitable wage structures.

140 (formerly Mech. and Ind. Eng. 138). Production Control. *Prerequisite: Ind. Eng. 130.* 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 (formerly Mech. and Ind. Eng. 139). Engineering Economy. *Prerequisite: Econ. 153.* I and II. *(2).*
Economic selection of equipment, consideration of cost, methods of financing, depreciation methods, and the planning of future production. Not open to students below junior year.

210. Industrial Engineering Problems. *Prerequisite: Ind. Eng. 100 or permission of instructor.* 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 (formerly Mech. and Ind. Eng. 237). Industrial Management—Field Work. *Prerequisite: Ind. Eng. 120.* I and II. *(3).*
Principles of production developed in Industrial Engineering 100 and 120 are applied to specific problems in factory management. Inspection trips to manufacturing plants, with problems and discussions based on these trips. A laboratory fee is required.

230 (formerly Mech. and Ind. Eng. 238). Industrial Procurement. *Prerequisite: Ind. Eng. 100.* I. *(3).*
Inventory management, selection of sources, price analysis, standards and specifications, organization of a purchasing department, buying policies. Lectures, recitations, cases.

240 (formerly Mech. and Ind. Eng. 240). Seminar in Industrial Engineering. *Prerequisite: Ind. Eng. 120 and permission of instructor.* II. *(2).*
Current topics in industrial engineering. Reading, research, and preparation of papers.

MATHEMATICS*

Professor Hildebrandt; Professors Carver, Churchill, Copeland, Craig, Dwyer, Fischer, Nesbitt, Rainich, Rainville, Rothe, Samelson, Thrall, and Wilder; Associate Professors Bartels, Bott, Coburn, Dolph, Dushnik, Hay, Jones, Kaplan, LeVeque, Moise, Nyswander, Piranian, Reade, and Young; Assistant Professors Carr, Coe, Darling, Harary, Kazarinoff, Leisenring, Lohwater, Lyndon, Marx, Ritt, Rouse, Titus, Ullman, and Wendel; Dr. Addison, Dr. Auslander, Mr. Bedient, Mr. Butcher, Dr. Clarke, Mr. Davis, Dr. Galler, Dr. Gehring, Dr. Goldman, Dr. E. L. Griffin, Dr. J. S. Griffin, Mr. Keisler, Dr. Livesay, Mr. Lyjak, Dr. Maxwell, Dr. Munkres, Dr. Palermo; Lecturer, Mr. Callahan.

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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 (for Schedule T). 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.

14. Plane and Solid Analytic Geometry (for Schedule T). 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.

15. Solid Analytic Geometry. I and II. *(2).*

Surface tracing and locus problems in space; planes; straight lines; quadric surfaces; space curves.

17, 18. Plane and Solid Analytic Geometry and Calculus (for Schedule T). *Prerequisite: permission of chairman of department and student's classifier.* 17, I; 18, II. *(4 each).*

For students outstanding in mathematics. Material covered will be that included in Math. 13, 14, and 53, so that students who have completed these two courses are prepared for Math. 54.

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; bearings and fixes.

33. Math. I (for Schedule S). *Prerequisite: one and one-half years high school algebra, one year plane goemetry, one-half year solid geometry, one-half year trigonometry.* I and II. *(4).*

Review of exponents, radicals, quadratic equations, binomial theorem; functions and graphs, the straight line; derivatives, differentiation of algebraic and trigonometric functions; indefinite and definite integrals.

34. Math. II (for Schedule S). *Prerequisite: Math. 33.* I and II. *(4).*

Arc length, volume and area of figures of revolution; inequalities, theory of equations; the straight line, curves, tangents, normals, Newton's method, conics; trigonometric functions, logarithmic and exponential functions; integration.

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.

53. Calculus I (for Schedule T). I and II. *(4).*
Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

54. Calculus II (for Schedule T). *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. Math. III (for Schedule S). *Prerequisite: Math. 34.* I. *(4).*
Integration; vectors, curvature; elementary probability and statistics; determinants; planes, quadric surfaces, straight lines, curves in space; partial derivatives, tangent planes, total differentials; least squares, curve fitting.

56. Math. IV (for Schedule S). *Prerequisite: Math. 55.* II. *(4).*
Areas, volumes, centroids, inertia, pressure, work, multiple integrals, series, indeterminate forms, complex numbers, differential equations.

57. Differential Equations. *Prerequisite: Math. 54.* I and II. *(2).*
Simple types of ordinary equations of the first and second order; linear equations with constant coefficients; applications to geometry, mechanics, and electrical circuits.

103. Differential Equations. *Prerequisite: one year of calculus.* I and II. *(3).*
Elementary course in ordinary differential equations, with more detailed treatment of topics listed in Math. 57, together with the study of more general linear and nonlinear equations.

104. Differential Equations for Systems Analysis. *Prerequisite: one year of calculus. (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.

141. Theoretical Mechanics I. *Prerequisite: Math. 53 and 54.* I. *(3).*
Introduction to vectors; fundamental concepts of mechanics, plane statics, work, energy, thin beams, cables, frames; plane kinematics and dynamics.

142. Theoretical Mechanics II. *Prerequisite: Math. 141 and 103.* II. *(3).*
Kinematics and dynamics of a particle and of a rigid body in space, including a study of the spherical pendulum, the gyroscope, and impulsive motion.

[**145. Celestial Mechanics.** Omitted in 1956-57.]

147. Modern Operational Mathematics. *Prerequisite: elementary differential equations or advanced calculus (or Math. 150).* 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 equivalent.* 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 and preferably Math. 57 or 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 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.

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. *Prerequisite: Math. 151.* II. *(3).*

Selected topics from elliptic integrals, calculus of variations, Fourier series, and complex value functions.

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 their equivalents.* 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. *(3).*

Statistical methods of quality control; normal, binomial, and Poisson distributions; Shewhart control chart; sampling methods for scientific acceptance inspection. Mathematics 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.* 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).*
An introduction to the mathematical theory of statistics; general theory of averages and dispersion; standard variates and moments; frequency distributions and frequency functions; introduction to the theory of sampling. 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).*
Simple and multiple correlation, bivariate frequency functions, nonlinear regression; sampling theory and probable error. General principles of statistical inference; estimation. Students cannot receive credit for both Math. 162 and 164.

165. Significance Tests. *Prerequisite: Math. 163 and 164 or equivalent.* I. *(3).*
Theory of significance tests suitable for small samples, including the Student-Fisher and the variance ratio and χ^2 and varied applications, including standardization and quality control in industry.

166. Analysis of Variance and Fiducial Inference. *Prerequisite: Math. 165.* II. *(3).*
Theory and application of the analysis of variance and covariance; design of experiment; confidence intervals and coefficients with applications.

172. Graphical Methods and Empirical Formulas. *Prerequisite: Math. 53 and 54.* II. *(3).*
Graphical representation of functions, construction of graphical charts, graphical differentiation and integration, curve fitting, determination of constants in empirical formulas, application of the method of least squares, interpolation, graphical solution of differential equations.

173. Methods in High-Speed Computation I. I and II. *(3).*
Organization of, problem preparation for, and the general use of high-speed electronic computing machines from the point of view of scientific and engineering computations. Coding and solution of experimental problems on the Michigan Digital Automatic Computer (MIDAC).

174. Methods in High-Speed Computation II. *Prerequisite: Math. 103 and 113.* II. *(3).*
The mathematics used with high-speed electronic computing machines. Present attacks on: integration of ordinary differential equations, solutions of large-scale linear systems, determination of eigenvalues and eigenvectors, integration of partial differential equations, function evaluation; coding and solution of problems on MIDAC.

175. Theory of the Potential Function. *Prerequisite: Math. 150 or 151.* I. *(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. I and II. *(2).*
Study of the formal processes of vector analysis, followed by applications to problems in mechanics and geometry.

[**178. Introduction to the Mathematical Theory of Optics.** Omitted in 1956-57.]

[242. **Problems in Heat Conduction and Diffusion.** Omitted in 1956-57.]

243. **Mathematical Theory of Turbulence.** *Prerequisite: advanced calculus.* II. *(3).*
The kinematics and dynamics of the von Karman-Howarth theory for general isotropic turbulence and Kolmogoroff's similarity hypothesis for local isotropic turbulence. Applications to the decay of turbulence. The theory of self-preserving correlation functions, Robertson's invariant theory of isotropic turbulence, and other recent developments of the theory.

[244. **Compressible Fluid Flows.** Omitted in 1956-57.]

[245. **Advanced Mechanics.** Omitted in 1956-57.]

246. **Hydromechanics.** I. *(3).*
General equations of motion of a fluid; irrotational motion of an incompressible fluid; two- and three-dimensional flow problems; transformation theory and adiabatic flow; viscosity.

[247. **Mathematical Elasticity.** I. *(3).* Omitted in 1956-57.]

249. **Methods in Partial Differential Equations.** I. *(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.** Omitted in 1956-57.]

251. **Modern Topics in Mathematical Physics.** II. *(3).*
Deals with those parts of general operator and eigenvalue theory and representation theory which pertain to the applications in theoretical physics.

252. **Advanced Fourier Analysis.** I. *(3).*
General properties of orthogonal systems; convergence criteria for Fourier series; the Fourier integral; Fourier transform and Plancherel theorem; elements of Wiener's harmonic analysis; applications.

255. **Direct Methods in Calculus of Variations.** II. *(3).*
The method of steepest descent in relaxation theory; Dirichlet and Raleigh-Ritz principles and their application to Sturm-Liouville systems and partial differential equations.

257. **Special Functions in Classical Analysis.** *Prerequisite: permission of instructor.* I. *(3).*
Gamma, Bessel, Legendre, hypergeometric, and elliptic functions as treated in Whittaker and Watson's *Modern Analysis.* Generalized hypergeometric functions, Hermite and Laguerre polynomials.

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

1. Introductory Course in Mechanical Engineering. *Prerequisite: completion of freshman year in engineering.* I and II. *(1).*
The field of mechanical engineering. Lectures, bluebooks, and written assignments. Two one-hour periods a week.

13. Heat Engines. *Prerequisite: Phys. 45 and Math. 53.* I and II. *(4).*
Elementary thermodynamics, fuels and combustion, and principles involved in the application of heat to the various forms of heat engines, including steam boiler, steam engine, steam turbine, internal-combustion engine, and plant auxiliaries. Lectures, recitations, problems. For nonmechanical engineering students.

14. Mechanical Engineering Laboratory. *Prerequisite: Mech. Eng. 13.* I and II. *(2).*
Elective for students who are not required to take Mech. Eng. 17. Methods of testing and some of the principles of power engineering.

17. Mechanical Engineering Laboratory. *Prerequisite: Mech. Eng. 105.* I and II. *(1).*
First course. Elementary testing of a steam turbine, diesel-electric plant, centrifugal pump, power pump, and steam boiler; use and calibration of instruments, and calculation and interpretation of results. Laboratory, computation, and reports.

22. Plastic Working of Metals. *Prerequisite: Ch. and Met. Eng. 1.* I and II. *(3).*
A basic study of plastic deformation of metals by rolling, drawing, stamping, pressing, forging, extrusion, etc. Evaluation of materials for such operations on a basis of their physical and mechanical properties. Survey of equipment and processes, relating theory to actual design and operation of metal-working equipment. Two recitations and one three-hour laboratory period a week.

31 (formerly Prod. Eng. 31). Machining Ia. *Prerequisite: Ch. and Met. Eng. 1 and Mech. Eng. 80 or Phys. 46.* I and II. *(2).*
For mechanical and aeronautical engineers. Use of metal-cutting tools, machine tools, and accessories; composition, preparation, and application of cutting tools, cutting fluids, and properties of the materials worked correlated with cutting speeds and feeds for efficient production; observance of use and design of basic machine tools and application of the above principles to their operation. One recitation and one three-hour laboratory period a week.

32 (formerly Prod. Eng. 32). Machining I. *Prerequisite: Ch. and Met. Eng. 1 and Mech. Eng. 80 or Phys. 46.* I and II. *(3)*
For industrial engineers. Fundamental relations between product requirements, properties of materials, metal-cutting behavior, machine tools and cutting tools; nature of machine tools and their use in machining parts; influence of original design on this use; case studies of parts to be machined, selected to emphasize the unique characteristics of each basic type of machine tool. In the laboratory the student operates the machines. Two one-hour recitations and one three-hour laboratory period a week.

80. Mechanism. *Prerequisite: Phys. 45 and Drawing 2.* I and II. *(2).*
Elementary course covering linkages, cams and followers, gear trains, wrapping connectors, and other mechanism. Two two-hour periods a week.

82. Elements of Machine Design. *Prerequisite: Drawing 3, Eng. Mech. 2 (and preceded or accompanied by Mech. Eng. 80 for students in mechanical engineering and naval architecture).* I and II. *(3).*

Basic machine design considerations and application of the theory of strength and rigidity to machine parts. Three one-hour periods a week.

86. Advanced Machine Design. *Prerequisite: Mech. Eng. 82.* I and II. *(3).*

Analysis, layout, and design of machines and machine parts. Two four-hour periods a week.

104. Fundamentals of Fluids Machinery. *Prerequisite: Mech. Eng. 105 or 13.* I and II. *(3).*

Theory, construction, and operation of the principal types of fluids machinery. Lectures, problems, and written recitations.

105. Thermodynamics I. *Prerequisite: Phys. 45 and Math. 53.* I and II. *(3).*

Basic course in engineering thermodynamics, embracing: First Law, ideal gases, specific heats, properties of vapors, steady flow and nonflow processes, reversibility, Carnot cycle and the Second Law, available and unavailable energy and entropy, mixtures of ideal gases and vapors, combustion.

106. Thermodynamics II. *Prerequisite: Mech. Eng. 105 and Math. 54.* I and II. *(3).*

Primarily for mechanical engineers. Equations of state for real gases, flow of gases and vapors through nozzles and orifices, air compressors and air engines, gas turbines and jet propulsion, vapor cycles for power plants, mechanical refrigeration, introduction to heat transfer.

107. Applied Energy Conversion. *Prerequisite: Mech. Eng. 106 or equivalent.* I and II. *(3).*

Economic conversion of natural energy in stationary power plants. Major topics treated; combustion practice, steam generation, steam turbines, diesel engine power plants, hydraulic power plants, gas turbines, atomic energy, power plant economics, load curves, energy rates. Selected power plant problems are assigned.

108. Mechanical Engineering Laboratory. *Prerequisite: Mech. Eng. 17 and 106.* 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; two periods of four and one-half hours each a week.

110. Design of Power Plants. *Prerequisite: Mech. Eng. 107 and Eng. Mech. 4.* II. *(3).*

Type, capacity, and arrangement of equipment to meet the requirements of a modern steam-power plant. Drafting-room work consists of a layout of a plant showing arrangement of principal equipment. Computations and drawing; two four-hour periods a week.

111. Fundamentals of Heat Transfer. *Prerequisite: Mech. Eng. 105.* I and II. *(2).*

Study of conduction, convection, and radiation under steady flow conditions, boiling and condensation. Introduction to transient heat flow. Insulating materials and experimental methods of determining heat transfer properties.

112. Power Plant Combustion Processes. *Prerequisite: Mech. Eng. 106 or equivalent.* I. *(2).*
Mechanisms, kinetics, and chemical reactions of combustion processes. Ignition and propagation of flame reactions. Properties of fuels and oxidizers. Air-breathing and nonair-breathing power plant applications.

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. Lectures, recitations, problems.

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, problems. Two four-hour periods a week.

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. Lectures, recitations, problems.

123. Industrial Air Conditioning. *Prerequisite: Mech. Eng. 105 or 13.* I and II. *(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. Lectures, recitations, problems.

124. Industrial Exhaust and Ventilation Laboratory. *Prerequisite: preceded or accompanied by Mech. Eng. 123.* II. *(2).*
Measurement of low velocity air flow; determination of air-flow pattern around exhaust slots and hoods over cold and heated tables; determination of efficiency of dust-collecting equipment. Laboratory, computations, and reports. Two three-hour periods a week.

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; temperature control. Lectures, recitations.

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 a week.

* Only one of the following courses may be taken for credit toward a degree: Mech. Eng. 116 and 162.

127. Air-Conditioning Laboratory. *Prerequisite: Mech. Eng. 17 and 125.* II. *(3).*
Advanced experimental study in the field of air conditioning.

128. Heating and Ventilation. *(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.

131 (formerly Prod. Eng. 107a). Metals and Alloys Laboratory. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 107.* I and II. *(1).*
Laboratory evaluation of 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.

132 (formerly Prod. Eng. 131). Machining II—Manufacturing Equipment and Processes. *Prerequisite: Mech. Eng. 31 or 32.* I and II. *(3).*
Design, operation, and use of machine tools, jigs and fixtures, dies, cutting tools, and other accessories as applied to job shop, semiproduction and mass production processes are studied. The relation between design of product, metal, and fabricating process is emphasized. Fits, surface quality, and production costs; routings, cutting tools, machinability, and speeds and feeds are correlated. Two recitations and two three-hour laboratory periods a week.

133 (formerly Prod. Eng. 132). Advanced Studies in Production. *Prerequisite: Mech. Eng. 132.* I and II. *(3).*
The student selects a project designed to give him experience in using theoretical principles to improve production machining processes. Studies may be made of jigs and fixtures, automatic inspection, instrumentation, cycle design and control, automation, tool design, etc., in accordance with the students' special interests. A wide variety of production machine tools, inspection equipment, and laboratory instruments are available for this purpose.

134 (formerly Prod. Eng. 114). 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 each week.

135 (formerly Prod. Eng. 115). Die Casting and Powder Metallurgy. *Prerequisite: Ch. and Met. Eng. 13 and 125, or Ch. and 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, one two-hour design period each week.

136 (formerly Prod. Eng. 123). Stamping. *Prerequisite: Ch. and Met. Eng. 102 and Mech. Eng. 132.* II. *(2).*
Physical and metallurgical properties of materials for stamped metal parts are studied as to their influence on product design and production practice. Particular emphasis is placed on the design of a product to permit its manufacture by the stamping process. The operating characteristics of presses, dies, and auxiliaries are studied.

140 (formerly Prod. Eng. 142). Tool Design. *Prerequisite: Mech. Eng. 132.* I. *(2).*
Studies of the application of theories of machinability and economics to cutting practice, design of jigs, fixtures, and small tools. Two lectures and one two-hour design period a week.

142. Design Theory of Pumping Machinery. *Prerequisite: Mech. Eng. 104.* I and II. *(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. Lectures, recitations and problems.

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

144 (formerly Prod. Eng. 141). Design for Production. *Prerequisite: Ch. and Met. Eng. 11 or 12, and Mech. Eng. 132.* II. *(2).*
Correlations between functional specifications of a product and process characteristics are developed Emphasis is placed on the manner in which both the theoretical and the practical aspects of production processes tend to limit product design. Two one-hour periods a week.

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, laboratory demonstrations.

151 (formerly Prod. Eng. 151). Process Instrumentation. *Prerequisite: Math. 54 and Phys. 46.* I and II. *(2).*
Principles involved in the measurement of temperature, pressure, flow, liquid level, and speed; the fundamentals of automatic control systems and the use of components in the design of production control equipment. Two lectures and one recitation a week.

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. Three one-hour periods a week.

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 and 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 hard tops, 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 a week.

160. Aircraft Power Plants. *Prerequisite: Mech. Eng. 105.* I and II. *(3).*

Construction and operation of aircraft engines and their auxiliaries. Critical discussion of the reasons for the various types of construction used in reciprocating and turbine engines now in service.

161. Aircraft Power Plants—Experimental Tests. *Prerequisite: Mech. Eng. 17 and 114 or 160.* 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.

***162. Design of Aircraft Engines.** *Prerequisite: Mech. Eng. 82 and 114.* I and II. *(3).*

Current practice; preliminary calculations for principal dimensions of an aircraft engine, determination of gas pressure and inertia forces and resultant bearing loads; sketches of principal parts. Lectures, drawing. Two four-hour periods a week.

164. Gas Turbines and Jet Propulsion. *Prerequisite: Mech. Eng. 106.* I. *(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.* II. *(2).*

Construction and operation of diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries.

171 (formerly Prod. Eng. 171). Dimensional Quality Control. *Prerequisite: Mech. Eng. 31 or 32.* I and II. *(3).*

A study of standards, specifications, the nature of quality, inspection principles, measuring and gaging equipment, and quality control procedure.

Class periods are devoted to discussions of pertinent topics while the laboratory periods are used to observe inspection practices and to evaluate the different types of equipment available for this purpose. Two one-hour recitations and two three-hour laboratory periods a week.

* See footnote in connection with Mech. Eng. 116, p. 124.

172 (formerly Prod. Eng. 161). Welding. *Prerequisite: Ch. and Met. Eng. 107 or 117 or 127 or permission of instructor.* I and II. *(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 (formerly Prod. Eng. 162). 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 period each week.

174 (formerly Prod. Eng. 163). 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 period each week.

180. Vibration Isolation and Reduction in Mechanical Design. *Prerequisite: Eng. Mech. 3.* I and II. *(3).*

The isolation or reduction of vibratory forces or motions in machines and supporting structures, including the application of such principles to spring characteristics; critical speeds of shafts; balancing of rotating and reciprocating machinery; torsional vibrations of crankshafts; vibration absorbers; gyroscopic action or motion; related industrial equipment and experimental techniques.

181. Design of Machine Tools. *Prerequisite: Mech. Eng. 82 and 31 or 32.* I. *(3).*

Specification, design, construction, and operation of a variety of tool-room and production machine tools; bearings, lubrication, materials, motors, and controls. Hydraulic units and circuits are studied and units of machine tools are designed, bill of materials prepared, and vibrations studied. Power requirements based on specified cutting practice are determined and used as a basis of design.

182 (formerly Prod. Eng. 182). Parts Processing. *Prerequisite: Mech. Eng. 132 or permission of instructor.* II. *(3).*

Complete routings are made for each of several selected parts which are to be manufactured in accordance with a given schedule. Each routing covers the list of operations; the machine tools for each operation together with their accessories, such as cutting tools, jigs, fixtures, dies, inspection instruments, and cutting fluids; the time of each operation, based on speeds, feeds, handling time, etc., and the number of machines for each operation.

[**185. Process Equipment Selection and Design.** *Prerequisite: Eng. Mech. 2 and Mech. Eng. 82 or Ch. and Met. Eng. 113.* *(3).* Open to seniors and graduate students only. Not offered in 1956-57.]

186. Strength Criteria in Design and Development. *Prerequisite: Mech. Eng. 82.* I and II. *(3).*

The treatment of stresses, rigidity, and strength in machine design and development; limitation of theoretical methods; nature and importance of fatigue of metals, residual stresses, and stress corrosion; design criteria for strength under steady, repeated, and combined loadings; experimental stress analysis techniques and interpretation; fatigue testing equipment.

203. Advanced Instrumentation and Control. *Prerequisite: a degree in engineering or permission of instructor.* I and II. *(3).*

Automatic controls; fluid metering; measurement of temperature, humidity, pressure, displacement, strain, speed, sound, etc.

204. Research in Fluids Engineering. *Prerequisite: Mech. Eng. 104 and 108.* I and II. *(2-3).*

Advanced study in the fluids engineering field. Theory, design, equipment performance, or laboratory research.

205. Advanced Thermodynamics. *Prerequisite: Mech. Eng. 106 and 108.* I. *(3).*

Definitions and scope of thermodynamics, First and Second Laws, Maxwell's relations, Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.

206. Advanced Applied Thermodynamics. *Prerequisite: Mech. Eng. 205 or permission of instructor.* II. *(3).*

Thermodynamic behavior of solids, liquids, and gases at high and low pressures; power from solar energy, nuclear energy, and other nonfuel energy sources; thermodynamics of kinetic pumps; high-speed turbines and turbocompressors; steam-power plant cycles at high temperatures and pressures; other subjects selected in allied fields of application.

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.

208. Research in Heat-Power Engineering. *Prerequisite: Mech. Eng. 106 and 108.* I and II. *(2-3).*

Advanced study in special lines of work in which the student may be interested. Theory, design, equipment performance, or laboratory research.

211. Heat Transmission. *Prerequisite: Mech. Eng. 106 and 111 and Eng. Mech. 4.* II. *(3).*

Theory of heat transmission to vapors, liquids, and solids; steady and transient flow of heat; insulating materials; industrial application in the field of mechanical engineering. Lectures, recitations, and problems.

214. Advanced Theory of Internal-Combustion Engines. *Prerequisite: Mech. Eng. 114.* II. *(3).*

Advanced thermodynamics of the reciprocating and flow engines; chemical equilibrium and kinetics of combustion; theory and control of detonation; combustion chamber analysis; superchargers and supercharging.

215. Research in Internal-Combustion Engineering. *Prerequisite: permission of instructor.* I and II. *(To be arranged).*

Investigation of the theory, design, and construction of internal-combustion engines, and laboratory research.

227. Research in Air-Conditioning Engineering. *Prerequisite: Mech. Eng. 127.* I and II. *(3).*
Advanced study in the air-conditioning engineering field. Theory, design, equipment performance, or laboratory research.

228. Studies in Natural Ventilation. *Prerequisite: Mech. Eng. 108.* I and II. *(2).*
Theory of air movement through buildings by wind and temperature difference; deductions from test data at hand; some experimental work of an illustrative nature, and possibly something of a research nature.

251. Automobile Engineering Seminar. I and II. *(1).*
Preparation of one paper on current topics of the automobile industry and one covering an investigation on some special subject. Reading, preparation of papers, and class discussions.

253. Advanced Automobile Design and Research. *Prerequisite: Mech. Eng. 151 and 153. (To be arranged).*
Special problems in the design of some automobile or truck unit. Drawing.

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, reports.

264 (formerly Prod. Eng. 264). Advanced Working, Treating, and Welding of Metal. *Prerequisite: Ch. and Met. Eng. 107, or equivalent.* I and II. *(2).*
Special problems on these subjects may be elected by students interested in steel treatment and processing. Two recitations a week.

273 (formerly Prod. Eng. 273). Machinability. *Prerequisite: Mech. Eng. 132.* I and 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.

[**282. Superpressure Process Equipment and Technique.** *Prerequisite: Mech. Eng. 82 and 106 or Ch. and Met. Eng. 111.* II. *(3).* Omitted in 1956-57]

304. Fluids Engineering Seminar. *Prerequisite: Mech. Eng. 204.* I and II. *(To be arranged).*
Advanced study in the fluids engineering field. Theory, design, or laboratory research.

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 Engineering Seminar. *Prerequisite: Mech. Eng. 208.* I and II. *(To be arranged).*
Advanced study in special problems in which the student may be interested. Theory, design, or laboratory research.

315. Internal-Combustion Engineering Seminar. *Prerequisite: Mech. Eng. 215.* I and II. *(To be arranged).*
Investigation of the theory, design and construction of internal-combustion engines and associated equipment, or laboratory research.

327. Air Conditioning Engineering Seminar. *Prerequisite: Mech. Eng. 227.* I and II. *(To be arranged).*

355. Automotive Engineering Seminar. *Prerequisite: Mech. Eng. 255.* I and II. *(To be arranged).*
Advanced experimental and research work. Laboratory and reports.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

11. Introduction to Practice. *Prerequisite: sophomore standing and Draw. 1 and 2.* I and II. *(2).*
Types of ships, nomenclature, methods and materials of construction, shipyard and drawing room practices; details of shell expansion and other mold loft work. The lines of a vessel are faired, and drawings prepared for simple ship structures. Lectures, recitations, and drawing room.

12. Form Calculations I. *Prerequisite: Nav. Arch. 11, Math. 53, 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. Lectures and recitations.

13. Form Calculations II. *Prerequisite: preceded or accompanied by Nav. Arch. 12.* I and II. *(3).*
Preparation of a body plan from given offsets; the necessary calculations for the preparation of hydrostatic and launching 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. Lectures, recitations.

22. Structural Design II. *Prerequisite: Nav. Arch. 21.* I and II. *(2).*
Student develops the "Midship Section" and "Structural Profile and Decks" for an assigned vessel according to the Rules of the Classification Society.

123. Advanced Structural Design. *(To be arranged).*

131. Ship Design I. *Prerequisite: Nav. Arch. 13 and preceded or accompanied by Nav. Arch. 21.* I. *(3).*
Review of statical stability, the dynamical stability, rolling, pitching, and seagoing qualities of ships; rudders, turning, and maneuvering; freeboard; tonnage; grounding and dry docking; estimates and calculations involved in the preliminary design of ships. Lectures and recitations.

132. Ship Design II. *Prerequisite: Nav. Arch. 22 and 137 and preceded or accompanied by Nav. Arch. 131.* I and II. *(4).*
Given the owner's general requirements the student prepares a complete

preliminary design of a suitable ship, including form, power, and strength calculations; midship section, lines, inboard and outboard profiles, and arrangement plans. Drawing room.

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. Lectures and recitations.

137. Specifications, Contracts, and the General Arrangement of Vessels. *Prerequisite: senior standing or permission of instructor.* I. *(3).*
Principal features of ship specifications and contracts, methods and practices of planning and estimating for new construction and repair work; design and function of the various items of outfit, such as bilge and ballast systems, cargo gear, etc., and practices in the general arrangements of vessels. Lectures and recitations.

141. Marine Propulsion Machinery. *Prerequisite: Mech. Eng. 105 and Eng. Mech. 1.* I and II. *(2).*
Principles of construction and operation of main propulsion machinery and ancillary plant. Lectures and recitations.

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 steam generator. Drawing room.

143. Design of Marine Propulsion Machinery. *Prerequisite: Nav. Arch. 146 and Mech. Eng. 113 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. Drawing room.

144. Design of Marine Power Plant. *Prerequisite: Nav. Arch. 146 and 147.* 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. Drawing room.

145. Advanced Reading and Seminar in Marine Engineering. I and II. *(To be arranged).*

146. Analysis of Marine Machinery. *Prerequisite: preceded or accompanied by Nav. Arch. 141.* I and II. *(2).*
Calculations on performance and preliminary design of main and auxiliary machinery. Lectures and recitations.

147. Marine Auxiliary Machinery. *Prerequisite: Elec. Eng. 5 and Nav. Arch. 141.* I and II. *(2).*
Piping systems; electrical distribution; engine room auxiliaries; deck machinery; steering gear; and emergency apparatus. Lectures and recitations.

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. Lectures and recitations.

152. Naval Tank. *Prerequisite: Eng. Mech. 4.* I and II. *(2).*
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. Lectures, drawing room, and laboratory.

153. Research in Naval Tank. *Prerequisite: Nav. Arch. 152.* I and II. *(To be arranged).*

154. Advanced Reading and Seminar in Naval Architecture. I and II. *(To be arranged).*

155. Piloting and Celonavigation. *(3).*
Compass error, piloting, various sailings, latitude, longitude, and lines of position from celestial observations; use of radar and direction finders.

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. *Prerequisite: senior status or 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 (formerly Nuclear Eng. 190). Introduction to Nuclear Engineering. I and II. *(3).*
Open to seniors and graduate students. Introductory treatment of the application of theoretical physics in the production of nuclear energy to develop a broad background in atomic and nuclear science. Elementary particles, electromagnetic radiation, waves, quantization and energy levels, radioactivity, measurement of nuclear phenomena, nuclear disintegration and fission, nuclear reactors.

192. Measurement in Nuclear Engineering. *Prerequisite: Nuclear Eng. 191 or permission of instructor. (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 and crystal conduction 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. Procedures and Design in the Handling of Radioactive Materials. *Prerequisite: Nuclear Eng. 191, 192, or permission of instructor.* I. *(2).*
Procedures in the safe handling of radioactive materials, hazard evaluations, design of laboratories and waste disposal facilities. One hour lecture, three hours laboratory 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. Thompson 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: Elec. Eng. 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. Lectures and discussions.

294. Wave Mechanics in Nuclear Engineering. *Prerequisite: Nuclear Eng. 291. (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. 294. (3).*
Derivation of neutron flux equations for monoenergetic neutrons with uniform or varied emission time. Analysis of homogeneous reactor configurations and study of heterogeneous reactor structure. Analysis of requirements for reactor control systems.

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.

298. Nuclear Reactor Laboratory. *Prerequisite: Nuclear Eng. 291 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. Research in Nuclear Engineering. *(To be arranged).*
Open to qualified graduate students.

PHYSICS*

Professor Dennison; Professor Barker, Crane, Laporte, Sutherland, Uhlenbeck, and Wolfe; Associate Professors Case, Glaser, Hazen, Katz, Luttinger, Mc-

* College of Literature, Science, and the Arts.

Cormick, Parkinson, Pidd, and Wiedenbeck; Assistant Professors Hough, Krimm, Levinthal, Peters, and Wood; Mr. Chagnon, Mr. Hecht, Dr. Jones, and Dr. Terwilliger.

45. Mechanics, Sound, and Heat. I and II. *(5).*
Calculus should be elected concurrently. Two lectures, three recitations, and one two-hour laboratory period a week.

46. Electricity and Light. *Prerequisite: Phys. 45.* I and II. *(5).*
Two lectures, three recitations, and one two-hour laboratory period a week.

53. Elementary Mechanics. *Prerequisite: preceded or accompanied by Math. 33. (4).*
Mechanics of particles, kinematics, Newton's laws of motion, wave motion in mechanical systems, special relativity. One lecture, three recitations, and one laboratory period a week.

54. Electricity, Light, and Modern Physics. *Prerequisite: Phys. 53 and preceded or accompanied by Math. 54 or equivalent. (4).*
Electricity and magnetism, physical optics, atomic and nuclear structure. One lecture, three recitations, and one laboratory period a week.

103. Introduction to the Use of Radioactive Isotopes. *Prerequisite: Phys. 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: Phys. 46.* I. *(2).*
Fundamental experiments on the nature of light, electricity, and matter.

147. Electrical Measurements. *Prerequisite: Phys. 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 four-hour laboratory period a week.

165. Electron Tubes. *Prerequisite: Phys. 147.* II. *(3).*
Characteristics of electron tubes and their functions as detectors, amplifiers, and generators.

166. Electron Circuits. *Prerequisite: Phys. 165.* I. *(3).*
Characteristics of high-frequency circuits and their radiations. Two lectures, one laboratory period a week.

171. Intermediate Mechanics. *Prerequisite: Phys. 46, Math. 103.* I and II. *(3).*
Statics and dynamics; the equations of d'Alembert, Poisson, Laplace, and Lagrange.

172. Mechanics of Fluids. *Prerequisite: Phys. 171.* II. *(2).*
Statics and elementary dynamics of fluids.

173. Introduction to Physics of the Solid State. *Prerequisite: Phys. 196 or permission of instructor.* II. *(3).*
Structure and properties of crystalline solids.

175. Vibration and Sound. *Prerequisite: Phys. 171 and Math. 57.* I. *(3).*
Mathematical study of waves and of vibrating mechanical systems.

177. Applications of Physical Measurements to Biology. *Prerequisite: Phys. 46 and eight hours of biological science.* I. *(3).*

178. Selected Problems in Biophysics. *Prerequisite: Phys. 105 and Math. 53.* II. *(2).*
Structures of proteins, steroids, and other molecules of biological interest, and methods for their determination.

179. Biophysics: Large Molecules. *Prerequisite: Phys. 186 and Math. 54.* II. *(3).*
Thermodynamics and optical properties of assemblies of large molecules.

180. Intermediate Electricity and Magnetism. *Prerequisite: Phys. 147 and Math. 150 or 154.* II. *(3)*
Principles of electrostatics and electromagnetism.

181. Heat. *Prerequisite: Phys. 46 and Math. 54.* I. *(2).*
Thermal expansion, specific heats, changes of state, and van der Waals' equation; elementary kinetic theory and the absolute scale of temperature.

183. Laboratory in Heat. I. *(2).*
To follow or accompany Physics 181. Use of modern methods and instruments for the measurement of thermal quantities.

185. Introduction to Infrared Spectra. *Prerequisite: Phys. 26 or 46 and Math. 54.* II. *(2).*
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: Phys. 46 and Math. 54.* II. *(3).*
Theory of interference, diffraction, polarization.

188. Laboratory in Light. II. *(2).*
To accompany or follow Physics 186. Experiments on interference, diffraction, polarization, double refraction, and the fundamental properties in light.

191, 192. Introduction to Theoretical Physics. *Prerequisite: Phys. 171 and Math. 150 or 154.* 191, I; 192, II. *(3 each).*
Procedures employed in the mathematical formulation and solution of problems in theoretical physics. Recommended as a preparation for the courses numbered 205 and above.

193, 194. Applied Spectroscopy. *Prerequisite: Phys. 196.* 193, I; 194, II. *(4 each).*
Equipment and methods for spectrochemical analysis, with laboratory practice,

196. Atomic and Molecular Structure. *Prerequisite: Math. 57 and five hours of intermediate physics or physical chemistry.* I and II. *(3).*
Recent developments, based on fundamental experiments; determination and description of characteristic energy levels, and the classification of electrons.

197. Nuclear Physics. *Prerequisite: Phys. 105 or 196.* II. *(2).*
Natural radioactivity; nuclear physics; apparatus and methods of nuclear physics; artificial transmutations and cosmic rays.

198. Introduction to Quantum Theory. *Prerequisite: Phys. 171 and 196, Math. 103.* I. *(3).*
Suitable for advanced undergraduates and beginning graduate students.

199. Laboratory in Nuclear Physics. II. *(2).*
To accompany or follow Phys. 197. Measurements on the characteristics of various nuclear transformations.

205, 206. Electricity and Magnetism. *Prerequisite: Phys. 147 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; Phys. 207 is a prerequisite for Phys. 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: Phys. 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: Phys. 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 and Atomic Structure. *Prerequisite: Phys. 196. Phys. 211 is a prerequisite for Phys. 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).*

238. Nuclear Theory. I. *(3).*

256. Molecular Spectra and Molecular Structure. *(3).*

COMMITTEES AND FACULTY*

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ex officio

W. G. DOW, term, 1952-56
E. F. BRATER, term, 1953-57
A. M. KUETHE, term, 1954-58
G. V. EDMONSON, term, 1955-59

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J. C. BRIER, *Chairman*, G. L. ALT, T. M. SAWYER, and J. G. YOUNG.

* Listed for the academic year, 1955-56.

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Wilbur Clifton Nelson, M.S.E. *Professor of Aeronautical Engineering and Chairman of the Department of Aeronautical Engineering*
Arnold Martin Kuethe, Ph.D., *Felix Pawlowski Professor of Aerodynamics*
David J. Peery, Ph.D., *Professor of Aeronautical Engineering*
Julius David Schetzer, M.S., *Professor of Aeronautical Engineering*
Lawrence Lee Rauch, Ph.D., *Professor of Aeronautical Engineering*
Edgar James Lesher, M.S.E., *Associate Professor of Aeronautical Engineering*
Robert Milton Howe, Ph.D., *Associate Professor of Aeronautical Engineering*
James Eugene Broadwell, Ph.D., *Associate Professor of Aeronautical Engineering*
Richard Boyd Morrison, Ph.D., *Associate Professor of Aeronautical Engineering*
Gabriel Isakson, Sc.D., *Associate Professor of Aeronautical Engineering*
Maurice Andre Brull, Ph.D., *Assistant Professor of Aeronautical Engineering*
John Randolph Sellars, Ph.D., *Assistant Professor of Aeronautical Engineering*
Jack Raymond Jennings, M.S.E. (E.E.), *Instructor in Aeronautical Engineering*
Edward Otis Gilbert, M.S.E. (E.E.), *Instructor, USAF Guided Missiles Program*
Elmer Grant Gilbert, M.S.E. (E.E.), *Instructor in Aeronautical Engineering and USAF Guided Missiles Program*
Hans Peter Liepman, Ph.D., *Lecturer in Aeronautical Engineering and Director, Supersonic Wind Tunnel, Engineering Research Institute*

JAMES A. NICHOLLS, M.S.E., *Lecturer in Aeronautical Engineering and Associate Research Engineer, Engineering Research Institute*
MAHINDER SINGH UBEROI, Ph.D., *Lecturer in Aeronautical Engineering and Associate Research Engineer, Engineering Research Institute*
HARRY EDWARD BAILEY, Ph.D., *Lecturer in Aeronautical Engineering and Associate Research Engineer, Engineering Research Institute*
THOMAS CHARLES ADAMSON, JR., Ph.D., *Lecturer in Aeronautical Engineering and Associate Research Engineer, Engineering Research Institute*
GEORGE MAKOV, M.S., *Lecturer in Aeronautical Engineering and Research Assistant, Engineering Research Institute*

CHEMICAL AND METALLURGICAL ENGINEERING

DONALD LAVERNE KATZ, Ph.D., *Professor of Chemical Engineering and Chairman of the Department of Chemical and Metallurgical Engineering*
GEO. GRANGER BROWN, Ph.D., Ch.E., D.Eng., *Edward DeMille Campbell University Professor of Chemical Engineering and Dean of the College of Engineering*
ALBERT EASTON WHITE, Sc.D., *Professor Emeritus of Metallurgical Engineering and Director Emeritus of the Engineering Research Institute*
JOHN CROWE BRIER, M.S., *Professor of Chemical Engineering*
CLAIR UPTHEGROVE, B.Ch.E., *Professor of Metallurgical Engineering*
RICHARD SCHNEIDEWIND, Ph.D., *Professor of Metallurgical Engineering*
LEO LEHR CARRICK, Ph.D., *Professor of Chemical Engineering*
LARS THOMASSEN, Ph.D., *Professor of Chemical and Metallurgical Engineering*
CLARENCE ARNOLD SIEBERT, Ph.D., *Professor of Chemical and Metallurgical Engineering*
ROBERT ROY WHITE, Ph.D., *Professor of Chemical and Metallurgical Engineering*
RICHARD A. FLINN, Sc.D., *Professor of Metallurgical Engineering*
HAROLD A. OHLGREN, B.A., B.S., D.Sc., *Professor of Chemical Engineering and Assistant Director of the Engineering Research Institute*
LLOYD EARL BROWNELL, Ph.D., *Professor of Chemical and Metallurgical Engineering*
JAMES WRIGHT FREEMAN, M.S.E., Ph.D., *Professor of Metallurgical Engineering and Research Engineer in the Engineering Research Institute*
MAURICE JOSEPH SINNOTT, Sc.D., *Professor of Metallurgical Engineering*
DONALD WILLIAM MCCREADY, Ph.D., *Associate Professor of Chemical Engineering*
RICHARD EMORY TOWNSEND, M.S.E., Ch.E., *Associate Professor of Chemical and Metallurgical Engineering*
JOSEPH J. MARTIN, D.Sc., *Associate Professor of Chemical and Metallurgical Engineering*

GEORGE BRYMER WILLIAMS, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

LINDSEY M. HOBBS, Ph.D., *Associate Professor of Materials Engineering and Director of Michigan Memorial—Phoenix Project No. 43*

LAWRENCE H. VAN VLACK, Ph.D., *Associate Professor of Materials Engineering*

JESSE LOUIS YORK, Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

JULIUS THOMAS BANCHERO, Ch.E., Ph.D., *Associate Professor of Chemical and Metallurgical Engineering*

STUART WINSTON CHURCHILL, Ph.D., *Associate Professor of Chemical Engineering*

LLOYD L. KEMPE, Ph.D., *Associate Professor of Chemical Engineering and Associate Professor of Bacteriology, Medical School*

WILLIAM ALLEN SPINDLER, M.S., *Assistant Professor of Metallurgical Engineering*

EDWIN HAROLD YOUNG, M.S.E., *Assistant Professor of Chemical and Metallurgical Engineering*

DAVID VINCENT RAGONE, Sc.D., *Assistant Professor of Metallurgical Engineering*

CHARLES WILLIAMS PHILLIPS, Ph.D., *Assistant Professor of Chemical and Metallurgical Engineering*

CHARLES MANSON THATCHER, Ph.D., *Assistant Professor of Chemical Engineering*

KENNETH FRASER GORDON, Sc.D., *Assistant Professor of Chemical Engineering*

EDWARD ERNEST HUCKE, Sc.D., *Assistant Professor of Metallurgical Engineering*

RUSSELL BERNHARD MESLER, Ph.D., *Assistant Professor of Nuclear Engineering*

WILBUR CHARLES BIGELOW, Ph.D., *Assistant Professor of Science, and Lecturer in Chemistry, College of Literature, Science, and the Arts*

WALTER BERTRAM PIERCE, *Assistant Professor of Foundry Practice*

RALPH WAYNE KRAFT, JR., B.S. (Met. E.), *Instructor in Metallurgical Engineering*

RONALD DAVID GEORGE CROZIER, M.S.E., *Instructor in Chemical and Metallurgical Engineering*

GEORGE AUSTIN COLLIGAN, B.Met.E., *Instructor in Chemical and Metallurgical Engineering*

JOHN GRENNAN, *Instructor in Foundry Practice*

HOWARD ROBERT VOORHEES, S.M., *Lecturer in Chemical Engineering and Research Associate, Engineering Research Institute*

ALEXANDER WEIR, JR., Ph.D., *Lecturer in Chemical Engineering and Associate Research Engineer, Engineering Research Institute*

JOHN VINCENT NEHEMIAS, A. M., *Lecturer in Chemical and Metallurgical Engineering and Research Associate, Engineering Research Institute*

CIVIL ENGINEERING

EARNEST BOYCE, M.S., C.E., *Professor of Municipal and Sanitary Engineering and Chairman of the Department of Civil Engineering, and Professor of Public Health Engineering, School of Public Health*
ROBERT HENRY SHERLOCK, B.S. (C.E.), *Professor of Civil Engineering*
WALTER CLIFFORD SADLER, M.S., C.E., LL.B., *Professor of Civil Engineering*
LAWRENCE CARNAHAN MAUGH, Ph.D., *Professor of Civil Engineering*
WILLIAM STUART HOUSEL, M.S.E., *Professor of Civil Engineering*
BRUCE GILBERT JOHNSTON, Ph.D., *Professor of Structural Engineering*
ERNEST FREDERICK BRATER, Ph.D., *Professor of Hydraulic Engineering*
WALTER JOHNSON EMMONS, A.M., *Professor of Highway Engineering and Assistant Dean and Secretary of the College of Engineering*
VICTOR LYLE STREETER, Sc.D., *Professor of Hydraulics*
EDGAR WENDELL HEWSON, Ph.D., *Professor of Meteorology*
EDWARD YOUNG, B.S.E. (C.E.) *Professor of Geodesy and Surveying*
JOHN CLAYTON KOHL, B.S.E. (C.E.), *Professor of Civil Engineering and Director of the Transportation Institute*
RALPH MOORE BERRY, B.C.E., *Professor of Geodesy and Surveying*
JOHN STEPHEN WORLEY, M.S., C.E., *Lecturer in Transportation Engineering and Curator Emeritus of the Transportation Library*
CLARENCE THOMAS JOHNSTON, B.S.C.E., C.E., *Professor Emeritus of Geodesy and Surveying*
ARTHUR JAMES DECKER, B.S. (C.E.), *Professor Emeritus of Civil Engineering*
WILLIAM CHRISTIAN HOAD, B.S. (C.E.), *Professor Emeritus of Civil Engineering*
CHESTER OWEN WISLER, M.S.E., *Lecturer in Hydrology, Department of Civil Engineering*
GLENN LESLIE ALT, C.E. *Associate Professor of Civil Engineering*
LEO MAX LEGATSKI, Sc.D., *Associate Professor of Civil Engineering*
JACK ADOLPH BORCHARDT, Ph.D., *Associate Professor of Civil Engineering*
WARD KARCHER PARR, B.S.E. (Ch.E.) *Associate Professor of Highway Engineering*
CLIFTON O'NEAL CAREY, C.E., *Associate Professor Emeritus of Geodesy and Surveying*
HAROLD JAMES MCFARLAN, B.S.E. (C.E.), *Assistant Professor of Geodesy and Surveying*
GEORGE MOYER BLEEKMAN, M.S.E., *Assistant Professor of Geodesy and Surveying*
ROBERT BLYNN HARRIS, M.S.C.E., *Assistant Professor of Civil Engineering*
FRANK EVARISTE LEGG, JR., M.S., *Assistant Professor of Engineering Materials*
DONALD NATHAN CORTRIGHT, M.S.E., *Assistant Professor of Civil Engineering*

CLINTON LOUIS HEIMBACH, B.S.E. (Transp.), B.S.E. (Civil), *Assistant Professor of Railroad Engineering*
EUGENE ANDRUS GLYSSON, M.S.E., *Assistant Professor of Civil Engineering*
ROBERT OSCAR GOETZ, M.S.E. (C.E.), *Instructor in Civil Engineering*
WADI SALIBA RUMMAN, M.S.E. (C.E.), *Instructor in Civil Engineering*
ALBERT NELSON DINGLE, Sc.D., *Lecturer in Meteorology, and Associate Research Meteorologist, Engineering Research Institute*
EDWIN A. BOYD, *Consultant, Department of Civil Engineering*

DRAWING (ENGINEERING)

RUSSELL ALGER DODGE, M.S.E., *Chairman of the Department of Engineering Drawing, Professor of Engineering Mechanics, and Chairman of the Department of Engineering Mechanics.*
JULIUS CLARK PALMER, B.S., *Professor of Engineering Drawing*
DEAN ESTES HOBART, B.S., *Professor of Engineering Drawing*
ROBERT CARL COLE, A.M., *Professor of Engineering Drawing*
MARTIN J. ORBECK, C.E., M.S.E., *Professor of Engineering Drawing*
HENRY WILLARD MILLER, B.S., M.E., *Professor of Engineering Drawing*
FRANK RICHARD FINCH, Ph.B., *Professor Emeritus of Engineering Drawing*
PHILIP ORLAND POTTS, B.M.E., *Associate Professor of Engineering Drawing*
MAURICE BARKLEY EICHELBERGER, B.S., *Associate Professor of Engineering Drawing*
FRANK HAROLD SMITH, M.S.E., *Associate Professor of Engineering Drawing*
HERBERT JAY GOULDING, B.S. (M.E.), *Consultant, Department of Engineering Drawing*
ALBERT LORING CLARK, JR., B.S.E. (M.E.), *Assistant Professor of Engineering Drawing*
FRANCIS X. LAKE, Ph.D., *Assistant Professor of Engineering Drawing*
ROBERT SEATON HEPPINSTALL, M.S. (M.E.) *Assistant Professor of Engineering Drawing*
DONALD CRAIG DOUGLAS, B.S.M.E., *Assistant Professor of Engineering Drawing*
ALFRED WILLIAM LIPPHART, B.S.E. (Ae.E.), LL.B., *Assistant Professor of Engineering Drawing*
ROBERT HORACE HOISINGTON, M.S., *Assistant Professor of Engineering Drawing*
RAYMOND CLARE SCOTT, M.Ed., *Assistant Professor of Engineering Drawing*
WALTER EDGAR THOMAS, M.S.I.E., *Assistant Professor of Engineering Drawing*
FINN CHRISTIAN MICHELSEN, B.S.E. (Math.), M.S.E. (Nav. Arch.), *Instructor in Engineering Drawing*
FRANKLIN HERBERT WESTERVELT, M.S.E. (M.E.), *Instructor in Engineering Drawing*

GEORGE EMBER, JR., M.S., *Instructor in Engineering Drawing*
WILLIAM HAVILAND STEELE, B.S. (Ch.E.), B.S. (E.E.), *Instructor in Engineering Drawing*

ELECTRICAL ENGINEERNG

STEPHEN STANLEY ATTWOOD, M.S., *Professor of Electrical Engineering and Chairman of the Department of Electrical Engineering*
ARTHUR DEARTH MOORE, M.S., *Professor of Electrical Engineering*
JOSEPH GALLUCHAT TARBOUX, Ph.D., *Professor of Electrical Engineering*
MELVILLE BIGHAM STOUT, M.S., *Professor of Electrical Engineering*
WILLIAM GOULD DOW, M.S.E., *Professor of Electrical Engineering*
LEWIS NELSON HOLLAND, M.S., *Professor of Electrical Engineering*
EDWIN RICHARD MARTIN, E.E., *Professor of Electrical Engineering.* On retirement furlough, 1955-56.
GUNNAR HOK, E.E., *Professor of Electrical Engineering*
HARRY H. GOODE, M.A., *Professor of Electrical Engineering*
HENRY JACOB GOMBERG, Ph.D., *Professor of Nuclear and Electrical Engineering, Assistant Director, Michigan Memorial—Phoenix Project, and Research Associate, AEC Biological Effects of Irradiation*
ALFRED HENRY LOVELL, M.S.E., *Lecturer in Electrical Engineering*
JOSEPH HENDERSON CANNON, B.S. (E.E.), *Professor Emeritus of Electrical Engineering*
HEMPSTEAD STRATTON BULL, M.S., *Associate Professor of Electrical Engineering*
JOHN JOSEPH CAREY, M.S. (E.E.), *Associate Professor of Electrical Engneering*
ALAN BRECK MACNEE, Sc.D., *Associate Professor of Electrical Engineering*
HOMER WILLIAM WELCH, JR., Ph.D., *Associate Professor of Electrical Engineering*
NORMAN ROSS SCOTT, Ph.D., *Associate Professor of Electrical Engineering*
RICHARD KEMP BROWN, Ph.D., *Associate Professor of Electrical Engineering*
FREDERICK THEODORE HADDOCK, JR., M.S., *Associate Professor of Electrical Engineering and Associate Professor of Astronomy, College of Literature, Science, and the Arts*
WALTER ALFRED HEDRICH, Ph.D., *Assistant Professor of Electrical Engineering*
JACK FRIBLEY CLINE, Ph.D., *Assistant Professor of Electrical Engineering*
LOUIS FRANK KAZDA, M.S.E., *Assistant Professor of Electrical Engineering*
WILLIAM KERR, Ph.D., *Assistant Professor of Electrical Engineering*
JOSEPH EVERETT ROWE, Ph.D., *Assistant Professor of Electrical Engineering*
JOSEPH AUBREY BOYD, Ph.D., *Assistant Professor of Electrical Engineering*
PHIL H. ROGERS, Ph.D., *Assistant Professor of Electrical Engineering*

CHARLES BRUCE SHARPE, Ph.D., *Assistant Professor of Electrical Engineering*

JAMES RICHIE BLACK, B.A. (Chem.), *Assistant Professor of Electrical Engineering and Research Engineer, Engineering Research Institute*

MELVIN BURTUS FOLKERT, M.S.E. (E.E.), *Instructor in Electrical Engineering*

KENNETH A. STONE, M.S.E., *Instructor in Electrical Engineering*

EDWARD ANTHONY MARTIN, M.S. (Phys.), *Instructor in Electrical Engineering*

HARVEY LOUIS GARNER, M.S., *Instructor in Electrical Engineering*

HERBERT ASHLEY BERNHARD, A.M., *Instructor in Electrical Engineering*

NELSON WARNER SPENCER, M.S.E. (E.E.), *Lecturer in Electrical Engineering and Research Engineer, Engineering Research Institute*

MURRAY HENRI MILLER, M.S.E. (E.E.), *Lecturer in Electrical Engineering and Research Associate, Engineering Research Institute*

HAROLD C. EARLY, M.S. (Phys.), *Lecturer in Electrical Engineering and Research Engineer, Engineering Research Institute*

JAMES HARVEY BROWN, M.S. (Phys.), *Lecturer in Electrical Engineering and Research Associate, Engineering Research Institute*

JOHN GEORGE MEEKER, M.S. (E.E.), *Lecturer in Electrical Engineering and Graduate Research Assistant, Engineering Research Institute*

DALE MILLS GRIMES, M.S., *Lecturer in Electrical Engineering and Associate Research Physicist, Engineering Research Institute*

HANSFORD W. FARRIS, M.S. (E.E.), *Lecturer in Electrical Engineering and Associate Research Engineer, Engineering Research Institute*

ENGINEERING MECHANICS

RUSSELL ALGER DODGE, M.S.E., *Professor of Engineering Mechanics and Chairman of the Departments of Engineering Mechanics and Engineering Drawing*

EDWARD LEERDRUP ERIKSEN, B.C.E., *Professor of Engineering Mechanics.* On retirement furlough first semester, 1955-56.

FERDINAND NORTHRUP MENEFEE, C.E., D.Eng., *Professor of Engineering Mechanics.* On retirement furlough, 1955-56.

JAN ABRAM VAN DEN BROEK, Ph.D., *Professor Emeritus of Engineering Mechanics*

JESSE ORMONDROYD, A.B., *Professor of Engineering Mechanics*

HOLGER MADS HANSEN, B.C.E., *Professor of Engineering Mechanics*

ROY STANLEY SWINTON, M.S.E., *Professor of Engineering Mechanics*

CHARLES THOMAS OLMSTED, B.S. (C.E.), *Professor of Engineering Mechanics.* On retirement furlough, 1955-56.

JOHN STEPHENSON MCNOWN, Ph.D., *Professor of Engineering Mechanics*

PAUL MANSOUR NAGHDI, Ph.D., *Professor of Engineering Mechanics*

RICHARD THOMAS LIDDICOAT, Ph.D., *Associate Professor of Engineering Mechanics*
FRANKLIN L. EVERETT, Ph.D., *Associate Professor of Engineering Mechanics*
ROBERT LAWRENCE HESS, Ph.D., *Associate Professor of Engineering Mechanics*
ERNEST FRANK MASUR, Ph.D., *Associate Professor of Engineering Mechanics*
EDWARD AXEL YATES, M.S.E., *Assistant Professor of Engineering Mechanics*
LYLE GERALD CLARK, M.S. (E.M.), *Assistant Professor of Engineering Mechanics*
RAYMOND A. YAGLE, M.S.E., *Assistant Professor of Engineering Mechanics*
SAMUEL KELLY CLARK, Ph.D., *Assistant Professor of Engineering Mechanics*
FRANKLIN ESSENBERG, JR., M.S.E., LL.B., *Instructor in Engineering Mechanics*
WILLIAM LLOYD WAINWRIGHT, M.S.E., *Instructor in Engineering Mechanics*
HADLEY JAMES SMITH, M.S., *Instructor in Engineering Mechanics*
TARIQ B. KHAMMASH, M.S., *Instructor in Engineering Mechanics*
BERTRAM HERZOG, M.S., *Instructor in Engineering Mechanics*
MUNIR RIDHA EL-SADEN, M.S.E., *Instructor in Engineering Mechanics*
RICHARD CHRISTIAN WILSON, M.S., *Instructor in Engineering Mechanics*

ENGLISH

CARL GUNARD BRANDT, LL.M., *Professor of English and Chairman of the Department of English in the College of Engineering, and Lecturer in Speech in the College of Literature, Science, and the Arts*
JESSE EARL THORNTON, A.M., *Professor of English, College of Engineering.* On retirement furlough, 1955-56.
CARL EDWIN BURKLUND, Ph.D., *Professor of English, College of Engineering*
IVAN HENRY WALTON, A.M., *Professor of English, College of Engineering*
WEBSTER EARL BRITTON, Ph.D., *Professor of English, College of Engineering*
GEORGE MIDDLETON MCEWEN, Ph.D., *Professor of English, College of Engineering*
JOSEPH RALEIGH NELSON, A.M., *Professor Emeritus of English, Counselor Emeritus to Foreign Students, and Director Emeritus of the International Center*
ROBERT D. BRACKETT, A.M., *Associate Professor of English, College of Engineering.* On retirement furlough, 1955-56.
WILLIAM HENRY EGLY, A.M., *Associate Professor of English, College of Engineering*
JOSHUA MCCLENNEN, Ph.D., *Associate Professor of English, College of Engineering*
WILFRED MINNICH SENSEMAN, Ph.D., *Associate Professor of English, College of Engineering*

W. Harry Mack, A.M., *Assistant Professor of English, College of Engineering.* On retirement furlough, 1955-56.

William Byrom Dickens, A.M., *Assistant Professor of English, College of Engineering*

Thomas Mitchell Sawyer, Jr., Ph.D., *Assistant Professor of English, College of Engineering*

Robert Percy Weeks, Ph.D., *Assistant Professor of English, College of Engineering*

Donald Arthur Ringe, Ph.D., *Assistant Professor of English, College of Engineering*

William McKendrey Jones, Ph.D., *Assistant Professor of English, College of Engineering*

Sidney Warhaft, Ph.D., *Assistant Professor of English, College of Engineering*

Stephen Sadler Stanton, Ph.D., *Assistant Professor 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*

Warne Conwell Holcombe, A.M., *Instructor in English, College of Engineering*

Arthur Willard Forbes, M.A., *Instructor in English, College of Engineering*

Richard John Ross, A.M., *Instructor in English, College of Engineering*

Ralph Andrew Loomis, A.M., *Instructor in English, College of Engineering*

Edward Merl Shafter, Jr., M.A., *Instructor in English, College of Engineering*

Michael Edward Adelstein, M.A., *Instructor in English, College of Engineering*

Niel Klendenon Snortum, A.B., *Instructor in English, College of Engineering*

INDUSTRIAL ENGINEERING

Wyeth Allen, B.M.E., D.Eng., *Professor of Industrial Engineering and Chairman of the Departments of Industrial Engineering and Mechanical Engineering*

Charles Burton Gordy, Ph.D., *Professor of Industrial Engineering*

Quentin C. Vines, B.S.E. (E.E.), M.E., *Associate Professor of Industrial Engineering*

Wilbert Steffy, B.S.E. (Ind.-Mech.), *Associate Professor of Industrial Engineering*

Edward Lupton Page, M.S.E. (I.E.), *Assistant Professor of Industrial Engineering*

MECHANICAL ENGINEERING

WYETH ALLEN, B.M.E., D.Eng., *Professor of Industrial Engineering, Chairman of the Departments of Mechanical Engineering and Industrial Engineering*

ORLAN WILLIAM BOSTON, M.S.E., M.E., *Professor of Mechanical and Production Engineering, Director of the University Instrument Shop, and Supervisor of War Department Gaging and Measuring Laboratory*

WALTER EDWIN LAY, B.M.E., *Professor of Mechanical Engineering*

HUGH EDWARD KEELER, M.S.E., M.E., *Professor of Mechanical Engineering*

EDWARD THOMAS VINCENT, B.Sc., *Professor of Mechanical Engineering*

CHARLES WINFRED GOOD, B.S.E. (M.E.), *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*

RICHARD GILMORE FOLSOM, Ph.D., *Professor of Mechanical Engineering and Director of the Engineering Research Institute*

JAY ARTHUR BOLT, M.S., M.E., *Professor of Mechanical Engineering*

GLENN VERNON EDMONSON, M.E., *Professor of Mechanical Engineering*

RANSOM SMITH HAWLEY, B.S. (E.E.), M.E., *Professor Emeritus of Mechanical Engineering*

ARNET BERTHOLD EPPLE, M.S., *Associate Professor of Mechanical Engineering*

KEITH WILLIS HALL, B.S.M.E., *Associate Professor of Mechanical Engineering*

ROBERT EDWIN MCKEE, M.A., *Associate Professor of Mechanical Engineering*

RUNE L. EVALDSON, Ph.D., *Associate Professor of Mechanical Engineering*

GORDON JOHN VAN WYLEN, Sc.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 Production Engineering, Department of Mechanical Engineering*

HOWARD REX COLBY, M.S.E., *Assistant Professor of Mechanical Engineering*

JOSEPH DATSKO, M.S.E., *Assistant Professor of Mechanical Engineering*

HERBERT HERLE ALVORD, M.S.E., *Assistant Professor of Mechanical Engineering*

THOMAS ALLAN BOYLE, JR., M.S., *Assistant Professor of Mechanical Engineering*

FREDERICK JOHN VESPER, 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*
ROBERT H. EATON, M.S.E., *Assistant Professor of Mechanical Engineering*
HARRY JAMES WATSON, B.M.E., *Assistant Professor of Mechanical Engineering*. On retirement furlough, 1955-56.
FREDERICK KENT BOUTWELL, M.S.E., *Instructor in Mechanical Engineering*
DONALD RAYMOND LONG, M.S.E., *Instructor in Mechanical Engineering*
KENNETH FREDERICK PACKER, M.S.E., *Instructor in Mechanical Engineering*
KENNETH C. LUDEMA, M.S.E., *Instructor in Mechanical Engineering*
WILLIAM MIRSKY, M.S.E., *Instructor in Mechanical Engineering*
RICHARD LEE JONES, M.S.E., *Instructor in Mechanical Engineering*
JOSEPH CASMERE MAZUR, M.S.E., *Instructor in Mechanical Engineering*
IRVING JEROME STEWART, M.S.E., *Instructor in Mechanical Engineering*
JOHN CHARLES TOBIN, M.S.E., *Instructor in Mechanical Engineering*
WILLIAM TELFER, *Instructor in Production Engineering, Department of Mechanical Engineering*
RICHARD CHRISTIAN WILSON, M.S., *Instructor in Mechanical Engineering*
CHARLES LIPSON, Ph.D., *Lecturer in Mechanical Engineering*

NAVAL ARCHITECTURE AND MARINE ENGINEERING

LOUIS ARTHUR BAIER, B.Mar.E., Nav.Arch., *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*
HARRY BELL BENFORD, B.S.E. (Nav. Arch. and Mar. E.), *Associate Professor of Naval Architecture and Marine Engineering*
KENNETH MADDOCKS, B.Sc. (Tech.), *Assistant Professor of Marine Engineering*

RULES AND PROCEDURES

COUNSELING

Counseling services of many types are available. A freshman desiring advice should call on his mentor, who will refer him, if necessary, to other persons or agencies.

Program advisers, whose names are at the heads of the several degree programs, are happy to discuss fields of engineering, selection of electives, and similar matters.

The Assistant Dean is available for consultation at his office at any time. Students who have special problems or who are uncertain concerning procedures may go to him for advice.

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. However, it is essential 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.

Physicians' 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.

MENTOR SYSTEM

Upon admission to the University each freshman student is assigned to a mentor group under the supervision of a member of the faculty. Fol lowing a carefully arranged schedule, each group as a unit progresses through the social activities, tests, and examinations of the Orientation period, which terminates with assignment to classes.

Students who are admitted from other colleges with academic standing above the freshman level also are assigned to groups in order to facilitate the various steps leading to classification and election of courses.

The freshman student continues to be a member of his mentor group throughout his first two semesters of attendance and the faculty adviser continues as mentor for the group. Both socially and in an advisory capacity he is the personal representative of the Dean, so that each student may call upon him at any time to discuss any subject relating to his college life.

Freshman students receive reports on each of their studies through their mentors or faculty advisers. These reports reach the mentor about six weeks after the beginning of the semester. He is, therefore, able to give students in his group definite information regarding their progress.

FRESHMAN ASSEMBLY

Attendance during the first semester at a weekly assembly is required of all freshmen. In the assemblies matters are discussed pertaining to the

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

students' orientation to college life and the improvement of study habits, or faculty members and visiting engineers may be invited to discuss subjects of interest.

Unexcused absences from assembly are considered by the Discipline Committee as acts of insubordination. After two absences unexcused by the head freshman mentor, the student may be placed on probation by the Discipline Committee. For more than two unexcused absences, the Discipline Committee may dismiss the student from the University.

SENIOR SEMINAR

In order to help students in starting their careers, the College conducts a weekly series of seminar 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.

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. All requests for changes in classification must be made on a printed form furnished by the Secretary of the College. A course may be dropped with the permission of the classifier after conference with the instructor in the course, and, except under extraordinary circumstances, any course dropped after the first eight weeks of the semester will carry a grade of "E."

3. 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.

4. 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.

5. 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.

6. 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.

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

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

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

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

8. 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.

9. 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.

10. 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 of 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 Assistant Dean).

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

16. Except as provided above, a student may not repeat a course which he has already passed. In exceptional cases this rule may be 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 thiry 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 of Michigan; *(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, physics, and engineering materials which are 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 of Michigan 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 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 on page 12 should complete the requirements of 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.

FOREIGN STUDENTS

All students whose native language is other than English shall, before matriculation and registration in the College of Engineering, be required to report at once to the Counselor to Foreign Students. Before they may be classified, such students shall satisfy him that they possess a sufficient knowledge of English to carry on work in the College of Engineering.

On recommendation of the counselor they may be referred to the proper classifier, who will give them a program of work such as he deems best. For his first semester, however, every foreign student is considered to be on trial. If at the end of the semester he passes his work, credit will be given; if, however, in spite of conscientious effort he fails, and his difficulties are, in the judgment of his instructors and of the counselor, due primarily to his lack of facility in the use of the English language, his record will be disregarded but he will then be referred to the Department of English for such work in English as he needs, to the limit of eight hours.

If a student is judged by the counselor to be unfitted even for such a trial program as that outlined above, he will be required to take for one semester such work in English as the counselor thinks necessary and may be allowed to visit such classes as may in the judgment of the counselor be profitable to him.

SUMMARY OF STUDENTS

1954-55

BOTH SEMESTERS AND 1954 SUMMER SESSION

	1st Year	2d Year	3d Year	4th Year	Special	Total
Civil	...	83	55	67	8	213
Mechanical	...	180	116	104	5	405
Electrical	...	150	126	88	17	381
Chemical	...	82	73	64	4	223
Naval Architecture and Marine	...	29	21	21	6	77
Aeronautical	...	55	51	34	5	145
Mathematics	...	6	10	25	..	41
Physics	...	13	21	19	..	53
Engineering Mechanics	...	6	9	9	1	25
Metallurgical	...	22	9	11	..	42
Mechanical and Industrial	...	...	1	1	..	2
Industrial	...	88	48	78	5	219
Materials	...	2	2	1	..	5
Unclassified, first year	655	...	...	...	4	659
Grand Total	655	716	542	522	55	2,490
Counted Twice	...	6	11	34	..	51
Net Total in Engineering	655	710	531	488	55	2,439

Undergraduates, College of Engineering	2,439
Students in engineering enrolled in summer sessions only	215
Students in engineering enrolled in Graduate School	652
Students in engineering extension courses*	297

* Extension students have been grouped according to schools and colleges from which instructors offering courses have been drawn. This does not indicate enrollment of the Extension Service students in the schools and colleges.

REGISTRATION SCHEDULES, 1956-57

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, 1956-57

MONDAY, SEPTEMBER 17, 1956

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

TUESDAY, SEPTEMBER 18, 1956

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

WEDNESDAY, SEPTEMBER 19, 1956

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

Second semester, 1956-57

MONDAY, FEBRUARY 4, 1957	8:30– 8:50	Merf	—Miller, E.	1:00– 1:10	Roq	—Rot
	8:50– 9:00	Miller, F.	—Miz	1:10– 1:20	Rou	—Rz
	9:00– 9:10	Mj	—Moro	1:20– 1:30	Sa	—Sarg
	9:10– 9:20	Morp	—Murm	1:30– 1:40	Sarh	—Sehl
	9:20– 9:30	Munn	—Nax	1:40– 1:50	Schm	—Schwartz, R.
	9:30– 9:40	Nay	—Ne	1:50– 2:00	Schwartz, S.	—Send
	9:40– 9:50	Nf	—Nz	2:00– 2:10	Sene	—Shel
	9:50–10:00	Oa	—Opa	2:10– 2:20	Shem	—Siel
	10:00–10:10	Opb	—Pak	2:20– 2:30	Siem	—Sk
	10:10–10:20	Pal	—Pats	2:30– 2:40	Sl	—Smith, L.
	10:20–10:30	Patt	—Pere	2:40– 2:50	Smith, M.	—Sol
	10:30–10:40	Perf	—Pick	2:50– 3:00	Som	—Stah
	10:40–10:50	Picl	—Pop	3:00– 3:10	Stai	—Steu
	10:50–11:00	Poq	—Pri	3:10– 3:20	Stev	—Sto
	11:00–11:10	Prj	—Ram	3:20– 3:30	Stp	—Sup
	11:10–11:20	Ran	—Reid, S.	3:30– 3:40	Suq	—Tas
	11:20–11:30	Reid, T.	—Richa	3:40– 3:50	Tat	—Thomp
	11:30–11:40	Richb	—Robertsn	3:50– 4:00	Thomq	—Toml
	11:40–11:50	Robertso	—Rop	4:00– 4:10	Tomm	—Tup
	Noon			4:10– 4:20	Tuq	—Vandeq
				4:20– 4:30	Vander	—Ver

TUESDAY, FEBRUARY 5, 1957	8:00– 8:10	Ves	—Walc	Noon		
	8:10– 8:20	Wald	—Wark	1:00– 1:10	Brb	—Brown, F.
	8:20– 8:30	Warl	—Webe	1:10– 1:20	Brown, G.	—Buc
	8:30– 8:40	Webf	—Wer	1:20– 1:30	Bud	—Bur
	8:40– 8:50	Wes	—Wh	1:30– 1:40	Bus	—Cam
	8:50– 9:00	Wi	—Willi	1:40– 1:50	Can	—Car
	9:00– 9:10	Willj	—Wolc	1:50– 2:00	Cas	—Cha
	9:10– 9:20	Wold	—Wre	2:00– 2:10	Chb	—Ci
	9:20– 9:30	Wrf	—Yz	2:10– 2:20	Cj	—Cohe
	9:30– 9:40	Za	—Zz	2:20– 2:30	Cohf	—Con
	9:40– 9:50	Aa	—Alc	2:30– 2:40	Coo	—Cou
	9:50–10:00	Ald	—Anderse	2:40– 2:50	Cov	—Cro
	10:00–10:10	Andersf	—Ark	2:50– 3:00	Crp	—Dam
	10:10–10:20	Arl	—Bab	3:00– 3:10	Dan	—Daz
	10:20–10:30	Bac	—Baq	3:10– 3:20	Db	—Deng
	10:30–10:40	Bar	—Bas	3:20– 3:30	Denh	—Din
	10:40–10:50	Bat	—Bec	3:30– 3:40	Dio	—Dou
	10:50–11:00	Bed	—Benr	3:40– 3:50	Dov	—Dup
	11:00–11:10	Bens	—Bes	3:50– 4:00	Duq	—Eg
	11:10–11:20	Bet	—Blac	4:00– 4:10	Eh	—En
	11:20–11:30	Blad	—Boe	4:10– 4:20	Eo	—Fan
	11:30–11:40	Bof	—Bot	4:20– 4:30	Fao	—Fil
	11:40–11:50	Bou	—Bra			

WEDNESDAY, FEBRUARY 6, 1957	8:00– 8:10	Fim	—Foc	Noon		
	8:10– 8:20	Fod	—Fran	1:00– 1:10	Kes	—Kiq
	8:20– 8:30	Frao	—Fz	1:10– 1:20	Kir	—Kni
	8:30– 8:40	Ga	—Gau	1:20– 1:30	Knj	—Koth
	8:40– 8:50	Gav	—Gill	1:30– 1:40	Koti	—Krug
	8:50– 9:00	Gilm	—Goldl	1:40– 1:50	Kruh	—Lami
	9:00– 9:10	Goldm	—Grah	1:50– 2:00	Lamj	—Lawre
	9:10– 9:20	Grai	—Gri	2:00– 2:10	Lawrf	—Leis
	9:20– 9:30	Grj	—Had	2:10– 2:20	Leit	—Lewi
	9:30– 9:40	Hae	—Ham	2:20– 2:30	Lewj	—Lit
	9:40– 9:50	Han	—Harrisn	2:30– 2:40	Liu	—Luca
	9:50–10:00	Harriso	—Hd	2:40– 2:50	Lucb	—M(a)cClel
	10:00–10:10	Hea	—Henl	2:50– 3:00	M(a)cClem	—M(a)cGi
	10:10–10:20	Herm	—Hile	3:00– 3:10	M(a)cGj	—M(a)cMa
	10:20–10:30	Hilf	—Holl	3:10– 3:20	M(a)cMb	—Mall
	10:30–10:40	Holm	—How	3:20– 3:30	Malm	—Marsg
	10:40–10:50	Hox	—Hur	3:30– 3:40	Marsh	—Mat
	10:50–11:00	Hus	—Jack	3:40– 4:00	Mau	—Mere
	11:00–11:10	Jacl	—Jog			
	11:10–11:20	Joh	—Jones, J.			
	11:20–11:30	Jones, K.	—Kam			
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