UNIVERSITY OF MICHIGAN
OFFICIAL PUBLICATION

College of Engineering Announcement

1949–1950

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EAST ENGINEERING BUILDING

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Announcement

1949—1950

ANN ARBOR, MICHIGAN
PUBLISHED BY THE UNIVERSITY

CONTENTS

CALENDAR

SUMMER SESSION

1949

June 20, Monday	Summer session begins
July 4, Monday	Independence Day, a holiday
July 30, Saturday	Six-week courses end in summer session
August 8–12, Monday–Friday	Entrance examinations
August 13, Saturday	Eight-week courses end in summer session

FIRST SEMESTER

September 19–24, Monday–Saturday	Orientation period
September 21–24, Wednesday–Saturday	Registration
September 26, Monday	First semester classes begin
November 24, Thursday	Thanksgiving Day, a holiday
December 16, Friday (evening)	Christmas recess begins

1950

January 3, Tuesday (morning)	Classes resume
January 16–20, Monday–Friday	Entrance examinations
January 23–February 3, Monday–Friday	Examination period
February 8–11, Wednesday–Saturday	Registration for second semester
February 11, Saturday	First semester ends

SECOND SEMESTER

February 6–11, Monday–Saturday	Orientation period
February 8–11, Wednesday–Saturday	Registration
February 13, Monday	Second semester classes begin
April 7, Friday (evening)	Spring recess begins
April 17, Monday (morning)	Classes resume
June 3–15, Saturday–Thursday	Examination period
June 5–9, Monday–Friday	Entrance examinations
June 17, Saturday	Commencement

PART I

OFFICERS AND FACULTY

ADMINISTRATIVE OFFICERS

ALEXANDER GRANT RUTHVEN, Ph.D., LL.D., Sc.D., *President of the University*

JAMES PICKWELL ADAMS, LL.D., *Provost of the University*

IVAN CHARLES CRAWFORD, C.E., Sc.D., *Dean of the College of Engineering*

WALTER JOHNSON EMMONS, B.S., A.M., *Assistant Dean and Secretary of the College of Engineering*

IRA MELVILLE SMITH, LL.B., LL.D., *Registrar of the University*

ALBERT EASTON WHITE, Sc.D., *Director of the Engineering Research Institute*

FACULTY

Members of the faculty are listed at the head of the particular unit in which they serve. A complete list is given in the *Register of Staff and Graduates.*

EXECUTIVE COMMITTEE

Dean I. C. CRAWFORD, Chairman ex officio

Professor L. A. BAIER, term, 1945–49

Professor A. H. LOVELL, term, 1946–50

Professor E. BOYCE, term, 1947–51

Professor J. C. BRIER, term, 1948–52

STANDING COMMITTEE

Dean I. C. CRAWFORD, Assistant Dean W. J. EMMONS, Professors L. A. BAIER, O. W. BOSTON, E. BOYCE, C. G. BRANDT, J. C. BRIER, G. G. BROWN, E. W. CONLON, E. L. ERIKSEN, R. S. HAWLEY, A. H. LOVELL, and H. W. MILLER.

COMMITTEE ON CLASSIFICATION

Associate Professor C. F. KESSLER, Professors M. B. STOUT, and J. C. PALMER, and Associate Professors D. W. MCCREADY and G. L. ALT.

COMMITTEE ON SCHOLASTIC STANDING

Professors C. B. GORDY, L. A. BAIER, L. C. MAUGH, R. SCHNEIDEWIND, and I. H. WALTON, Associate Professor F. N. CALHOON, and Assistant Professors A. L. CLARK, JR., and W. W. HAGERTY.

COMMITTEE ON DISCIPLINE

Professor A. MARIN, Assistant Dean W. J. EMMONS, and Associate Professor E. F. BRATER.

COMMITTEE ON SCHOLARSHIPS

Professors H. W. Miller, F. N. Menefee, R. V. Churchill, S. S. Attwood, and J. C. Brier.

COMMITTEE ON SUBSTITUTION AND EXTENSION OF TIME

Professors R. A. Dodge and J. M. Nickelsen and Associate Professor D. E. Hobart.

COMMITTEE ON COMBINED CURRICULUM

Professors C. Upthegrove and C. B. Gordy.

COMMITTEE ON COMBINED COURSES WITH COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS

Professors R. H. Sherlock, R. Schneidewind and Assistant Dean Emmons.

GENERAL INFORMATION

HISTORY

1. The University of Michigan, founded in 1817, is a part of the educational system of the state, and derives from the state the greater part of its revenue. The University includes the Colleges of Literature, Science, and the Arts, of Engineering, of Architecture and Design, and of Pharmacy, the Medical School, the Law School, the School of Dentistry, the School of Education, the School of Business Administration, the School of Forestry and Conservation, the School of Nursing, the School of Music, the School of Public Health, the W. K. Kellogg Foundation Institute: Graduate and Postgraduate Dentistry, and the Horace H. Rackham School of Graduate Studies, each of which publishes a separate *Announcement*.

In the legislative act of 1837, under which the University was organized in its present form, provision was made for instruction in engineering. The first professor of civil engineering was appointed in 1853, and the first degrees were conferred in 1860. The engineering courses were included in the College of Literature, Science, and the Arts until the close of the collegiate year 1894–95. At that time the College of Engineering was established by the Board of Regents as a separate department of the University. There are few older technical schools in the United States.

The aim of the College of Engineering is to lay a foundation of sound theory, sufficiently broad and deep to enable its graduates to enter understandingly on a further investigation of the several specialties of the engineering profession, and at the same time to impart such a knowledge of the usual professional practice as shall make the students useful upon graduation in any subordinate position to which they may be called. The technical branches are under the direct charge of those who have had professional experience as well as a full scientific training. The instruction fits the students, as far as possible, for the requirements of active practice. The Department of Engineering Research, now the Engineering Research Institute, was established in 1920. The general function and purpose of this department is to co-operate in every proper manner with the industries of the state.

EXTRACURRICULAR OPPORTUNITIES

2. Students at the University of Michigan enjoy many privileges outside their curricular activities. The Student Religious Association and the Ann Arbor churches minister to the spiritual, religious, and social needs of the student body; counselors in religious education have been chosen because of their effective work with young people.

Programs of solo and ensemble music are presented by the faculty and degree program students of the School of Music and by occasional guests. The University Musical Society provides several series of concerts by leading orchestras, chamber music groups, and soloists, at moderate prices. The University has in its galleries a small art collection of great merit; the Museum of Art and the Ann Arbor Art Association sponsor several loan exhibitions during the year.

University lectures are given without charge throughout the year by scientists, publicists, men of letters, and others; the Oratorical Association conducts a series of lectures at moderate prices in which important lecturers appear.

VETERANS' SERVICES

3. The Veterans Service Bureau aids veterans interested in attending the University by supplying information regarding educational benefits under state and federal laws. The Bureau co-operates with all University offices in assisting veterans to establish themselves as students.

All veterans attending the University of Michigan are required to register with the Veterans Service Bureau as an integral part of the registration process. This requirement is necessary to enable the University to (1) expedite certification of veterans to the Veterans Administration for subsistence payments; (2) guide the veterans in obtaining the maximum benefits to which they are entitled; and (3) maintain accurate records of the expiration of the eligibility period for educational benefits.

PROGRAMS OF STUDY

4. The College of Engineering has four-year programs of study which are accredited by the Engineers' Council for Professional Development in aeronautical, chemical, civil, electrical, mechanical, and metallurgical engineering, naval architecture and marine engineering, and engineering mechanics. In addition four-year curriculums not accredited by the Engineers' Council for Professional Development are offered in the specialized fields of mathematics and physics.

The Engineers' Council for Professional Development represents the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Chemical Engineers, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners. It undertakes to formulate criteria for colleges of engineering which will ensure to their graduates a sound educational foundation for practicing the engineering profession.

The work offered by the several departments is usually broader than the name of the department indicates. For example, under Chemical Engineering is given metallurgical, industrial, and general chemical engineering; under Civil Engineering, structural, hydraulic, sanitary, highway, highway traffic, and railroad engineering; under Electrical Engineering, power, communication, and illumination engineering and electrical design; under Mechanical Engineering, steam power, internal combustion, hydromechanical, heating, ventilating and refrigerating, automobile and industrial engineering, and machine design.

The Electrical and Mechanical Engineering departments offer five-year co-operative programs with industry, conforming substantially to the following principle: co-operative relations will be established only with such industries as are able and willing to offer a definite program of graded work of educational value. The student will undertake the co-operative work during the period of an entire semester or of an entire summer session. For details see sections 68 and 71.

COMBINED PROGRAMS WITH OTHER INSTITUTIONS

5. The College of Engineering has an agreement with Albion and Kalamazoo colleges and Western Michigan College of Education 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 accept the first year at the College of Engineering in lieu of the senior year and permit the student to graduate if his record is satisfactory.

Combined curriculums are offered with the College of Literature, Science, and the Arts of the University 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. See sections 66 and 67.

ORIENTATION PERIOD

6. During Orientation Period, before the opening of school, the campus is virtually turned over to new students. Each group of twenty freshmen is placed in charge of a faculty adviser. Routine matters, such as payment of fees, medical examination, and classification, are handled in such a way that waiting is eliminated as far as possible. In addition, many special features, such as talks, sings, mixers, inspection trips, and

discussion groups are included, the whole purpose being to give the student a proper introduction to the University.

No freshman will be excused from attendance during Orientation Period except on account of illness.

All students entering the College of Engineering with advanced standing will find that the University has organized for them an orientation program through the student organizations of the Michigan Union and the Michigan League. This program is designed to help the transfer students in the registration procedure and to acquaint them with the various types of student activities and with the social facilities of the campus. Participation in the program is voluntary for students entering with more than fourteen hours, but it is hoped that they will plan to take part in the entire program of activities.

Students admitted with advanced standing are urged to arrive early to adjust credits, to arrange for living accommodations, and to participate in the activities planned for them.

When admitted, every student will be furnished with instructions for subsequent procedure.

ROOM AND EMPLOYMENT SERVICE

7. Students on arriving in Ann Arbor can obtain information in regard to rooms and board by calling at the Office of Student Affairs, 1010 Administration Building, which assists newcomers in finding rooms and boarding places. The Personnel Office, 3012 Administration Building, conducts a free employment bureau for the benefit of students.

All undergraduate women of the University must make arrangements for their rooms, through the office of the Dean of Women, from the list of approved houses. This ruling applies to the undergraduate women enrolled in the College of Engineering. Individual adjustments can sometimes be made by securing special permission from the office of the Dean of Women.

FOREIGN STUDENTS

8. 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 Dr. Esson M. Gale, 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 such a program of work as he deems best. For his first semester, however, every foreign student is considered as 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 remanded 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. See section 41, International Center.

ADMISSION

9. The requirements for admission are the same for all students in engineering.

Applicants must be at least sixteen years of age, and must present satisfactory evidence of good moral character. For freshmen, the record of work done in the preparatory school must be presented on a form to be obtained from the Registrar of the University; for students transferring from other colleges, the transcript of record usually includes a satisfactory statement.

Students may be admitted on certificate, by examination, on credits from another college, or by a combination of these. They may also be admitted as special students.

REQUIREMENTS FOR ADMISSION

10. *a*) 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 must present a minimum of fifteen units which shall include two major sequences from Groups A and B, a minor sequence from Group C, and three units from Group D. A major sequence consists of a minimum of three units, a minor sequence of a minimum of two units.

PRESCRIBED SEQUENCES	UNITS
A. English	
A major sequence of at least three units is required................	3
B. Mathematics Group	
A major sequence of at least three units is required. This shall include algebra, one and one-half units, plane geometry, one unit, and solid geometry, one-half unit...	3

PRESCRIBED SEQUENCES	UNITS
(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	
A minor sequence of two units is required. This shall consist of one unit of physics and preferably one unit of chemistry, though botany, zoology, or biology may be offered in place of chemistry..............	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. If foreign language is offered it shall be chosen from Greek, Latin, French, German, or Spanish and not less than one full unit of a foreign language will be accepted...........	3
E. *The remaining units* required to make up the necessary fifteen units are elective from among the subjects listed above and any others which are counted toward graduation by the accredited school..............	4
Total	15

PROVISIONAL ADMISSION. In general, an applicant for admission either by certificate or by examination who lacks not more than two of the units prescribed may, if he presents fifteen acceptable units, be admitted provisionally. Deficiencies in mathematics must be made up during the first year of residence. Credit for courses which retire admission deficiencies will not be substituted for any of the 140 semester hours required for graduation, but if such work is elected in the College the resulting grades will be used in determining the semester-grade average. No student who has an admission deficiency outstanding at the beginning of his second year of residence, except in physics, will be allowed to enter his classes until such deficiency is removed. Only those applicants may be admitted provisionally whose records, with the exception of the deficiency, meet in every respect the entrance requirements.

b) ENGLISH. Four units of English should always be presented whenever it is possible.

c) CHEMISTRY AND TRIGONOMETRY. It is urgently advised that one unit of chemistry and one-half unit of trigonometry be included in the fifteen units offered for admission. The student who presents the full requirements without chemistry and trigonometry must take Chemistry 1 and Mathematics 7 or 8 in his first college year, which may necessitate more than the usual time to complete the graduation requirements. Chemistry and trigonometry are offered in the summer session to accommodate those students who wish instruction in them before entering college.

ADMISSION BY CERTIFICATE

11. Only those applicants are admitted by certificate who are officially recommended graduates of high schools accredited to this University 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 approved schools are urged to send direct to the Registrar, immediately at the close of the first semester of the senior year, upon the blank furnished by the University, the application of each prospective graduate intending to enter the freshman class at the beginning of the ensuing year. The applicant will be given a tentative report concerning his eligibility for admission, which will be confirmed when the principal's supplementary report of the final semester's work has been received by the Registrar. If the applicant's credentials are satisfactory, he will receive a certificate of admission to the University without examination, contingent only upon the passing of a medical examination at the time of registration.

As a general rule no advanced credit will be given for work done in the usual high-school course. If the student, however, presents more than the fifteen acceptable units for admission and includes more than two units of foreign language, the foreign language courses in excess of two units may be given credit if they are deemed equivalent to similar courses in the University. Such credit will be adjusted after admission.

Certificates from schools other than those officially approved by the University do not excuse an applicant from the admission examinations.

ADMISSION BY CERTIFICATE AND EXAMINATION

12. Candidates for admission who are graduates of accredited high schools and whose principals are willing to certify them in a part of the required fifteen units may, *at the discretion of the Registrar,* be admitted by certificate covering the units satisfactorily completed together with examinations covering the remaining units required for admission. For this purpose examinations will be provided only in the subjects listed

* A bulletin containing a list of the accredited schools in the state of Michigan will be sent upon request to the Bureau of Co-operation with Educational Institutions, University of Michigan.

under the specific groups—A, B, C, and D—in the requirements for admission of the various schools and colleges.

ADMISSION BY EXAMINATION

13. Candidates for admission who cannot qualify under either of the preceding methods may, *at the discretion of the Registrar,* qualify by offering fifteen satisfactory units by examination. The fifteen units required for admission by examination must be chosen from the subjects listed under the specific groups—A, B, C, D, and E—in the requirements.

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.

Those applicants for admission who are not entitled to enter on certificate and *who have been given permission* to take University entrance examinations should make definite arrangements with the Registrar at least one month in advance of the dates set for the examinations. Entrance examinations are held each year in August, January, and June. The applicant may divide the examinations, taking some either a year or a semester before the date of his admission, and the remainder at the time of admission. If he fails to secure the requisite number of units within this specified time he forfeits all credits for the subjects he may have passed.

Applicants desiring to validate credits in zoology by the University entrance examination must present laboratory notebooks at the time of the examination.

ADMISSION WITH ADVANCED STANDING

14. A student in another college or university who intends to enter the College of Engineering with advanced standing should examine carefully the curriculum of the department in which he intends to specialize and arrange his work accordingly. The applicant must present to the Assistant Dean a letter of honorable dismissal from an approved college, together with an official transcript of his college work and preparatory studies. The transcript must show a scholastic average of at least a full C pass, 75 per cent, and, for admission without deficiences, the requirements of section 10 must be satisfied.

As a rule the student should have completed the required work in English, mathematics, physics, chemistry, physical education, and the nontechnical subjects, and in drawing and engineering mechanics if his institution offers adequate instruction in them. All students are required to participate in the physical training program unless excused by the proper authority. See section 24.

The remaining requirements for students of engineering can usually be completed in two years if the student takes as electives, while an undergraduate, the mathematics required of engineering students and Drawing 1, 2, and 3. A student in the College of Literature, Science, and the Arts who desires to transfer to the College of Engineering should consult officials of the College of Engineering regarding required and permissible elections.

He is advised to write to the chairman of the department in which he wishes to specialize for advice and for information not found in this bulletin. The Assistant Dean of the College of Engineering will be glad to give information concerning admission requirements or other matters of a general nature.

Students who receive on admission less than thirty hours of advanced credit are tentatively considered as freshmen; those presumably to be graduated within one year are considered as seniors.

a) 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 diploma—and an official transcript of his studies.

A student who has completed a regular four-year course at an approved college or other institution may be admitted to the College of Engineering as a senior provided that, in general, 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. The courses to be taken during residence at the University will depend upon his previous training and will be determined by the chairman of the department concerned. Upon the satisfactory completion of such courses, covering at least one year's residence, the student will be recommended for the degree of Bachelor of Science in Engineering.

b) A student who has completed at least one year of work with a satisfactory grade average in an approved college may be admitted to advanced standing without examination.

c) A student who has not completed a year's college work in an approved college, but before entering the University has pursued studies beyond those required for admission, may be admitted to advanced standing. Entrance requirements in such cases may be satisfied by complying with the conditions stated in either section 11, 12, or 13.

ADMISSION ON COMBINED PROGRAMS

15. Students who have completed the first three years of the combined program arranged by the College of Engineering with Albion College, Kalamazoo College, and Western Michigan College of Education are admitted as juniors. For the admission of other students from these colleges see the regulations in section 14.

ADJUSTMENT OF ADVANCED CREDIT

16. At the time of admission records of studies taken elsewhere are reviewed by representatives of the several teaching departments of the College, or by the Assistant Dean in the cases 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 low pass grade.

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 generally not granted. When experience in industry closely parallels the content of a required course, however, the student may be excused from taking such course, thus gaining time for the election of subjects in which he is interested.

Applicants for advanced credit should apply at the time of admission at Room 259, West Engineering Building. It is desirable that credentials should be submitted as far in advance of registration week as practicable. Students desiring advanced standing in drawing must bring all drawings completed previous to entrance.

ADMISSION AS GRADUATE STUDENTS

17. Higher degrees in engineering are conferred in the Graduate School of the University. See the *Announcement* of the Horace H. Rackham School of Graduate Studies.

ADMISSION AS SPECIAL STUDENTS

18. 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

WEST ENGINEERING BUILDING

the selected courses, may be admitted as special students on the recommendation of the chairman of the departments of instruction 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 in order to succeed in engineering studies. Applicants for admission as special students should send as early as possible to the chairman of the department concerned 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 chairmen of the departments of instruction in which they register.

A special student may become a candidate for a degree by fulfilling the regular requirements for admission. See section 10.

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

ADMISSION OF VETERANS

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

FEES AND EXPENSES

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

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

To cover expenses students are urged to provide themselves with money orders or travelers' checks. 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. Every student must pay a semester fee. For Michigan students, the semester fee in the College of Engineering is $70 for each semester, for non-Michigan students, $175 for each semester.

These fees cover class instruction, use of libraries, physical education privileges, membership in the Michigan Union or Michigan League, and medical attention from the University Health Service and dispensary in accordance with regulations of the Health Service.

Reduced program fees. The election of six hours or fewer in the Law School or of nine hours or fewer in any other school or college is considered a reduced program. Those electing such a program must pay each semester the appropriate fee indicated below.

Before a student may elect a reduced program, permission must be obtained from the dean of the school or college in which enrollment is intended.

REDUCED PROGRAM FEES

GROUP	DESCRIPTION	MICHIGAN STUDENTS	NON-RESIDENTS
1	Election of three hours, registration for work on doctoral dissertations, library privileges, work *in absentia**	$ 25	$ 65
2	Four hours	35	90
3	Five hours	40	100
4	Six hours	45	115
5	Seven hours	50	125
6	Eight hours	55	135
7	Nine hours	60	145

a) All students in Group 1 may obtain privileges of the Health Service upon an additional payment of $10 per semester *at the time of registration.* Election of Health Service privileges is entirely optional to this group; however, those not electing such privileges are required to sign a waiver at the time they register.

b) All students in Groups 2, 3, 4, 5, 6, and 7 are entitled to Health Service privileges without further payment.

c) *At the time of registration* all students in the seven groups listed may obtain the following privileges upon payment of the additional sums specified: Michigan Union, $5.00, or Michigan League, $7.50. They may also obtain the privileges of admission to athletic events upon payment of the annual fee plus tax at the Administration Building, Ferry Field.

Regulations governing residence. The fees for students from Michigan are lower than those for students from other states or countries.

The burden of registering under proper residence is placed upon the student; and it is the duty of each student at registration, if there be any possible question of right to legal residence in Michigan *under the*

* All students working only on their dissertations are expected to pay the appropriate reduced program fee throughout the period. When the dissertation is completed while in residence during the summer session and degree is not conferred at that time, no fee will be charged students for the subsequent semester in which degree is conferred.

rules of the Regents, to raise the question with the registration officer and have such question passed upon and settled by the proper officers of the University, previous to registration. Any student who registers improperly under this rule shall, when discovered, be required to pay not only the proper nonresident fees, but shall be assessed, as an addition to the fee for that semester, the sum of $10.

No one is deemed a resident of Michigan for the purpose of registration in the University unless he or she has resided in this state six months next preceding the date of proposed enrollment (see below for status of minors and married women).

No person shall be deemed to have gained or lost a residence in this state while a student at any institution of learning except by changes in status effected under the two paragraphs below.

The residence of students who are minors follows that of the parents or of the legal guardians.

The residence of a wife follows that of her husband.

Students who are minors, who come to the University from other states or countries, cannot be registered as residents of Michigan on the basis of having a resident of Michigan as guardian except on permission of the Regents in each case.

Aliens who have taken out their first papers, and the wives or minor children of such aliens who have otherwise met these requirements for residence are regarded as eligible for registration as residents of Michigan.

Discretion to adjust individual cases within the spirit of these regulations is lodged with the Secretary with the right of appeal to the Regents.

LATE REGISTRATION. Late registrations are not permitted except for veterans who were not in residence for the preceding semester or summer session. Because of the unprecedented demands which the enrollment for the first semester will make upon the University, it is essential that registration and classification be completed according to schedule.

LABORATORY FEES. No laboratory fees are charged, but those students who take laboratory work in such courses as chemistry, chemical engineering, pharmacy, bacteriology, or hygiene shall pay for the material consumed and for unusual breakage. The deposits required in advance range from $2.00 to $25, according to the course. The actual expense involved varies with the prudence and economy of the individual student.

INDEBTEDNESS TO THE UNIVERSITY. Students are expected to pay all accounts due the University not later than the last day of classes of each semester or summer session. Student loans which fall due during any semester or summer session which are not paid or renewed are subject to this regulation; however, student loans not yet due are exempt. Any unpaid accounts on the last day of classes will be reported to the Cashier of the University and until such accounts are paid:

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

b) All students owing such accounts will not be allowed to register in any subsequent semester or summer session.

GRADUATION. The "Bylaws" of the Board of Regents prescribe that no person shall be recommended for a degree until he has paid all the money due the University. To receive a degree at Commencement the candidate must be present in person. Others who have satisfied all the requirements for graduation, including the payment of all dues, will receive their degrees at a subsequent meeting of the Board of Regents.

LIVING EXPENSES. The expenses of students at the University may vary quite widely, depending upon individual resources and desires. The estimate of the average expenses during the first two semesters is based upon board for thirty-six weeks at approximately $14 to $18 a week and room at $5.00 to $9.00 a week. The cost of room and board in one of the University residence halls is approximately $560 for two semesters, depending upon the number of days in the semester and the type of room. Owing to fluctuating costs of food and labor, the Board of Governors of Residence Halls reserves the right to revise its charges at any time. For additional information concerning the cost of living in the University residence halls, the student may communicate with the Office of Student Affairs.

Living expenses are substantially reduced in Inter-Co-operative-Council houses, in which the work is shared among the members. For further information, write: Membership Secretary, Inter-Co-operative Council, 816 South Forest Avenue, Ann Arbor, Michigan.

The following items are necessary for an engineering student during the first year at the estimated costs shown:

Set of drawing instruments, board, T square, triangles, scales	$40
Slide rule, notebook, paper	20
Textbooks	75

REFUND OF FEES

21. SEMESTER FEES. *a*) No student is entitled to a refund in accordance with the scale below except upon (1) presentation to the Cashier of the University of a certificate of withdrawal from the proper office

of the school or college from which he or she is withdrawing, and (2) surrender to the Cashier of the University of the student receipt, the athletic coupon or book together with tickets issued to such student for future athletic events, the Michigan Union or Michigan League annual membership card, and the student identification card (if one has been issued). In case of loss of the student receipt, $5.00 will be deducted from the refund as a penalty, and a further deduction of $1.00 will be made if the student identification card is not surrendered. If the athletic coupon, book, and tickets for future athletic events are not surrendered, deductions at face value will be made for such items.

b) No refund will be granted unless applied for within ninety days after withdrawal.

c) A student who withdraws not more than two weeks after registration will be entitled to a refund of the entire semester fee.

d) A student who withdraws more than two weeks and less than four weeks after the beginning of the semester will be entitled to a refund of one-half the semester fee.

e) A student who withdraws more than four weeks and not later than eight weeks after the beginning of the semester will be entitled to a refund of 40 per cent of the semester fee.

f) A student who transfers from one school or college to another will receive a full refund of the fee from the school or college in which he or she first enrolled and will be required to pay the full semester fee in the school or college to which transfer is made.

g) A student who transfers from full-time to part-time status will receive a refund in accordance with regulations *c*, *d*, and *e*, above, and will be required to pay the entire part-time semester fee.

h) A student who transfers from part-time to full-time status will receive a full refund of the part-time semester fee and will be required to pay the entire full-time semester fee.

i) Refunds for short courses will be made pro rata on the basis of the foregoing rules.

SUMMER SESSION. *a*) The same general regulations under *a* and *b* governing the refund of semester fees shall apply to summer session refunds.

b) A student who withdraws not more than one week after registration will be entitled to a refund of the entire fee.

c) A student who withdraws more than one week and less than two weeks after the beginning of the session will be entitled to a refund of one-half the fee.

d) A student who withdraws more than two weeks and not later than four weeks after the beginning of the session will be entitled to a refund of 40 per cent of the fee.

HEALTH SERVICE APPROVAL

22. The following classes of students require Health Service approval before payment of fees:

a) Students who wish to enroll for the first time, to re-enroll after an absence of a full semester, or who are specifically listed for approval, must obtain Health Service approval as part of registration. Such approval is to be based upon assurance of health safety to the entrant and associates as determined by a suitable examination and evidence of vaccination (immunity to smallpox). Vaccination may be waived by the Director of the Health Service for applicants who file statements of objection on religious grounds properly signed, in case of minors, by parents or guardians. Such waiver shall release the University from the responsibility of financial assistance to the applicant who contracts smallpox.

b) 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.

UNIVERSITY HEALTH SERVICE

23. Through its Health Service, the University supplies health instruction and protection, with generous care of illness as part of the student's regular privileges. Attention to sickness includes operations, medical care, and fifteen to thirty days' hospitalization for acute illnesses which may develop after semester enrollment. The service is also available to students in the summer session and to those of the winter session who remain during holiday vacations. The department occupies a new building admirably suited to its work, which is situated on Fletcher Avenue.

The offices where students may receive usual medical attention, including special examinations and medicines, are on the lower floors of the building and are open regularly during class hours. Students may consult any staff physician at choice, but certain physicians are their regularly assigned medical advisers. Attention which requires a special visit of a physician, such as to the student's room, carries a University charge to the patient.

Bed care is regularly given in the sixty-bed infirmary on an upper floor of the Health Service building. Extra expense for private rooms, special nursing, etc., is likely to result for patients sent to other hospitals. The physicians of the Medical School and Hospital co-operate with the Health Service whenever students need the attention of such additional specialists.

FACILITIES AND REQUIREMENTS FOR PHYSICAL EDUCATION

24. *a*) The University is provided with excellent gymnasiums; Waterman Gymnasium for men and Barbour Gymnasium for women. The field house for women in Palmer Field provides bowling alleys, indoor golf school, indoor archery range, rifle range, lockers, and showers.

The athletic field, known as Ferry Field, comprising seventy-eight acres of land, has been set apart and equipped for outdoor sports of every kind. The University eighteen-hole golf course is situated southwest of Ferry Field. In addition to the playing field there are a football stadium seating 87,000, a baseball stand accommodating 8,000, an Athletic Administration Building, an indoor playground known as Yost Field House, and the Sports Building.

The Field House and the Sports Building give a complete athletic plant that functions the year round.

The physical education program for men and women students enrolled in the University includes (1) a required program, (2) hygiene lectures, (3) an intramural sports program, and (4) intercollegiate athletics (for men).

Required physical education program. All students must complete satisfactorily a physical education requirement. Each student upon entering the University is given a complete health examination on the basis of which he or she is placed in a health group. Students are limited to suitable types of activity according to their health groupings. (See below for details concerning this program.)

Hygiene requirement. Each entering freshman is required to take, without credit, a series of lectures in community and personal health and to pass an examination on the content of these lectures. Transfer students with freshman standing are also required to take the course unless they have had this course elsewhere. Veterans are exempt from this requirement.

b) Intramural athletics. A threefold intramural program is conducted with (1) competition (team and individual) in thirty-five different sports, (2) instruction in many of these sports, and (3) informal workouts. Opportunities for competition are offered for all men's organized groups on the campus. For details see the *Handbook of Intramural Sports* available at the Sports Building, Ferry Field, and the *Intramural Sports Announcement* and the *Bulletin* of the Women's Athletic Association available at the Barbour Gymnasium, Office 15.

INTERCOLLEGIATE ATHLETICS. Intercollegiate competition is offered in football, basketball, baseball, track and field, swimming, hockey, wrestling, golf, and tennis. Students interested in joining any of these squads should see the coach in charge. Members of these teams may substitute this participation for P.E.M. during the season of competition.

c) PHYSICAL EDUCATION REQUIREMENTS FOR MEN. * All students entering the University from the secondary schools shall be required to complete satisfactorily a one-year course in physical education and any requirements for a given student beyond this one-year term shall be made by the Health Committee in accordance with the needs of the individual concerned.

The Health Committee shall decide whether or not a student entering the University with less than two years' credit from another institution of higher learning has satisfactorily met the one-year requirement in physical education, and shall, upon the basis of the physical examination taken at the time of admission, determine whether or not further physical education is necessary, and shall determine the nature and amount of any further work required.

PROGRAM. The required program is centered around the physical education needs, interests, and desires of each student. It includes not only basic motor fitness but also opportunities for experiences in competitive sports and the acquisition of essential skills in basketball, badminton, boxing, golf, gymnastics, swimming, tennis, track, weight-lifting, wrestling, handball, softball, and volleyball.

REMEDIAL PHYSICAL EDUCATION. Students who are unable because of physical or medical deficiencies to take part in the regular physical education classes are assigned to a section in remedial physical education. Individual instruction and training are given in an adapted activities program.

SWIMMING REQUIREMENT. All students are required to pass a standard swimming test. Those students who are unable to swim must remain in a swimming class until the test requirements are fulfilled.

LOCATION OF CLASSES. The entire physical education and athletic plant has been made available for the program of physical education. In general, however, the required and remedial programs will take place at Waterman Gymnasium.

*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.

LOCKERS. Each student is to purchase a locker and towel at a cost of $2.00 a semester. There is a refund of fifty cents at the end of the semester when the last towel is returned. The locker and towel fee is paid at Waterman Gymnasium on the first day of classes.

UNIFORM. Each participant is to provide himself with a regulation uniform consisting of shorts, "T" shirt, and gymnasium shoes.

REQUIREMENTS FOR PASSING THE COURSE. The requirements for passing the course are based on (1) attendance, (2) efficiency in activities, (3) sports knowledge, and (4) motor fitness scores.

ABSENCES. 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 must be presented to the Waterman Gymnasium office for approval.

d) PHYSICAL EDUCATION REQUIREMENT FOR WOMEN. All freshman women must complete satisfactorily a minimum requirement in physical education extending through the two semesters of the freshman year. This required course of instruction is subject to the University regulations regarding the quality of work and the attendance.

Women students entering the University with junior standing from other colleges will, in general, have fulfilled the freshman physical education requirement. The Assistant Dean will determine the status of each individual's physical education requirement.

MENTOR, ASSEMBLY, AND PLACEMENT SYSTEMS

25. *a*) Upon admission to the University each freshman student is assigned to a mentor group under the supervision of a member of the faculty. Following a carefully arranged schedule, each group as a unit progresses through the social activities, tests, and examinations of the Orientation Period which finally terminate 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. 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 for the discussion of any subject relating to his college life.

b) 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 the students in his group definite information regarding their progress.

c) Attendance at weekly assembly is required of all freshmen. Unexcused absences subject the absentee to discipline. In the assemblies matters are discussed pertaining to the 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.

d) During the senior year each student is requested to fill out a personnel record and file it with his professional department. The chairman of the department, or special officer designated for the purpose, will then assist the student to find satisfactory employment after graduation by furnishing information as to available openings, and arranging contacts and interviews. From what is usually a long experience, the placement officer will advise the student as to the intrinsic merits of the opportunities presented in the special fields.

The interest of the College in placement by no means ceases when a student graduates. Graduates are invited to file a still more comprehensive personnel record. On doing this, they secure all the co-operation the placement officer can give, either in placing a graduate in his first position or in enabling him to find a better position if he so desires. During the depression, College placement officers devoted a great deal of time and effort to the business of finding work for graduates.

HONOR SYSTEM

26. The students of the College of Engineering adopted the following system in 1916:

All examinations and written quizzes in the College are held under the Honor System, the object of which is to create that standard of honor which is essential to a successful engineer and a good citizen. Students are expected to uphold the system or declare their objections to it, 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 does not ask for an examination under a proctor:

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

The Student Honor Committee consists of nine members appointed by the Engineering Council.

RULES GOVERNING ELECTION OF STUDIES

27. *a*) Each classifier has full authority as to the hours of study assigned to a student.

b) No student is permitted to elect fewer than twelve hours, and no student whose grade average for the preceding semester is less than three is permitted to elect more than eighteen hours a semester, except by permission of the classifier.

c) No credit will be allowed to a student for work in any course unless the election of the work is formally entered on his office classification card.

d) After classification, no study can be taken up or dropped without special permission of the classifier. The time for dropping any course without record is limited to eight weeks from the opening of the semester. A course may be dropped only with the permission of the classifier after conference with the instructor in the course, and except under extraordinary circumstances, permission to drop courses after the first eight weeks of the semester will be granted only with grade E. Students who have been absent from studies at any time in the semester for more than a week, because of illness or other emergency, should consult the Assistant Dean concerning a necessary revision of their programs.

e) All requests must be made out on a printed form furnished by the Secretary of the College.

f) A student is required to drop a part of his work at any time if he appears to be undertaking too much; or to take additional work if he is thought not to be sufficiently employed.

g) Only such students as are regularly enrolled in a class will be allowed to take quizzes, tests, or final examinations in the same.

h) The faculty reserves the right to withdraw the offer of any elective study not chosen by at least six persons.

i) After matriculation, a student cannot, without special permission of the faculty, be admitted to examination in any one of the courses given until he has received in the University the regular instruction in such course.

j) The normal number of hours that students should carry each semester is between sixteen and eighteen. Students who support themselves wholly or in part should so inform their classifier and should elect a smaller number of hours. It is very difficult for a student supporting himself to carry a full schedule and to 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.

ADMISSION DEFICIENCIES

28. An applicant who fails, or is deficient, in some part of the admission requirements may, at the discretion of the Assistant Dean, be ad-

mitted, provided he passes in fifteen units; but the removal of entrance deficiencies shall take precedence over all other work; any deficiency must be removed at one of the next two regular examinations for admission, but the classifier is empowered and instructed to see that students entering this College with deficiency remove the same so far as possible during the first semester of residence.

No student who has any admission deficiency, with the exception of physics, outstanding at the beginning of the second year of residence will be allowed to enter his classes until such deficiency is removed, unless for valid reason an extension of time is granted for its removal.

NONTECHNICAL ELECTIVES

29. All regular students in the College of Engineering are required to complete not fewer than six hours of nontechnical electives selected as follows:

No course offered by an engineering professional department or by the Department of Metal Processing or of Chemistry shall be considered as nontechnical, except that plane trigonometry and Chemistry 1 and 3 when taken for University credit will be accepted in place of nontechnical electives.

Not more than four semester hours of military or naval science shall be considered as nontechnical.

If as many as six hours in any subject except English are required for graduation, any hours in excess of six in such subject shall not be considered as nontechnical.

Up to six hours in any subject not required in a particular program for graduation may be considered as nontechnical electives, except as limited in the preceding rules. Where less than six hours of any permissible subject are required for graduation, the difference between this requirement and six hours may be considered as nontechnical.

Students who anticipate electing a foreign language are urged to consult with their advisers regarding the choice of the foreign language.

EXAMINATIONS

30. Examinations in college work are held at the end of each semester, but classes are likely to be examined at any time, without notice, or with one week's notice, on any part of their work. The regular examination in any course at the end of each semester is an essential part of the work of the course.

MARKING SYSTEM

31. At the end of each semester the quality of the work of every student in each course which he elects and completes is reported by the

instructor as A (excellent), B (good), C (satisfactory), D (passed), or E (not passed).

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.

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.

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. It will not necessarily be the grade reported for the partly completed course.

At the time of completing 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.

RULES GOVERNING GRADES AND SCHOLARSHIP

32. *a*) 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.

b) The average grade is determined on the basis of A equals 4 points, B equals 3 points, C equals 2 points, D equals 1 point, and E equals 0.

c) 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.

d) No student who has earned a general average grade below 2.0 in the courses elected in this College may be graduated.

e) 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.

f) 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.

g) 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.

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

i) A student on probation who obtains an average semester or summer session grade of 2.0 or more is automatically removed from probation, provided his general average is 2.0 or better; if not he shall be placed on the warned list.

j) 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.

k) A student will be required to withdraw from this College for any one of the following reasons:

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

2 If he is on probation and fails to obtain an average grade of 2.0, or C, during a semester or summer session.

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

4 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.

l) 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.

m) 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 *e, f, g, h, i, j,* and *k* above.

n) 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 department of specialization (for freshmen, the Assistant Dean).

o) 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.

p) 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 department of specialization (for freshmen, the Assistant Dean) upon recommendation of the department of instruction concerned.

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

EXCUSES FOR ABSENCES

33. 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 * should explain irregularities of attendance to their instructors.

Unexcused absences from Assembly during the freshman year 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 send the student home for insubordination.

CLASS STANDING

34. The following classification of a student in terms of credit hours applicable to his program has been approved by the faculty: sophomores should have from thirty to thirty-three hours, juniors sixty-seven to seventy hours, and seniors 100 to 104 hours, or a reasonable chance to graduate within a year. The Assistant Dean will make decisions in unusual cases. The faculty recognizes as upperclassmen: (*a*) those students in good standing, i.e., not on probation, 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 department heads may qualify for graduation within one year.

* For the definition of upperclassmen, see section 34.

An upperclassman's privileges will be withdrawn should his average grade for all work at the University fall below C or should he be put on probation and will be restored when his delinquency is removed.

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

35. 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.)

Engineering students must obtain this permission or dismissal from the Assistant Dean.

REQUIREMENTS FOR GRADUATION

36. To secure a degree in the College of Engineering, a student must meet the following requirements:

a) He must complete the required courses of his department.

b) He must complete a sufficient number of electives approved by the head of his department to make a total of 140 credit hours with an average grade of 2.0 or above. See section 32.

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 homework.

c) He must spend one year in residence and complete at the University of Michigan a minimum of thirty credit hours of the 140 hours required. Attendance at four summer sessions will be accepted as the equivalent of one year in satisfying the present resident requirement.

d) He must obtain a total of 148 credit hours to receive degrees in two departments, and he must complete the requirements for both degrees.

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.

DEGREES CONFERRED IN THE COLLEGE OF ENGINEERING

37. The University of Michigan confers on all graduates of the College of Engineering the degree of Bachelor of Science in Engineering, the diploma designating the branch of engineering that the student has pursued. See section 4 for programs of study.

DEGREES CONFERRED IN THE HORACE H. RACKHAM SCHOOL OF GRADUATE STUDIES

38. Graduate courses are offered in the Horace H. Rackham School of Graduate Studies leading to the degree of Master of Science in Engineering, Doctor of Philosophy, Doctor of Science, Civil Engineer, Mechanical Engineer, Electrical Engineer, Chemical Engineer, Metallurgical Engineer, Naval Architect, Marine Engineer, and Aeronautical Engineer.

Any student who has received a bachelor's degree from the College of Engineering of this University or from some other university or technical school of recognized standing may enroll in the Graduate School for the degree of Master of Science in Engineering and for other higher degrees. See the *Announcement* of the Horace H. Rackham School of Graduate Studies, which may be had on application.

Students enrolled in the Graduate School must have a subject of specialization, but studies may not be selected exclusively in the single department concerned with the subject. Cognate subjects should be selected in other departments. While it is expected that at least half of the work will be in a single department and also that the work will have unity, narrow specialization is discouraged. After a student has selected his department of specialization he should confer with the professors under whom he expects to study and with them arrange the details of his course.

RELATION OF STUDENTS TO THE CIVIL AUTHORITIES

39. Students are temporarily residents of the city, and like all other residents, are amenable to the laws. If guilty of disorder or crime, they are liable to arrest, fine, and imprisonment. A rule of the University provides that, if a student is arrested or convicted by the civil authorities, he shall be cited to appear before the University Committee on Student Conduct or the faculty of the college in which he is matriculated, and shall be liable to suspension or expulsion.

MICHIGAN UNION AND MICHIGAN LEAGUE

40. The University of Michigan Union was organized and incorporated under the laws of the state of Michigan in 1904 to establish a

University social center, to provide a meeting place for faculty, alumni, and students of the University, to furnish a home for alumni when in Ann Arbor, and to supply a place for wholesome relaxation for students. As a social center it encourages and stimulates activities that are for the welfare and enjoyment of the student body, thus fostering a richer, more intense University life, a product of the student's own work. In recognizing neither artificial barriers nor distinctions, the Union serves as a democratizing influence on the student body; in emphasizing the social value of education, it complements the work of the University in its endeavor to graduate broadly educated men and good citizens. Membership in the Union is restricted to men.

The Union Building is exceptionally well appointed. Among its many attractions are a swimming pool; six bowling alleys; a barber shop; a billiard room with twenty-four tables; a library; a lounging room; restaurant service, including a cafeteria, a main dining room, and an assembly hall adapted to use for banquets, meetings, conventions, smokers, concerts, and dances; and 160 sleeping rooms for the alumni and guests of members.

The following men students are entitled to all the privileges of the Michigan Union:

a) Those who pay the full-time semester fee.

b) Part-time students during the regular session who elect to pay an additional fee of $5.00 a semester.

c) Those enrolled for full-time work during the summer session.

Payment under (*a*) and (*b*) during four college years automatically secures a life membership in the Michigan Union.

The Michigan League is the women's self-governing organization at the University. Every undergraduate woman becomes a member upon entering the University and is entitled to all the privileges offered by the organization.

The Michigan League Building, erected by alumnae and friends of the University and completed in 1929, provides for the women of the University a clubhouse similar in scope to that of the Michigan Union for men.

The following women students are entitled to all the privileges of the Michigan League:

a) Those who pay the full-time semester fee.

b) Part-time students during the regular session who elect to pay an additional amount of $7.50 a semester.

c) Those enrolled for full-time work during the summer session.

Payment under (*a*) or (*b*) above during four college years automatically secures a life membership in the Michigan League.

INTERNATIONAL CENTER

41. The constantly growing number of students from foreign countries brought about the appointment, many years ago, of a special Counselor to Foreign Students. In 1938, when a new wing was added to the Michigan Union, a part of the building, with a separate entrance from Madison Street, was equipped to serve as a meeting place for foreign students and a center for the counseling and other services especially provided for their benefit. Living quarters are not provided, since the University believes that visitors to this country will profit much more from their stay if they mingle with the native-born American students in the residence halls and rooming houses and at the table, instead of living as a more or less segregated group. Through the International Center, however, the University attempts to extend a special hospitality to the representatives of other countries in its student body and, by relieving them of some of the problems and difficulties experienced by individuals far from home and in utterly strange surroundings, to make their stay in the United States an experience to which they can look back with friendly feelings and pleasant memories.

Foreign students are assisted by the staff of the International Center to make suitable living arrangements and to select and enter upon the studies for which they have come. Since the language is often a difficulty, through the English Language Service conducted by the Center foreign students are assisted to gain a command of the language in the shortest possible time. The Center also provides lounging, reading, meeting, and recreation rooms and conducts social gatherings at which foreign students may meet with each other and with the native-born students and faculty members of the University.

SOCIETIES

42. Engineering council. The Engineering Council of the University of Michigan, formed under a constitution in 1927, is an organization of students representing all departments of the College of Engineering. Its members are the presiding officers of the student branches of the American Institute of Electrical Engineers, the American Institute of Chemical Engineers, the American Society of Mechanical Engineers, and the American Society of Civil Engineers; of Tau Beta Pi, Sigma Rho Tau, Triangles, and Vulcans; of the Quarterdeck and Aero clubs; the presidents of the freshman, sophomore, junior, and senior classes, together with one special representative from the sophomore class to serve for three years, and two representatives from the junior class to serve for two years; and the editor of the *Michigan Technic*. The Council aims

to co-ordinate the activities of the various technical societies and clubs, to assure continuity in policy for the classes, and to develop co-operation between the student body and the faculty.

MICHIGAN TECHNIC. The students publish monthly for eight months of the school year a magazine called the *Michigan Technic,* which contains articles contributed by alumni, faculty, and students on technical topics and other matters of interest to the College.

STUDENT BRANCH, AMERICAN SOCIETY OF CIVIL ENGINEERS. This chapter was founded in 1923. At the present time its membership consists of civil engineering students from the sophomore, junior, and senior classes who are in good standing in the University. New members are elected each semester upon written application.

MECHANICAL ENGINEERING SECTION. This section of the general society is also a student branch of the American Society of Mechanical Engineers. Meetings of the section are held about once a month. Some of the meetings are of a purely social nature while others are addressed by members of the faculty or by outside engineers and businessmen on subjects of general interest to the profession.

ELECTRICAL ENGINEERING SECTION. A student branch of the American Institute of Electrical Engineers. In joining it, the student makes a connection which usually extends throughout his whole professional life after graduation, and which helps him materially by furnishing opportunities for advancement. The meetings, which are held twice each month, are managed entirely by the students, who procure speakers from among themselves or from among professionals in the field, and who derive valuable experience in self-expression, as well as technical knowledge, from the discussions in which they engage. Each member of the branch receives *Electrical Engineering,* which is issued once each month.

STUDENT CHAPTER, AMERICAN INSTITUTE OF CHEMICAL ENGINEERS. The chapter holds regular meetings for discussions of professional interest by experienced engineers; sponsors visits to plants operating processes of chemical interest; normally holds an annual banquet and picnic; and organizes trips to regional and national American Institute of Chemical Engineers conventions, when near the University. Membership provides access to copies of *Chemical Engineering Progress,* official publication of the American Institute of Chemical Engineers, and entitles the member to a reduced subscription rate while a member of the Student Chapter and for three years after leaving school. Membership in the Student Chapter normally leads to the higher levels of membership after graduation, with all the privileges and profits of lifelong association with the leaders in the chemical engineering field.

STUDENT AFFILIATED SOCIETY, AMERICAN INSTITUTE OF METALLURGICAL ENGINEERS. The society holds technical meetings at which outside speakers discuss some topic of interest to the student engineers. Trips to various plants are arranged by this group which enable the student to observe metallurgical operations of a wide nature. Student membership in the American Institute of Metallurgical Engineers entitles the holder to copies of *Metals Technology* and allows for continued student membership for one year after leaving school.

STUDENT BRANCH, INSTITUTE OF THE AERONAUTICAL SCIENCES. Membership is open to all aeronautical engineering students. Meetings are held about once a month and are of both a social and a technical nature.

QUARTERDECK SOCIETY is an organization of students in the Department of Naval Architecture and Marine Engineering and is recognized by the Society of Naval Architects and Marine Engineers as the student branch at the University of that organization, although membership in it does not carry membership in the national organization. Accepted applicants are first made probationary members and each is required to submit a satisfactory paper on some subject in the field of naval architecture and marine engineering as a condition of full membership. Technical meetings are held throughout the year, at which these papers and those prepared by the members are read.

TAU BETA PI, the national engineering honor society, has a chapter in the College of Engineering. For membership in this society good scholarship is essential.

NATIONAL SOCIETY OF SIGMA XI has a chapter in the University. The aim of the society is to encourage research. High scholarship and the promise of ability in research are required of its candidates.

STUMP SPEAKERS' SOCIETY OF SIGMA RHO TAU. A branch of the intercollegiate engineering speakers' society founded at the University of Michigan to develop ability in public discussion and debate. The major object of the organization is to ensure a closer bond of understanding between the applied scientist and the general public through the development of speech activities among colleges of architecture, engineering, and technology. The society has a package library and clipping service in its library reference room in the West Engineering Building. It debates national engineering problems with local societies and adjacent branches.

PHI ETA SIGMA, a national honorary society for freshman men, elects members each year on the basis of high scholarship.

PHI KAPPA PHI, a national scholastic honor society, elects its members each year from the senior classes of all schools and colleges on the basis of scholarship, personality, and service to the University.

National Signal Corps fraternity. Pi Tau Pi Sigma, a national honorary Signal Corps fraternity, elects its members each year from the junior and senior classes of the third and fourth years of Signal Corps ROTC on the basis of outstanding scholarship and military proficiency.

Scabbard and Blade is a national ROTC honorary military fraternity. Members of the third and fourth year ROTC are elected to Scabbard and Blade upon the basis of meritorious academic standing and exceptional traits of leadership.

The Society of American Military Engineers (University of Michigan post). The aim of the society is, in part, to advance knowledge of the science of military engineering, to encourage, foster, and develop relations of helpful interest between the engineering profession in civil life and that in the military service; to hold meetings for the presentation and discussion of appropriate papers and for social and professional intercourse.

Regular students and members of military training units are eligible for admission as student members of the University of Michigan Post.

FELLOWSHIPS

43. About thirty fellowships and scholarships are open to students in the Graduate School. Appointment is for the term of one year, but appointees are eligible for reappointment. An appointee is not required to render any service to the University aside from that involved directly in the responsibilities of the fellowship or scholarship assigned. It is expected that appointees devote all their time to their graduate work.

A distinction is drawn between fellowships and scholarships, the former, besides carrying the larger stipend, being assigned to the students of more experience and more clearly proved ability and independence in graduate study and research.

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 will be sent by the University upon request.

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 in certain lines.

SCHOLARSHIPS, PRIZES, AND STUDENT AID

44. A limited number of University scholarships are given in the Graduate School which provide a stipend equal to the amount of the semester fees, but not miscellaneous fees, and are open to residents of the state of Michigan who are graduates of the University of Michigan.

AMERICAN BUREAU OF SHIPPING PRIZE. A prize of $100 is offered each year by the American Bureau of Shipping to the student in naval architecture and marine engineering who obtains in the regularly prescribed courses the highest average for the last two years of the curriculum.

JOSEPH BOYER FUND. Established in 1938 by gift from Mrs. Henry E. Candler, Grosse Pointe, Michigan, as a memorial to her father. The income is to be used for the benefit of a member of the junior or senior class in the College of Engineering. The recipient of the award must be partly or entirely supporting himself in college, and must have shown himself to be a loyal American citizen.

UNIVERSITY SCHOLARSHIPS

CORNELIUS DONOVAN SCHOLARSHIPS. These scholarships were established in 1922 by a bequest of Cornelius Donovan, C.E. '72, Eng.D. (hon.) '12, for award to meritorious senior students in engineering who are working their way through college. These scholarships are awarded in amounts of $200 each. To be eligible, students must be American citizens, partly or entirely self-supporting, and must have completed a minimum of forty-five hours of work at the University of Michigan with a minimum general average of 2.5. Applications must be filed in the office of the Assistant Dean of the College of Engineering before March 15. The awards are published in May and are paid in the amounts of half of the award when the recipients have enrolled for the next regular semester.

ROBERT CAMPBELL GEMMELL MEMORIAL SCHOLARSHIPS. In memory of her brother, Robert Campbell Gemmell, B.S. (C.E.) '84, C.E. '95, M.Eng. (hon.) '13, this scholarship fund was founded in 1926 by Mrs. Lillian Gemmell Boal (Mrs. S. H. Boal) of Oakland, California, by a gift to the University of $10,000. It is available for freshman or sophomore students in the College of Engineering who are of general worthiness and deserving character. These scholarships are awarded in amounts of about $100 each. To be eligible, students must be American citizens, partly or entirely self-supporting, and must have completed a minimum of fifteen hours of work at the University of Michigan with a minimum general average of 2.5. Applications must be filed in the office of the Assistant Dean of the College of Engineering before March 15. The awards are published in May and are paid in full after the recipients have enrolled for their next regular semester.

HARRIET EVELEEN HUNT SCHOLARSHIPS. Established in 1937 by Ormond E. Hunt, B.S. '07, M.E. (hon.) '32, as a memorial to his mother. The income from the fund is distributed in annual awards. To be eligible, students must be American citizens, partly or entirely self-supporting, and must have completed at least forty-five semester hours of work at the

University of Michigan with a minimum average of 2.5. Applications must be filed in the office of the Assistant Dean of the College of Engineering before March 15. The awards will be paid the same as for the Donovan Scholarship.

ALBERT KAHN SCHOLARSHIP. Established in 1941 by gift from Associated Architects and Engineers, Inc., Detroit, through Mr. Albert Kahn. In conformity with the wishes of the donor, the income from this gift of $5,000 is used to provide scholarships for which students in the College of Architecture and Design or the College of Engineering are eligible. Emphasis is placed on the candidate's record as to courses in the mechanical and electrical equipment of buildings. The fund is to be administered by the Dean of the College of Architecture and Design and the Dean of the College of Engineering. Applications should be made at the office of either dean. Students may apply during their sixth semester of residence.

SIMON MANDLEBAUM SCHOLARSHIPS. Established in 1929 by a bequest of the late Mary S. Mandlebaum (Mary S. Mandelle) of Detroit, Michigan, in memory of her father, Simon Mandlebaum. These scholarships are awarded in amounts of about $400 each. To be eligible students must be American citizens, partly or entirely self-supporting, and must have completed a minimum of forty-five hours of work applicable for the degree. They must have been in residence at the University of Michigan for at least one year. Applications must be filed in the office of the Assistant Dean of the College of Engineering before April 1. The awards are published in May and are paid in equal amounts when the recipients have enrolled for the first and second semesters respectively of the following year.

FRANK SHEEHAN SCHOLARSHIP IN AERONAUTICS. Founded in 1929 by Miss Mildred Sheehan as a memorial to her brother, Frank P. Sheehan, a student in the University from 1917 to 1919 and in 1924–25. The income on this gift of $20,000 is used as a scholarship or scholarships for students who intend to follow a career in aeronautics or aeronautical engineering. It is available to students who have completed at least two years' work in the College of Engineering with a grade distinctly above the average. Usually two scholarships are available each year.

MINNIE HUBBARD SMITH REVOLVING FUND. Dispensed as gifts to juniors and seniors in civil engineering. Applications should be made to the Chairman of the Department of Civil Engineering.

LOAN FUNDS

45. The following loan funds have been established especially for the use of engineering students who are in need of aid to complete their studies: Class of 1915 Engineering Loan Fund and Benjamin Sayre Tuthill

Loan Fund, George H. Benzenberg Loan Fund and William J. Olcott Scholarship Loan Fund (not available for freshmen); Class of 1914 Engineering Loan Fund (for seniors, no interest before note matures); Class of 1917 Engineering Loan Fund and the John Frank Dodge Loan Fund (for juniors and seniors); Marian Sarah Parker Memorial Loan Fund (for women); and J. B. and Mary H. Davis Trust Fund (Geodesy and Surveying). These special loan funds, together with a number of all-University funds which are open to students in engineering, are described in the bulletin, *Student Loan Funds,* which is available on request. Applications should be made to the Office of Student Affairs, 1010 Administration Building.

BEQUESTS AND OTHER GIFTS

46. The University of Michigan has in recent years become more and more frequently the recipient of bequests and donations from public-spirited alumni and citizens of Michigan and other states who see in the state university a means of serving the present and the future. Over one-quarter of the University's permanent assets in funds, lands, buildings, and equipment have been contributed. The University has more than one hundred and fifty permanently endowed trust funds. These funds are administered with most scrupulous and precise attention to the terms and conditions laid down by the donors. The University is always desirous to widen its field of service by receiving gifts of funds to be held in trust to provide professorships, scholarships, loans, and other benefits as illustrated by the descriptions of these already existing trust funds. Correspondence on the subject of needs is solicited and will receive prompt, candid replies. Persons desiring to place property in trust permanently for the benefit of education may well remember that "The Regents of the University of Michigan" is a constitutional corporation, the highest form of body corporate known to the law.

The forms of bequest given below are not intended to take the place of the services of a competent attorney in the drafting of a will, but they may be suggestive and stimulating to the mind of a public-spirited citizen who contemplates the making of a will or a gift during his or her lifetime, and they are believed to be in legal form adapted to the inclusion in a will. A form of bequest is as follows:

"I give, devise, and bequeath to The Regents of the University of Michigan

....

....

(here insert the sum or the property bequeathed)

for the following purposes...

(here insert the purpose of the bequest)

In the light of experience, even in so young a country as the United States of America, it is apparent that no one can unmistakably read the future. This fact has resulted in reducing to practical uselessness certain bequests, made in earlier days for purposes then important, to various of the older educational institutions of the country. With the idea of permitting most useful continuance of the benefaction in general accord with the purposes of the donor, even if with the changes of the years the precise original purpose of the gift should prove to be no longer a real need, it is suggested that such a benefaction, the income of which is to be devoted to a specified purpose, might wisely contain a clause similar in general to the following:

In the event that, in the opinion of the said Regents, the needs to meet which this bequest is made should pass out of existence with the passage of time or not require all of the income provided, then the said Regents are hereby expressly given authority and charged with the duty to use the said income or so much of it as in their discretion may seem for the best advantage of the University, for other purposes allied to or in harmony with the spirit and purpose of this bequest as above expressed; or if such approximation of my specific purpose is in the discretion of the Regents inexpedient or impracticable then and in that event the Regents shall use the income for whatever educational or University needs they may see fit, as trustees of the University in general and of this fund in particular, since it is my purpose and intent that the income shall not lie idle and useless but shall be active and useful in contributing currently to the benefit of mankind through education.

Further, modern givers of large sums have in numerous instances taken the grounds (1) that owing to changes in social and economic conditions, no one can foresee the future with sufficient clearness to warrant making any bequest for specific purposes in perpetuity, and (2) that if trustees are competent and worthy to be entrusted with investment of the principal and use of the income, they are competent to use the principal in the light of future social and economic conditions. Should a testator desire to give such discretion to the Regents at the end of a period of years he could do so by use of the following or a similar clause:

If after this bequest shall have been in operation for.................... years or more the Regents within their discretion as trustees shall believe that my general purpose in making this bequest, namely, the benefit of mankind through education, would be better served by the expenditure of both principal and income than by the continued expenditure of the income only, then and in that event the said Regents are expressly authorized and empowered to sell the securities or other property in which such principal shall then be invested, or to sell any part thereof, and to expend the proceeds thereof as may in their opinion at that time be as near as feasible to the purposes hereinabove specified for the best advantage of the University of Michigan in any phase of its then accepted and proper activities.

PART II
NONPROFESSIONAL DEPARTMENTS

STUDIES OF THE FIRST YEAR

47. There is a common first year for all students entering without deficiencies or advanced credits. After the first year, each student indicates the branch of engineering he expects to follow and is then enrolled as a student in that branch.

In the second year there is some variation among the curriculums for the different branches of engineering, though not so great as to make transfers difficult; but in the third and fourth years there are marked differences, and a student transferring from one department to another does so with difficulty and with some loss of time.

Schedules of studies for the second and succeeding years will be found in the section devoted to the various degree-conferring departments.

The schedule of studies for first-year students is as follows:

FIRST SEMESTER

COURSES	HOURS
*Math. 13 (Alg. and Anal. Geom.)	4
English 11 (1)	3
English 21 (2)	1
Drawing 1	3
†Chem. 5E or Ch. and Met. Eng. 1 and Met. Proc. 1	5
Assembly	0
Phys. Ed. or Mil. or Nav. Sci.	0 or 1
	16 or 17

SECOND SEMESTER

COURSES	HOURS
*Math. 14 (Pl. and Sol. Anal. Geom.)	4
English 12 (3)	2
English (Group II)	2
Drawing 2	3
Ch. and Met. Eng. 1 and Met. Proc. 1 or †Chem. 5E	5
Assembly	0
Phys. Ed. or Mil. or Nav. Sci.	0 or 1
	16 or 17

* See footnote, page 134, and description of Math. 17 and 18, section 70.
† See note, section 52. Students planning to take chemical or metallurgical engineering see section 66, first year program.

Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science is elected as a substitute. Enrollment in military science is for a period of four semesters.

The above schedule assumes that the student has presented for admission the full requirement in algebra and geometry, and also trigonometry and chemistry as described in section 10*a*. Should the student have entered without trigonometry or chemistry, or both, the schedule will be modified by substituting Mathematics 7 or 8 for Mathematics 13, and/or Chemistry 1 or 3, first semester, followed by Chemistry 4 or 6, second semester, in place of

Chemistry 5E. The student entering without solid geometry will take Mathematics 6 without credit.

If admission requirements have been fully met on entrance, the trigonometry described in section 10*a* and Chemistry 1 or 3 taken in college will give credit toward graduation as nontechnical subjects. See section 29.

The classifier in consultation with the student will arrange a schedule intended to adjust the irregularities as quickly as possible. Students are required to remove all deficiencies, with the exception of physics, during this first year, unless granted an extension of time. See section 28.

NONPROFESSIONAL COURSES

48. In the following sections are listed courses given entirely, or primarily, for students in engineering, and in addition those courses which they frequently elect. For other courses see the *Announcements* of the College of Literature, Science, and the Arts, the School of Business Administration, and others.

A student may elect a course in another college if it is listed in any engineering curriculum, but he is usually required to secure the approval of the deans if the course is not intended for engineers. Approval is denied if the student's preparation for the course is deemed inadequate.

In addition to those listed below, there are many other departments in which engineering students may elect courses. The College of Engineering also receives students from other colleges of the University.

The Roman numeral indicates the semester in which the course is given: the first semester—I, the second semester—II. The italic numeral enclosed in parentheses indicates the number of hours credit for the course: (*3*) denotes three hours credit.

49. ASTRONOMY

Professors Goldberg, McLaughlin, and McMath*; Associate Professors Aller, Miller, Mohler,* and Rossiter†; Assistant Professors Dodson and Losh; Dr. Pierce; Mr. Bauer.

A full list of the courses offered by the Department of Astronomy may be found in the *Announcement* of the College of Literature, Science, and the Arts. Those which may be of particular interest to engineering students are listed below:

* At the McMath-Hulbert Observatory of the University.

† Professor Rossiter is in charge of the Lamont-Hussey Observatory of the University of Michigan, Bloemfontein, Orange Free State, South Africa.

EXCLUSIVELY FOR UNDERGRADUATES

11. Introductory Astronomy: The Solar System. *Prerequisite: two years of high-school mathematics or Math. 7, which may accompany Astron. 11.* I and II. (*4*).

An elementary discussion of the methods and tools of the astronomer and the results obtained by applying them to the solar system. Three lectures and one three-hour laboratory period each week.

12. Introductory Astronomy: Stars, Nebulae, and Galaxies. *Prerequisite: Astron. 11.* I and II. (*4*).

A continuation of Astronomy 11. The universe beyond the limits of the solar system as revealed by modern astronomical research. Three lectures and one three-hour laboratory period each week.

30. The Solar System and the Universe. *Not open to first-semester freshmen nor to students who have taken Astron. 11 or 12.* I and II. (*3*) McLaughlin and Miller.

Lectures on the methods and results of astronomical exploration. The present status of knowledge of the heavenly bodies and their organization. The relation of astronomy to other sciences. Man's place in the universe. For students not enrolled in Astron. 33, observing periods of one hour are held weekly.

61. Practical Astronomy. *Prerequisite: four hours of astronomy and one semester of calculus.* I. (*4*) Miller.

Theory of determination of time, latitude, longitude, azimuth, and stellar positions by visual methods. Least squares and interpolation. Observation with the transit, zenith telescope, sextant, and equatorial. Three lectures and one laboratory period weekly.

73. Advanced General Astronomy. *Prerequisite: Phys. 25 and 26 and one semester of calculus.* I. (*3*) Bauer.

Selected mathematical and physical principles forming the basis of modern astronomy.

74. Advanced General Astronomy. *Prerequisite: Astron. 73.* II. (*3*) Bauer.

Continuation of Astron. 73.

103. History of Astronomy. *Prerequisite: Astron. 11 and 12 or 30 or equivalent.* I. (2) Losh.

A history of astronomy from the dawn of science, treating especially of its modern development.

104. Development of American Astronomy. *Prerequisite: Astron. 103.* II. (2) Losh.

A study of the progress of astronomy in the United States.

50. BACTERIOLOGY

Professors Soule and Nungester; Assistant Professors Lofgren and Lawrence; Dr. Kempe.

51. General Bacteriology. *Prerequisite: Chem. 4.* I. (*4*).

Deposit, $5.00. The classification, morphology, multiplication, and distribution of bacteria, their requirements for growth and their chemical products. The principles of sterilization and disinfection are brought out, and special emphasis is given to their practical application. Techniques of pure culture study are developed and extended to include consideration of the yeasts and molds.

105. Water Analysis. First half of I. *(2)*.

Open to students of sanitary engineering and to others who are qualified.

105*a*. Special Problems on Water Analysis. I and II. *(To be arranged.)*

110. General Bacteriology. *Prerequisite: Chem. 53.* II. *(4)*.

Lectures and recitations. Qualified students from all schools and colleges may elect this course as it is the only lecture course offered by the department.

111A. Practical Bacteriology. *Prerequisite: Chem. 53.* I. *(3)*.

A laboratory course open to students other than those of the Medical School.

151. Physiology of Bacteria. *Prerequisite: Bact. 51 or 111A and Chem. 53.* II. *(3)*.

Deposit, $5.00. Lectures, demonstrations, and laboratory work dealing with bacteria and their environment. Studies of growth, death, nutrition, and microbic fermentations are included.

160. Microbiological Engineering. *Prerequisite: Chem. 53 desirable.* II. *(3)*.

Deposit, $5.00. Introductory lecture and laboratory work to acquaint the chemical engineer, chemist, and sanitary engineer with bacteriology and the more specialized fields of sanitary bacteriology, industrial waste treatment, and fermentations.

51. BUSINESS ADMINISTRATION

Professors Stevenson, Griffin, Paton, Rodkey, Jamison, Blackett, Tracy, E. H. Gault, Riegel, Waterman, Wolaver, Dixon, and others.

The courses listed below are deemed to be 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. *(4)*.
12. Principles of Accounting. *(4)*.
51. Principles of Marketing. *(3)*.
61. Money and Banking. *(3)*.
62. Financial Principles. *(3)*.

105. Business Law: Contracts. (*3*).

106. Business Law: Organizations and Securities. (*3*).

111. Industrial Cost Accounting. (*3*).

124. Statistical Method for Engineers. (*3*).

141. Production Management. (*3*).

142. Industrial Relations. (*3*).

52. CHEMISTRY

Professors Schoepfle, Willard, Bartell, Fajans, Bachmann, Ferguson, Anderson, Halford, and Brockway; Associate Professors McAlpine, Soule, Hodges, and Case; Assistant Professors Carney, Meloche, Weatherill, Keller, Westrum, and Smith; Dr. Parry, Dr. Rondestvedt, Dr. Vaughan, and Dr. Templeton.

The aims of the fundamental course in general chemistry, required of all engineering students, are primarily the development of a scientific attitude and the acquisition of such chemical facts as form a part of the store of knowledge of any well-informed person. Further courses in analytical, organic, and physical chemistry are required of students in chemical and metallurgical engineering.

The Chemistry Building provides excellent facilities for the work of all the schools and colleges of the University. Lecture rooms and classrooms, laboratories for class instruction and individual research, a fully equipped stock room, and the chemical library which contains about thirteen thousand volumes and is especially rich in complete sets of journals; 115 journals are currently received.

1. General and Inorganic Chemistry.* I and II. (*4*).

An 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*).

An 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*).

A continuation of Chem. 1 or 3 designed for students who are planning to take one or more further courses in chemistry. Students in engineering who are not planning to enter the curriculum in Chemical and Metallurgical 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 work.

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*

* Engineering students entering without chemistry will elect Chem. 1 and 4 or 6. Those presenting an approved unit of chemistry for entrance will take Chem. 5E unless advised to elect Chem. 3 and 4 or 6 as a result of the Orientation Period examination. All students satisfactorily completing the work will be allowed credit for Chem. 1 or 3 as a nontechnical elective.

or 3, credit for which will be counted as a nontechnical elective, followed by Chem. 4 or 6. I and II. (*5*).

The fundamental principles of chemistry and a study of the more important elements and compounds, omitting the common nonmetallic elements. Two lectures, two recitations, and six hours of laboratory work.

6. GENERAL CHEMISTRY. *Prerequisite: Chem. 1 or 3.* II. (*4*).

A continuation of Chem. 1 or 3 designed for students who are planning to take no further courses in chemistry. This includes all engineering students except those planning to enter the curriculum in Chemcial and Metallurgical 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.

21E. GENERAL AND ANALYTICAL CHEMISTRY. *Prerequisite: Chem. 5E or 4, or equivalent.* I and II. (*4*).

Includes systematic qualitative analysis for the more important metals and acids, the principles of chemical equilibrium, and the simpler methods of volumetric analysis. Three lectures or recitations and two three-hour laboratory periods.

41. QUANTITATIVE ANALYSIS. *Prerequisite: Chem. 21E.* I and II. (*4 required, may be taken for 5*).

Includes the study of gravimetric, volumetric, and electrolytic methods, and the analysis of limestone and brass. The solution of stoichiometric problems is emphasized. Two recitations and three four-hour laboratory periods.

53. ORGANIC CHEMISTRY. *Prerequisite: Chem. 5E or 4, or equivalent.* I and II. (*4*).

Intended for students who desire a more elementary course than Chem. 67E and 169E. Four lectures or recitations.

67E. ORGANIC CHEMISTRY. *Prerequisite: Chem. 21E.* I and II. (*3*).

An elementary course covering only aliphatic and alicyclic compounds. Should be followed by Chem. 169E. Lectures and recitations.

83E. ELEMENTARY PHYSICAL CHEMISTRY. *Prerequisite: Chem. 21E or its equivalent, Phys. 46, and a knowledge of calculus.* I and II. (*4*).

The fundamentals of physical chemistry including an elementary exposition of the states of matter, solutions, chemical equilibrium, the phase rule, chemical kinetics, thermo- and electro-chemistry, atomic theory, and molecular structure. Three lectures and two recitations.

141. ADVANCED QUANTITATIVE ANALYSIS. *Prerequisite: Chem. 41 and Phys. 36.* I and II. (*4–5*).

The analysis of iron and other ores, a silicate rock, ferrous and nonferrous alloys. A study of special methods and reagents, and the reactions of all the elements. Lectures and quiz, twice a week; laboratory, two or three periods a week.

169E. ORGANIC CHEMISTRY. *Prerequisite: Chem. 67E.* I and II. (*5*).

A continuation of Chem. 67E, covering aromatic compounds. Lectures, recitations, and laboratory.

171. ELECTROCHEMISTRY. *Prerequisite: Chem. 83E.* I. (*2*).
An elementary treatment of the fundamentals of the subject. Two lectures.

185, 186. PHYSICOCHEMICAL MEASUREMENTS. *Prerequisite: preceded or accompanied by Chem. 41 and 83E.* 185, I and II; 186, I and II. (*2 each*).
Methods for the determination of molecular weight, viscosity, surface tension, reaction rate, solubility, etc., optical measurements with polarimeter, refractometer, spectrometer. Laboratory work.

188. PHYSICAL CHEMISTRY. *Prerequisite: Chem. 4 or 5E, 21E, and calculus.* II. (*4*).
The 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. 83E and 141.* II. (*2*).
Lectures and laboratory work.

255. ADVANCED ORGANIC CHEMISTRY. *Prerequisite: Chem. 169E.* I. (*2*).
The commercial preparation of intermediates and dyes, and certain topics in the theory of organic chemistry. Two lectures and reading.

256. ADVANCED ORGANIC CHEMISTRY. *Prerequisite: Chem. 169E.* II. (*2*).
The industrial application of some catalytic processes, and the synthesis of plastics, rubber, fibers, etc. Two lectures and reading.

285. PHYSICOCHEMICAL MEASUREMENTS. I and II. (*1–4*).
A continuation of Chem. 185, 186. Includes electrical measurements such as conductivity, transport numbers, and electromotive force, work with the hydrogen electrode, experiments with colloids, and the determination of some of the more important physicochemical constants.

291. COLLOID CHEMISTRY. *Prerequisite: permission of the instructor.* I. (*2*).
The fundamental principles. Two lectures.

294. COLLOID CHEMISTRY LABORATORY. *Prerequisite: preceded or accompanied by Chem. 291.* II. (*2*).
An application in the laboratory of the principles of colloid chemistry. Laboratory work.

53. ECONOMICS

Professors Sharfman, Paton, Remer, Dickinson, Elliott, Watkins, Haber, Peterson, Adams, and Ford; Associate Professors Ackley and Musgrave; Assistant Professors Palmer and Patterson; Mr. Anderson, Mr. Levinson, Mr. Suits, Mr. Dieckman, Mr. Dowd, Mr. Myslicki, Mr. Smith, Mr. Stevens, and others.

Economics 53 and 54 are introductory courses designed especially for students in the College of Engineering and are prerequisites to the election by engineering students of the more advanced courses in the Department of Economics listed below. However, upperclassmen 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. *Econ. 53 is a prerequisite to Econ. 54.* 53, I and II; 54, I and II. (*3 each*).

For students of the College of Engineering and of Architecture and Design and other professional schools and colleges. Offers a 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. Not open to freshmen.

71, 72. ACCOUNTING. *Econ. 71 is a prerequisite to Econ. 72.* 71, I and II; 72, I and II. (*3 each*).

The concepts and procedures of accounting from the standpoint of investors and business management. Not open to freshmen.

101, 102. MONEY AND CREDIT. *Prerequisite: Econ. 53 and 54. Econ. 101 is a prerequisite to Econ. 102.* 101, I and II; 102, I and II. (*3 each*).

Deals with the nature and functions of money and banking and gives attention to war and postwar monetary problems.

121, 122. LABOR. *Prerequisite: Econ. 53 and 54. Econ. 121 is a prerequisite to Econ. 122.* 121, I and II; 122, I and II. (*3 each*).

The background and development of the American labor movement. Considers problems of workers, including insecurity and wages; union history, organization, policies; personnel management; labor legislation.

123. SOCIAL SECURITY. *Prerequisite: Econ. 121 or permission of instructor.* I. (*3*).

The application of the principles of social insurance to the problems of economic insecurity; unemployment compensation, old age and survivors' insurance, and health insurance. Considers federal and state legislation and current proposals.

131. CORPORATIONS. *Prerequisite: Econ. 53 and 54. I.* (*3*).

A study of large enterprises and especially of 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*).

The nature and problems of the transportation industry from the standpoint of government regulation.

134. PUBLIC UTILITIES. *Prerequisite: Econ. 53 and 54.* II. (*3*).

The nature and problems of the public utility industries from the standpoint of government regulation.

153. MODERN ECONOMIC SOCIETY. I and II. (*3*).

A brief survey of economic principles and their application to questions of public policy. For seniors and graduates who have had no course in economics and who desire one semester of work in the subject. Does not admit to advanced courses.

173. FUNDAMENTALS OF ACCOUNTING. I and II. (*3*).

A survey course which emphasizes cost determination and financial statements. Not open to students who have had Economics 71.

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*).

An introduction to the principal methods of statistical analysis as applied to economic problems.

181. Public Finance. *Prerequisite: Econ. 53 and 54.* I. (*3*).

A study of the principles and problems of government finance—federal, state, and local.

54.
ENGLISH

Professors Brandt, Thornton, Burklund, and Walton; Associate Professors Brackett and Egly; Assistant Professors Britton, McEwen, McClennen; Mr. Mack, Mr. Senseman, and Mr. Sawyer.

The work in English aims to prepare the student to speak and write effectively and to develop in him a genuine interest in reading as a means of enlarging his fund of ideas and enriching his background. Throughout his four years he is therefore afforded a liberal choice of courses in composition, both written and oral, and of courses in the appreciation and critical reading of literature.

General requirements. All students of the College of Engineering are required to take ten hours of English. Regularly, they will take English 11 (1) and 21 (2) in their first semester, and English 12 (3) in their second semester, with one of the two-hour courses listed in Group II. In addition, they must take, in their junior or senior year, a two-hour course chosen from Group III. Students in civil engineering must take English 136 (6) for their upperclass requirement.

Any student who fails to maintain a satisfactory standard of English in any course in the College of Engineering is reported to the office of the Assistant Dean. The Assistant Dean refers the case to the Department of English for study and recommendation. The report of the department is made to a special committee composed of the Assistant Dean, the chairman of the student's department of specialization, and the chairman of the Department of English. This committee may require the student to elect further work in English or may prescribe such other study as shall be deemed necessary.

Grouping of courses. Groups I and II include courses which satisfy the freshman requirement. Group II offers, also, nontechnical electives in public speaking, composition, and contemporary literature to all students who have satisfied the freshman requirement. Group III offers courses to satisfy the upperclass requirement. Junior, senior, and graduate students may also take courses in this group as nontechnical electives.

Library facilities. The English Department has a special collection of several thousand volumes, which is at present situated in the Chemical Engineering Library on the third floor of the East Engineering Building.

GROUP I

English 11 (1), 12 (3), and 21 (2) 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.

11 (1). THEME WRITING. I and II. (*3*).

An introductory course in composition and the study of literature. Prepared themes; frequent impromptus; readings in essays, prose fiction, drama, and poetry. This course is a prerequisite for all courses in English except English 21.

12 (3). EXPOSITORY WRITING. *Prerequisite: English 11 and 21.* I and II. (*2*).

A continuation of English 11 with special emphasis on the longer composition.

21 (2). ORAL EXPOSITION. I and II. (*1*).

A practice course in public speaking which must be taken with English 11. Written outlines, extemporaneous and impromptu speaking, informal debates, and other oral exercises. Two hours of classwork.

GROUP II

One of these courses must be elected to complete the freshman requirement; the others give credit as nontechnical electives. Three to five papers, besides impromptus, are required. *Prerequisite: English 11 and 21.*

31 (8). ADVANCED COMPOSITION. (*2*).

For students who desire special practice in the various forms of composition.

41 (4). PUBLIC SPEAKING FOR ENGINEERS. (*2*).

The problems of organization, illustration, and effective presentation in public address, affording frequent opportunity for practice and class criticism.

46 (5). THE SCIENTIFIC AND TECHNICAL LECTURE. (*2*).

The preparation and delivery of lectures on scientific subjects intended for scientific societies or for popular assemblies; presentation of technical reports and demonstration methods.

51 (20). CONTEMPORARY LITERATURE. (*2*).

Reading and analysis of contemporary prose, fiction, drama, and poetry.

56 (23). THE SHORT STORY. (*2*).

Reading and analysis of short stories from the nineteenth and twentieth centuries.

63 (21). CONTEMPORARY DRAMA.

Representative dramas from Ibsen to the present day.

65 (22). CONTEMPORARY NOVEL. (*2*).

Reading and discussion of outstanding European and American novels from about 1890 to the present.

75 (19). CONTEMPORARY POETRY. (*2*).

The principal British and American poets of the twentieth century. Readings, lectures, and discussions.

GROUP III

These courses, except English 136 (6), which may be elected only by seniors and graduate students, are open to upperclassmen and may be taken for graduate credit, provided that the student has the approval of his department of specialization and completes additional work. A considerable amount of written work is required in all these courses. *Prerequisite: English 11 (1), 12 (3), 21 (2), and one course in Group II.*

136 (6). THE TECHNICAL REPORT. (*2*).
Written and oral exercises, the major assignments to be correlated as closely as possible with the technical work of the student. Open to seniors and graduates only.

141 (7). ARGUMENTATION AND DEBATE. (*2*).
Study of problems most commonly met by engineers in furthering their projects; emphasis on clear thinking and convincing argument; frequent opportunity for extemporaneous presentation of material.

156 (24). THE PROFESSIONAL STUDENT AND HIS READING. (*2*).
Studies in literature in relation to philosophy and the social sciences.

158 (27). THE LITERATURE OF SCIENCE. (*2*).
Review of the writings of eminent scientists—ancient, modern, and contemporary.

161 (30). SHAKESPEARE. (2).
Eight of the principal plays.

162 (25). THE DRAMA. (*2*).
Significant dramas in classical and modern western civilizations.

167 (26). THE NOVEL. (*2*).
Reading and discussion of major works in the prose fiction of the eighteenth and nineteenth centuries.

175 (28). AMERICAN LITERATURE. (*2*).
Reading in the works of representative leaders in American thought.

181 (29). LITERARY MASTERPIECES. (*2*).
Works of exceptional merit in the various literary forms.

55. FORESTRY AND CONSERVATION

Professors Dana, Allen, Graham, Ramsdell, Young, Kynoch, Baxter, and Chase; Associate Professors R. Craig, Jr., and O'Roke; Assistant Professors Patronsky and Carow; Forest Manager Murray.

All forestry courses are given in the Natural Science Building or in the Wood Utilization Laboratory.

31. INTRODUCTION TO FORESTRY. II. (*3*).
Economic and social importance of forestry; character, distribution, management, and utilization of our timber resources; forest influences; relation between forestry and wood technology.

101. TREE IDENTIFICATION AND DISTRIBUTION. *Prerequisite: Bot. 1.* I. (*3*).
Classification, identification, characteristics, and distribution of the more important forest trees of the United States.

108. AERIAL FOREST MAPPING. *Prerequisite: For. 115.* II. (*1*).
Use of aerial photographs in forest mapping and timber estimating.

128. PATHOLOGY OF WOOD. *Prerequisite: permission of instructor.* I and II. (*3*).
Recognition and control of the important agents which cause decay and stain in wood and wood products.

130. FOREST ENTOMOLOGY. *Prerequisite: Zool. 1.* I. (*3*).
Characteristics, life histories, types of injury, and control of insects attacking forest trees and forest products.

154. LOGGING AND MILLING. II. (*3*).
Methods and costs of logging and of lumber manufacture.

158. WOOD-USING INDUSTRIES—PLANT OPERATION. *Prerequisite: For. 160 and 162.* S.S. (*8*).
Studies of design, detailing, and billing; selection and operation of woodworking machinery; plant layout, routing, and scheduling; finishing; packaging and shipping, merchandising.

159. WOOD-USING INDUSTRIES—GENERAL. I. (*3*).
Requirements, processes, and products of the major wood-using industries of the United States.

160. TOOLS OF THE WOOD-USING INDUSTRIES. I. (*3*).
Character and use of the principal tools, both hand and machine, employed in the wood-using industries.

161. MACHINABILITY OF WOOD. *Prerequisite: For. 160.* I. (2).
Action of cutting edges on wood in the process of machining, and power required for their efficient use.

162. STRUCTURE AND IDENTIFICATION OF WOODS I. I. (*3*).
Structure, identification, properties, and uses of North American woods.

163. STRUCTURE AND IDENTIFICATION OF WOODS II. *Prerequisite: For. 162.* II. (2).
Structure, identification, properties, and uses of tropical woods, with special reference to the microscopic structure of woods.

164. PHYSICAL AND MECHANICAL PROPERTIES OF WOODS I. *Prerequisite: Phys. 25 and For. 162.* I. (*3*).
The physical and mechanical properties of woods, and the relation of these properties to their industrial utilization.

165. PHYSICAL AND MECHANICAL PROPERTIES OF WOODS II. *Prerequisite: For. 164.* II. (2).
Continuation of Forestry 164.

166. SEASONING AND KILN DRYING OF WOODS. *Prerequisite: For. 162.* I. (*3*).
Air drying, kiln drying, and chemical seasoning of woods by various methods.

167. DESIGN OF WOODWORKING MACHINERY. *Prerequisite: For. 160, 162, and 164.* II. (*3*).
Analysis of commercial woodworking machinery from the standpoint of strength, safety, and efficiency; study of bearings and lubrication; problems in calculation of strength required in various parts of woodworking machines; drawing of machine parts.

169. PROTECTION OF WOOD FROM DESTRUCTIVE AGENCIES. *Prerequisite: For. 162.* II. (*3*).
Protection of wood from destruction or deterioration, particularly by decay, fire, and insects.

170. LUMBER GRADING AND SPECIFICATIONS. *Prerequisite: For. 162.* I. *(3)*.

American lumber standards and their application, including actual practice in lumber grading and identification, and in the drafting of bills of materials and specifications.

172. PLYWOOD AND LAMINATED CONSTRUCTION. *Prerequisite: For. 162.* II. *(4)*.

Manufacture, properties, and utilization of plywood, including the choice and use of adhesives.

174. DESIGN AND CONSTRUCTION OF CONTAINERS. *Prerequisite: For. 162.* II. *(2)*.

Kinds, characteristics, and handling of materials used in containers; principles of container design and construction.

176. FOREST ECONOMICS. *Prerequisite: Econ. 51, 53, or 153.* II. *(3)*.

Economic principles and problems involved in the handling of forest lands and in the utilization and distribution of forest products.

182. FOUNDATIONS OF FOREST MANAGEMENT. *Prerequisite: For. 115.* I. *(3)*.

Preparation and revision of forest working plans.

183. FOREST VALUATION. *Prerequisite: For. 182.* II. *(3)*.

Methods of appraising the value of forest properties; appraisal of damages; forest taxation and insurance; determination of the right use of land.

185. FOREST INDUSTRY ECONOMY. I. *(3)*.

Economy in productive enterprise; measuring the output of men and machines; bonus, task, and piece-rate systems of payment; selection of logging methods and equipment; planning for minimum cost in logging operations.

191. FOREST POLICY. I. *(3)*.

Development of federal, state, and private forest policies; forest resources and products, and their place in the economic and social life of the nation.

194. CONSERVATION OF NATURAL RESOURCES. I and II. *(3)*.

Natural resources of the United States in soil, forests, minerals, and water; their contribution to the economic and social development of the country.

196. SMALL FOREST INDUSTRY MANAGEMENT. *Prerequisite: For. 182.* II. *(3)*.

Rounds out, correlates, and supplements the material contained in the other basic courses offered by the School, with special reference to the analysis, interpretation. and presentation of data.

367, 368. GRADUATE SEMINAR IN LAND UTILIZATION AND LAND-USE PLANNING. *Prerequisite: permission of committee.* I and II. *(2 or 3)*.

Designed for students whose academic program or field experience has brought them in contact with problems of land utilization and land-use adjustment in the United States, and who wish to pursue the subject more intensively. The seminar will survey the field from various viewpoints and the student will pursue a problem of his choosing with the approval and direction of a faculty committee headed by Willett F. Ramsdell, George Willis Pack Professor of Forest Land Management, to whom application for admission to the seminar should be submitted.

56. GEOLOGY

Professors Landes, Ehlers, Hussey, Eardley, and Kellum; Associate Professors Turneaure, Belknap, and Senstius; Assistant Professors Hibbard, Wilson, Stumm, and Sinclair; Dr. Walker, Mr. Strong, and others.

The Department of Geology is in the Natural Science Building, occupying the four floors of the northern half of the eastern front of the building.

11. Introductory Geology. I and II. *(4)*.

A general course leading to an understanding of the principles of physical and structural geology, required of students of civil engineering, and open to others as an elective. Lectures, recitations, laboratory, and excursions.

For other courses in geology to which students of engineering are eligible, see the *Announcment* of the College of Literature, Science, and the Arts. It is suggested that Geology 12 (Historical Geology), 131 (Soil Geology), and 40 (Economic Geology) are especially useful courses for engineering students.

SUMMER SESSION

Geology 11 is given at Camp Davis, Wyoming.

57. MECHANISM AND ENGINEERING DRAWING

Professors Miller, Finch, and Palmer; Associate Professors Hobart, Cole, Orbeck, and Potts; Assistant Professors Clark, Eichelberger, Smith, Lake, Heppinstall, Bittinger, Hoisington, Sr., Hoisington, Jr., Lipphart, Douglas, VanAntwerp, Nielsen, and Scott.

Engineering Drawing 1, 2, and 3 comprise the total course in engineering drawing in the four-year curriculum. The content of these three courses has been arranged to include elementary engineering drawing and descriptive geometry. The emphasis is on the language of drawing, on exposition by orthographic projection from form concepts, and on translation of orthographic projection into form concepts or reading a drawing. It is the thorough mastery of the language of drawing which the engineering student here acquires for his courses in design, laboratory demonstrations, and later professional service.

1. Elementary Engineering Drawing. I and II. *(3)*.

The principles of orthographic projection; practice in the making of working drawings; correct drafting-room practice in conventional representation; the use of instruments; practice in lettering: freehand for dimensions and notes, and mechanical for titles; reading and checking of drawings; drill on geometric construction; instruction on blue and brown printing; practice in tracing; original drawing on tracing papers. Three two-hour drafting-room periods, three hours homework a week.

2. Descriptive Geometry. *Prerequisite: solid geometry and Eng. Draw. 1.* I and II. *(3)*.

Outlined, and problems chosen to accomplish the principal purpose of developing working facility in solving the five basic geometrical problems of engineering. These are the 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. Since these are vital problems in engineering design, it has been felt wise to shape the subject of this course to the purpose. At the same time the principles of technical descriptions of engineering projects are covered. Three two-hour drafting-room periods, three hours homework a week.

3. ADVANCED ENGINEERING DRAWING. *Prerequisite: Eng. Draw. 1 and 2.* I and II. (*2*).

Instruction includes engineering sketching of models in orthographic, isometric, and oblique projection; practice in making of working drawings from sketches; sketching of engineering ideas and plans; the principles of land plats, contours, and profiles; the principles of graphical presentation of facts; structural drafting; practice in reading of drawings by analysis of structures. Two two-hour drafting-room periods, two hours homework a week.

11. ENGINEERING DRAWING. II. (*1*).

Elementary drawing for forestry students. Use of instruments, geometric constructions, lettering practice, orthographic projection, dimensioning, and elementary working drawings. Drawing assignments are taken as far as possible from subject material with which the forestry student will later have contact. One three-hour drawing 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.

58. METAL PROCESSING

Professor Boston; Associate Professors Gilbert and Colwell; Assistant Professors McKee, Rote, Spindler, Truckenmiller, and Wagner; Mr. Holmes, Mr. Burgess, Mr. Conger, Mr. Pierce, Mr. Smith, Mr. Sowa, and Mr. Telfer.

The object of the courses in metal processing is to acquaint engineering students with fundamental principles, modern methods, and industrial applications relating to all phases of metal processing. Metallurgy, design, and methods of fabricating materials are correlated with manufacturing processes.

The Metal Processing Laboratories occupy four floors in the center wing of the East Engineering Building. Classrooms and locker rooms are arranged adjacent to the laboratories. An electric freight elevator serves all floors. Materials, such as sands, refractories, coke, iron and steel scrap, and pig iron, are stored in rooms under the court of the building.

MACHINE TOOL LABORATORY, with a floor area of 9,000 square feet on the first floor, has been arranged to demonstrate machines, tools, and methods using the two types of machine shop processes, namely, tool room and production. This laboratory has been equipped with more than one hundred modern types of machines embracing the latest features of design and construction. They are powered with the most recent developments in electrical, mechanical, and hydraulic drives and controls.

MACHINABILITY LABORATORY, on the second floor, contains drill presses, tappers, lathes, and millers equipped with dynamometers, potentiometers, wattmeters, and special instruments to study problems of machinability and metal cutting. Equipment for metallographic work, hardness inspection, surface finish studies, and vibration testing is also available. An adjacent room contains fifteen types of tool and cutter grinders.

DESIGN ROOM on the second floor will accommodate eight students at a time majoring in tool, jig and fixture, die, and gage design, machine tool design, and other phases of tool engineering.

UNIVERSITY INSTRUMENT SHOP, on the second floor at the east end, is equipped for fine instrument work. Research and special apparatus for the University is constructed. This work is handled by a permanent staff of instrument makers and is independent of instruction given to students.

METAL WORKING, TREATING, WELDING, AND PHYSICAL TESTING LABORATORY, 60 by 100 feet, on the third floor, is equipped with tensile, bend, and universal testing machines of both mechanical and hydraulic types; laboratory and production types of hardness testers; gas fired and electrically heated furnaces of many types for heat treatment of metals and alloys; induction and flame hardening equipment; AC and DC arc welders; gas welding and cutting equipment; hydrogen and helium arc welders, and electric resistance, spot, seam, and gun welders for both steel and aluminum; mechanical and air operated forging hammers and allied heating equipment, and controls are available for the study of hot and cold worked metal.

FOUNDRY LABORATORY. A combination jobbing and production foundry is operated in the 60 by 130 foot laboratory on the fourth floor. Molds are produced by floor, bench, or production machine operations. Melting is done in a 36-inch cupola, a 200-pound indirect arc furnace, a 200-pound high-frequency induction furnace, and a 100-pound gas-fired crucible furnace. Core making, cleaning, sand testing, and metal testing facilities are also available in the foundry. Additional equipment for vacuum melting and casting, metallographic studies, and chemical analysis is available in supplementary foundry laboratories.

GAGING AND MEASURING LABORATORY, 1,800 square feet, is situated in Rooms 2300 and 2311 on the second floor, center wing of the East Engineering Building. This laboratory contains equipment to illustrate the use, operation, and design of measuring and inspection instruments. For making measurements of forms, angles, and sizes there are available devices of almost every type, such as surface plates, projectors, comparators, standard centers, master blocks, sine-bar fixtures, and microscopes. It contains the equipment of the War Department's Detroit Ordnance District Gage Laboratory, in addition to that owned by the University.

1. ENGINEERING MATERIALS AND PROCESSES (CH. and MET. ENG. 1). *Prerequisite: an acceptable high-school course in chemistry or Chem. 3.* (*5*).

Metals, alloys, cement, clay products, protective coatings, plastics, fuels, and water; processes of forming: pressing, forging, rolling, welding, casting; testing of materials: hardness, tensile, compressive, bending, impact. Two lectures, three recitations, three hours laboratory. Required of all engineering students.

3. FOUNDRY (CH. and MET. ENG. 3). *Prerequisite: Metal Proc. 1.* (*4*).

A study of the principles and practice relating to the production of gray iron, malleable iron, steel, brass, bronze, and aluminum castings and their application. The constitution and properties of molding sands, core sands, and metal are considered in detail. Principles of design, risering, and gating also are discussed. Attention is given to the inspection, welding, and heat treatment of castings. Two recitations and two three-hour laboratory periods a week.

4. MACHINE SHOP. *Prerequisite: Metal Proc. 1 (Ch. and Met. Eng. 1) and Eng. Mech. 2. (4)*.

Planned, with laboratory, to give the student a clear conception of the relation between design, fabricated form and type of material, and manufacturing processes used in the production of parts in small, intermediate, and large quantities. Studies are made of all types of metal cutting and forming operations and their machines, tools, and accessories. Two recitations and two three-hour laboratory periods a week.

5. MACHINE SHOP I. *Prerequisite: Metal Proc. 1 (2)*.

A survey course in the use of metal cutting tools, machine tools, and accessories. The composition, preparation, and application of cutting tools, cutting fluids, and the properties of the materials worked are correlated with cutting speeds and feeds for efficient production. The laboratory work gives the student an opportunity to observe the use and design of basic machine tools and to apply the above principles to their operation. One recitation and one three-hour laboratory period each week.

9. FOUNDRY (CH. and MET. ENG. 9). *(2)*.

The principles, practice, and equipment used in molding, coremaking, melting, and cleaning of castings are studied both in the classroom and laboratory. Assignments also cover molding sand and cores, casting design, gating and risering. For students in metallurgical engineering. Two lectures and one three-hour laboratory period a week.

102. ADVANCED WORKING, TREATING, AND WELDING OF STEEL. *Prerequisite: Metal Proc. 1 (Chem. and Met. Eng. 1) and Chem. and Met. Eng. 107 or their equivalent. (2)*.

Further work on these subjects may be elected by students interested in steel treatment and processing. Two recitations a week.

103. ADVANCED FOUNDRY. *(3)*.

For those students who are especially interested in the foundry branch of engineering, advanced foundry instruction is offered on special problems. Arrangements are to be made with the instructor.

104. ADVANCED MACHINE SHOP. *Prerequisite: Metal Proc. 4. (3)*.

Provides an opportunity for a student to specialize in one or more machine shop processes of his particular interest. Provisions are made for advanced studies in production equipment such as automatic screw machines, production lathes, gear-processing machines, various types of bore-finishing machines, and production milling machines. Some machines of a tool-room type, involving highly developed operative skills, such as a thread grinder, jig-mill, and die-sinker may be included in this advanced study. Some students may process and produce a device of their own design. Arrangements are to be made with the instructor.

105. WELDING. *Prerequisite: permission of the instructor. (2)*.

A study of welding applications as to costs, shrinkage, stresses, distortions, and the weldability of metals; laboratory assignments include (1) arc welding.

(2) resistance, butt, spot, seam, and gun welding, (3) submerged arc, heli arc, and atomic hydrogen welding, (4) oxy-acetylene welding. One recitation and one three-hour laboratory period a week.

106. FOUNDRY COSTS AND ORGANIZATION. *Prerequisite: Metal Proc. 3. (2).*

A study of foundry costs methods, foundry records, and standard instructions for foundry operations. Lectures and assignments.

108. JIGS, FIXTURES, AND MACHINING TOOLS. *Prerequisite: Metal Proc. 4; Metal Proc. 111 is desirable. (2).*

A study is made of factors involved in large-quantity production by the machining processes. Machine tools and their uses, the application of theories of machinability to cutting practice, and the design of jigs, fixtures, and small tools are reviewed. Preliminary design computations and cost estimates are made. Two lectures and one two-hour design period a week.

109. MACHINABILITY. *Prerequisite: Metal Proc. 4. (3).*

Advanced studies are made of metal cutting from theoretical and practical viewpoints with reference reading and selected laboratory experiments. Experimental data on tool forces, power, tool life, rate of production, and surface quality are compiled into charts, slide rules, and mathematical equations so as to be of value in practice. One recitation and two three-hour laboratory periods a week.

110. MATERIALS FOR AIRCRAFT CONSTRUCTION (AERO. ENG. 140). *Prerequisite: Metal Proc. 4 and Aero. Eng. 101. (2).*

Designed for aeronautical engineering students to acquaint them with materials used in the design of aircraft. Numerous materials are studied as to their processing, costs, physical and chemical properties, and the thermal and chemical treatment best suited for resistance to corrosion, high strength-weight ratio, and ease of processing. One class and one three-hour laboratory period each week.

111. MEASURING AND GAGING. *Prerequisite: Metal Proc. 4 or 5. (2).*

Standards of measurement, mechanical dimensional control, equipment and methods used in measuring and gaging in manufacture, and statistical methods for quality control are studied. The facilities of the Measuring and Gaging Laboratory are available for practice. One recitation and one three-hour laboratory period each week.

112. PARTS PROCESSING. *Prerequisite: Metal Proc. 4 and approval of the instru tor. (3).*

Based on the subject matter of all previous metal processing courses. Complete routings are made for each of several selected parts which are to be manufactured in accordance with a given schedule. Each routing will cover 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 will be selected. The time of each operation will be computed, based on speeds, feeds, handling time, etc., and the number of machines for each operation determined. These machines can then be laid out in accordance with a systematic flow of material from rough stock to finished subassemblies and final assemblies, and a complete analysis of manufacturing cost is made.

115. MACHINE SHOP II. *Prerequisite: Metal Proc. 5.* (*2*).

A study is made of the design, operation, and use of machine tools devoted to job shop, semiproduction, and mass production. The relation between product design, metallurgy, and the fabricating processes is established. Fits, surface quality, and production costs are also studied. Two recitations and one three-hour laboratory period each week.

181. THE DESIGN OF MACHINE TOOLS (MECH. ENG. 181). (*3*).

See Mechanical Engineering.

59. MILITARY SCIENCE AND TACTICS

Professor Henion; Assistant Professors Ainsworth, Kiehl, McKelvey, Niccolls, Porter, Johnston, Merten, Rogers, and Stiles.

INFORMATION AND CONSULTATION. The office of the department is in the ROTC Building at 512 South State Street where members of the department are available for consultation and assistance.

Regularly enrolled students, who are physically qualified male citizens of the United States, are offered instruction in one of the six branches of the United States Army and two specialized fields of the United States Air Force. Upon successful completion of the course, the student is offered a commission as a second lieutenant in the branch or service for which his training has fitted him, except Medical Corps and Dental Corps, where the student is offered a commission as first lieutenant. Distinguished military students of the ROTC are offered direct commission in the Regular Army and Regular Air Force.

The Selective Service Act (Public Law 759—80th Congress) authorizes the Secretary of the Army and the Secretary of the Air Force to defer selected ROTC students from the draft until they have completed their ROTC training and four years of college. The number of deferments granted each ROTC unit is based on quotas assigned by the respective secretaries. Selection, based on competitive examinations, is made by the Professor of Military Science and Tactics. A student certified for deferral under this law must agree in writing to serve two years on active duty as an officer upon completion of his college training if ordered to do so by the Secretary of the Army or Secretary of the Air Force. Except for this provision, a reserve officer is not subject to active duty without his consent, except in time of national emergency. He may, however, increase his military knowledge, and qualify for promotion through Army extension courses or active duty training.

PAY AND ALLOWANCES—SUMMER CAMP. Pay and allowances begin with enrollment in the third year of the military science course and amount to approximately $290 for each of the last two years. In addition, the student receives approximately $112.50 plus all expenses for the six-week summer camp held between the third and fourth years of the military science course.

UNIFORMS. All ROTC students are furnished an officer's type uniform without charge.

CREDIT FOR PREVIOUS MILITARY TRAINING OR SERVICE. For information as to credit allowed for previous military training or service, students should consult the Department of Military Science and Tactics. In general, however, credit may be allowed on the following basis:

a) For twelve or more months' service, credit not to exceed the first two years of senior division ROTC (first two years of college ROTC course).

b) For six to twelve months' service, credit not to exceed first year of senior division ROTC (first year of college ROTC course). Less than six months' service carries no credit toward ROTC courses.

c) For not less than three years of junior ROTC, credit not to exceed the first year of senior division ROTC (first year of college ROTC course).

GENERAL. Six branches of the Army and two specialized fields of the Air Force are represented at the University. These branches of the Army are Dental Corps, Infantry, Medical Corps, Ordnance Department, Quartermaster Corps, and Signal Corps. Students are encouraged to select the course most closely related to their major field of specialization so that their civilian postgraduate experience may receive military recognition.

The first year of training is devoted primarily to subjects common to officers of all branches of the service. The last three years of the course involve specialized training in the technical and tactical skills of the branch in which the student enrolls.

EXTRACURRICULAR ACTIVITIES. *Photography*. The Signal Corps maintains a complete set of photographic equipment, including a developing laboratory. These facilities are available to ROTC students who are interested in photography.

Amateur Radio. An amateur radio station is operated under the joint sponsorship of the Electrical Engineering Department and the Signal Corps section of the ROTC. Code practice equipment is maintained for training radio operators.

Rifle Team. All ROTC students are eligible to compete for the rifle team. Those demonstrating the greatest proficiency will represent the unit in intercollegiate and national matches.

SOCIETIES. *Pi Tau Pi Sigma*. A national honorary Signal Corps fraternity which elects its members each year from the junior and senior classes of the third and fourth years of Signal Corps ROTC on the basis of outstanding scholarship and military proficiency.

Scabbard and Blade. Scabbard and Blade is a national ROTC honorary military fraternity. Members of the third and fourth year ROTC are elected to Scabbard and Blade upon the basis of meritorious standing and outstanding traits of leadership.

Pershing Rifles. Pershing Rifles is a national ROTC honorary military society. Members of the first and second year ROTC who demonstrate a high degree of military ability and interest are elected to membership.

Air ROTC Club. The Air ROTC Club is a professional and social club of the advanced students in the Air ROTC. It is dedicated to the study of military and civil aviation.

Army Ordnance Association, University of Michigan Post. Composed of local scientists, educators, industrialists, students, and members of the various components of the armed services who are interested in advancing the engineering aspects of ordnance in order to maintain industrial preparedness for the common defense. The aims of the Post are attained by field trips to local industrial and ordnance establishments, inviting eminent speakers to the local meetings, and close liaison with the activities of the National Association.

INDIVIDUAL COURSES. Courses leading to commissions in the following branches of the Officers' Reserve Corps are offered. Academic credit is given for ROTC training.

United States Air Force. Theoretical and practical work in the science of military aviation. Development of tactical and technical knowledge and skill in aerial navigation, communication, radar, airway traffic control, and personnel management. Seniors may specialize in air force communication or administration. An opportunity will be offered to interested students after graduation to become flying officers. Open to all students.

Dental Corps. Not open to undergraduates.

Infantry. The development of knowledge and skill in military organization, leadership and exercise of command, staff functions, tactics, weapons, personnel management, gunnery, and logistics. Open to all students.

Medical Corps. Not open to undergraduates.

Ordnance. Conference, laboratory work, and field trips to local industrial establishments covering the design and manufacture of tanks and other ordnance materiel. Ordnance as a technical and manufacturing branch of the Army utilizes engineering and scientific skills of the student pursuing a technical course of instruction. Students electing Mech. Eng. 150 (Automotive Engineering) may substitute special ordnance automotive field work for regular classroom hours. Open to students of the scientific colleges and the College of Engineering, including others enrolled in industrial engineering courses.

Quartermaster. An analysis of the principles and organization of supply administration. The development of technical understanding in the fields of procurement, distribution, manufacturing, warehousing, with related property accounting and fiscal procedures. The application of business management procedures to industrial and management problems, including a study of civil service operations and techniques in handling personnel problems. Open to all students.

Signal Corps. Study and analysis of the theory and practice of military communications, including visual, sound, wire, radio, pigeon, and messenger. Application of the science and skills of applied electricity to modern military communication systems. Provides an opportunity for students to utilize scientific skills and civilian occupation specialties in their careers as reserve officers. Open to students of electrical or mechanical engineering, electronics, or any other curriculum having a physics major.

PROGRAM

		Inf.	Ord.	Q.M.	Sig.C.	USAF
1st Yr.	1st Sem.	101	101	101	101	101
	2d Sem.	102	102	102	102	102
2d Yr.	3d Sem.	231	261	271	281	211
	4th Sem.	232	262	272	282	212
3d Yr.	5th Sem.	331	361	371	381	311
	6th Sem.	332	362	372	382	312
		SUMMER CAMP (Six Weeks—For all Branches)				
4th Yr.	7th Sem.	431	461	471	481	411
	8th Sem.	432	462	472	482	412

101. Orientation, Introduction to Military Science. (*2*).

102. Leadership, Elements of National Power. (*2*).

211, 231, 261, 271, 281. Tactics and Techniques of the Appropriate Branch of Service. (*2*).

212, 232, 262, 272, 282. Leadership, Tactics and Techniques of the Appropriate Branch of Service. (*2*).

311, 331, 361, 371, 381. Tactics and Techniques of the Appropriate Branch of Service. (*3*).

312, 332, 362, 372, 382. Individual Weapons, Tactics and Techniques of the Appropriate Branch of Service, Leadership and Exercise of Command. (*3*).

411, 431, 461, 471, 481. Military Administration and Personnel Management, Military Teaching Methods, Psychological Warfare, Tactics and Techniques of the Appropriate Branch of Service. (*3*).

412, 432, 462, 472, 482. Tactics and Techniques of the Appropriate Branch of Service, Leadership and Exercise of Command. (*3*).

60. MINERALOGY AND PETROGRAPHY

Professors Hunt, Ramsdell, and Slawson; Assistant Professor Heinrich.

The Mineralogical Laboratory comprises thirty-six rooms situated in the northwest part of the Natural Science Building.

The laboratory is well equipped with crystal models, natural crystals, and lecture and working collections of minerals, rocks, and thin sections. There is an excellent equipment of goniometers, polarization microscopes, and other crystallographic-optical instruments necessary for the thorough study of minerals. Likewise facilities for X-ray study of crystal structure are available, including the Weissenberg goniometer. The blowpipe and chemical laboratories possess every facility for the qualitative and quantitative determination of minerals and rocks. The equipment of the laboratory is such that attention can be given to graduate work and special investigations in mineralogy, crystallography, petrography, and mineralography.

31. Elements of Mineralogy. *Prerequisite: a knowledge of elementary inorganic chemistry.* I and II. (*3*).

Includes the elements of crystallography, and the physical and chemical properties, occurrence, uses, and determination of the more common minerals. Three lectures and three hours of laboratory a week.

151. OPTICAL CRYSTALLOGRAPHY. *Prerequisite: permission of the instructor.* I and II. *(3)*.

Detailed discussions of the behavior of crystals in polarized light. In the laboratory, applications to the examination of nonmetallic crystalline substances by means of the polarizing microscope and other crystallographic optical instruments will be stressed.

155. X-RAY ANALYSIS OF CRYSTALLINE MATERIALS. I. *(3)*.

Includes the Laue, Bragg, and powder methods of crystal structure determination, and the necessary crystallographic background for the use of these methods. Five hours of lecture and laboratory a week. Open to advanced students in mineralogy, chemistry, physics, and engineering.

156. X-RAY ANALYSIS OF CRYSTALLINE MATERIALS. II. *(3)*.

A continuation of Mineral. 155, in which the reciprocal lattice, and the rotation, oscillation, and Weissenberg methods of crystal structure determination are considered. Five hours of lecture and laboratory.

For full information about the courses in mineralogy, see the *Announcement* of the College of Literature, Science, and the Arts.

61. MODERN LANGUAGES

The study of a modern foreign language is considered of particular value to the student in the technical school, for it serves to broaden his outlook on life by introducing him to a new literature and a new civilization. With such an asset of a cultural and social nature added to his practical training, the student should represent the ideal type of university man, possessing a well-rounded and complete education beneficial to both himself and society.

The aim of the instruction in French, German, and Spanish is to help the student to a reading, writing, and speaking knowledge of those languages. The object of the courses of the first two years is to familiarize the student with the forms and the construction of the languages and to furnish him with practice in reading and speaking them.

The object of the courses of reading in scientific literature is to acquaint the student with the terminology and special vocabularies of the various sciences and thus enable him to consult books and periodicals bearing on his professional work with facility and profit. Many students read, besides the work assigned for the classroom, scientific articles in the numerous foreign periodicals to be found in the Engineering Library. These are of value to the student in the pursuit of much of his advanced work.

Students in aeronautical engineering are advised to elect German and students in mathematics and physics are advised to elect both French and German. Students who expect to do graduate work in chemical engineering are urged to acquire a reading knowledge of German.

Elective courses of two types are offered: (1) advanced courses in the language studied for those who wish to pursue work beyond actual requirements; (2) general courses in foreign literatures for cultural purposes.

FRENCH

1. ELEMENTARY FRENCH. I and II. (*4*).

Pronunciation, understanding of grammatical constructions, easy reading. Daily oral practice. Composition work is deferred.

2. ELEMENTARY FRENCH, Continued. *Prerequisite: French 1 or equivalent.* I and II. (*4*).

Continued oral practice, reading, grammar accompanied by exercises and easy composition. Conducted partly in French.

11 (51). FIRST SPECIAL READING COURSE. *Prerequisite: may not be elected for credit by students who have already received credit for high-school or college French.* I and II. (*4*).

Study of basic principles of grammar, training in pronunciation, easy graded readings. No credit toward graduation will be given for this course until French 12 has been satisfactorily completed.

12 (52). SECOND SPECIAL READING COURSE. *Prerequisite: French 11 or the equivalent.* I and II. (*4*).

Graded readings, simple to moderate in difficulty. Continued recognition drill in grammatical forms. Pronunciation drills. French 12 may be followed by French 91, with permission of instructor.

31. SECOND-YEAR FRENCH. *Prerequisite: French 2 or a two-year course in high school.* I and II. (*4*).

Careful reading and study of representative modern prose. Review and application of the essential principles of grammar by means of oral and written exercises and some composition. Continued practice in pronunciation and in hearing the spoken language; some conversation. Outside reading intended to develop the ability to read rapidly at sight. Conducted in French as far as possible.

32. SECOND-YEAR FRENCH, Continued. *Prerequisite: French 31 or a three-year course in high school.* I and II. (*4*).

French 32 may be followed by any or all of the following courses: French 91 (four hours credit), 61 (two hours credit), or 83 (two hours credit).

For advanced elective courses, consult the *Announcement* of the College of Literature, Science, and the Arts.

GERMAN

1. ELEMENTARY GERMAN. I and II. (*4*).

The essentials of the grammar, with practice in reading and writing German.

2. ELEMENTARY GERMAN. I and II. (*4*).

Continuation of German 1 (or of its equivalent, one year of high-school German). Pronunciation, grammar, easy readings, with practice in speaking and writing German.

31. SECOND-YEAR GERMAN. *Prerequisite: German 1 and 2 in the University or two years of German in high-school.* I and II. (*4*).

German prose. Selected readings from representative modern writers. Organic grammar reviews, practice in reading German at sight. Not open to students who have credit for German 35 or a more advanced course.

32. SECOND-YEAR GERMAN. *Prerequisite: German 1, 2, and 31 or three years of German in high school.* I and II. (*4*).

Continuation of German 31. Selected readings from modern writers and/or the classic poets. Not open to students who have credit for German 36 or a more advanced course.

For advanced elective courses and for courses in scientific German and chemical and technical German, consult the *Announcement* of the College of Literature, Science, and the Arts.

SPANISH

1. ELEMENTARY SPANISH. I and II. (*4*).

Grammar, oral work, and reading.

2. ELEMENTARY SPANISH. *Prerequisite: Spanish 1 or equivalent.* I and II. (*4*).

Continuation of Spanish 1.

31. SECOND-YEAR SPANISH. *Prerequisite: Spanish 2 or two years of high-school Spanish.* I and II. (*4*).

Reading of modern texts, grammar review, and conversation.

32. SECOND-YEAR SPANISH. *Prerequisite: Spanish 31 or three years of high-school Spanish.* I and II. (*4*).

Continuation of Spanish 31.

For advanced elective courses consult the *Announcement* of the College of Literature, Science, and the Arts.

SUMMER SESSION

Courses will be offered during the summer session.

62. NAVAL SCIENCE

Professor Wheeler; Associate Professors Smith, Varland, Sheehan, and Patton; Assistant Professors Valente, MacKellar, and Wickes.

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 a civil educational institution are:

1. To provide the student with a well-rounded course in basic naval subjects, which, in conjunction with a baccalaureate degree, will qualify him for a commission in the United States Naval Service.

2. To develop an interest in the naval service and a knowledge of naval practice.

3. By precept, example, and instruction to develop the psychology and technique of leadership in order that the young officer may be able to inspire others to their best efforts.

4. To supplement the academic work of the school year by summer cruises, aviation training, and/or Marine Camp 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 in 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 a retainer pay at the rate of $600 a year, with tuition, nonrefundable fees, and books provided by the Navy for a maximum period of four years while under instruction at the NROTC institution or during summer training cruises. Regular students are obligated to serve at least fifteen months or, at the discretion of the Secretary of the Navy, two 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. For administrative purposes they are referred to as Reserve Midshipmen. They are not entitled to the compensation or benefits paid Regular NROTC students except that they are entitled to the uniform issue, textbooks, and equipment for the naval science courses, and payment of commutation of subsistence (currently about $30 a month) during their last two years of NROTC training. Under this plan students must agree to accept a commission in the Naval or Marine Corps Reserve on graduation and, while undergraduates, to engage in one summer practice cruise of approximately three weeks' duration between the junior and senior years. After commissioning, however, if they so desire and their services are required, they may elect to be commissioned as ensigns, USN, or second lieutenants, USMC, and serve for two years on active duty. They may then apply, if they desire, for retention in the Service.

Physical requirements for all NROTC students are high. Vision must be 20/20 uncorrected by glasses. Height minimum is 66 inches, maximum 76 inches. Age limits 17 to 21. Naval physical examinations are required prior to final acceptance.

The Selective Service Act of 1948 requires all NROTC students subject to induction to agree in writing to accept a commission upon graduation, and to serve, subject to call by the Secretary of the Navy, not less than two years active duty. This permits a student to complete his entire course of instruction deferred from induction, but does not exempt him from registration.

Candidates for commissions in the Marine Corps are required to complete the same courses as all other candidates for the first two and one-half years.

From the middle of the third year, they will take courses as indicated by the letter "M" following the numerals of a class designation.

Students preparing for duty in the Supply Corps take the same courses as other naval officer candidates through the third year. The fourth year they are required to take the courses marked with the letter "S."

ADDITIONAL INSTRUCTION. Regular NROTC students will participate in three periods of summer training at naval stations or on board ship. With this in mind, certain instructional materials have been transferred to the summer programs. Marine officer candidates will spend the third summer in indoctrination training at the Basic School, Marine Corps Schools, Quantico, Virginia. Naval and Marine contract students will be required to have a minimum of three weeks of summer training, afloat or ashore.

ADDITIONAL COURSE REQUIREMENTS. (*a*) By the end of the sophomore year, every student must have satisfactorily completed one year of college physics. (*b*) All students who have not completed mathematics courses through trigonometry in the secondary school must complete these courses by the end of the sophomore year. (*c*) Every student must achieve proficiency in written and oral expression. The College will prescribe standards of proficiency and determine procedures necessary to achieve them. (*d*) Physical training will be taken by every student in accordance with college requirements. (*e*) Each student shall take such instruction in swimming as to qualify him as a First Class Swimmer, as described in NavPers 15007, *Physical Fitness Manual of the United States Navy*.

RECOMMENDED ELECTIVES. It is desirable that every student complete:

1. A sequence in mathematics, extending through calculus, and including spherical trigonometry.

2. A second year of physical science, such as advanced electricity and elementary electronics, for other than engineering students.

3. A one-year course in personnel management and administration.

4. A one-year course in the Foundations of National Power, or a comparable course approved by the academic authorities.

5. Two years of a foreign language (modern Romance, Germanic, Slavic, or Oriental), or demonstrate to the academic authorities by examination that he possesses a good reading knowledge and can make an acceptable written translation of one of the languages in question.

6. A public speaking course.

OVERLAPPING COURSES. When a naval course and a regular college course overlap to a marked degree, the Professor of Naval Science and the College authorities may omit or combine the courses.

An example of this procedure might be the combination of two engineering courses in such a way that the needs of regular and Navy students would be met. If desirable, laboratory periods can be sectioned so that different emphases are given to the study of appropriate types of machinery.

SPECIAL QUALIFYING EXAMINATIONS. Credit toward advanced standing in naval science courses will be given for active service in the Army or Navy only when substantiating examinations, administered by the Professor of Naval Science, have been successfully completed. These examinations will cover the complete content of the course involved; advanced standing for a part of a course will not be allowed. When approved by the Professor of Naval Science, courses successfully completed as a student at the United States Naval Academy, the United States Military Academy, the United States Coast Guard Academy, or the United States Merchant Marine Academy may be counted toward advanced standing in naval science if such course parallels the content of naval science courses.

LABORATORY PERIODS. A weekly laboratory period totaling at least two hours in length shall be scheduled for NROTC students. At least 70 per cent of these periods will be used for laboratory work and practice in connection with naval science courses as outlined. Approximately 30 per cent of the laboratory periods will be utilized for close order drill, weather permitting. When unable to hold close order drill, laboratory sessions shall be substituted to augment the assigned laboratory schedule.

EXAMINATIONS. In the following schedule of courses, locally constructed examinations will be administered midsemester. An examination program will be prepared by the Navy Department for the naval science subjects, prescribed examinations to be administered at the semester end.

101. NAVAL ORIENTATION. I. *(3)*.

102. NAVAL ORIENTATION. II. *(3)*.

201. NAVAL WEAPONS. I. *(3)*.

202. NAVAL WEAPONS. II. *(3)*.

301. NAVIGATION. I. *(3)*.

302. NAVIGATION. II. *(3)*.

302M. CONCEPTS OF MILITARY POLICY, POWER, AND PRINCIPLES. II. *(3)*.

401. NAVAL MACHINERY. I. *(3)*.

402. NAVAL ADMINISTRATION AND LEADERSHIP. II. *(3)*.

401M. ANALYSIS OF AMERICAN BATTLES. I. *(3)*.

402M. AMPHIBIOUS OPERATIONS. II. *(3)*.

401S. NAVY SUPPLY. I. *(3)*.

402S. NAVY SUPPLY. II. *(3)*.

63. ENGINEERING RESEARCH INSTITUTE

Professor A. E. White, Director; Professor C. W. Good, Assistant Director; W. E. Quinsey, Assistant to the Director; H. F. Poehle, Research Co-ordinator; Project Personnel: A. P. Fontaine, Director of Aeronautical Research, Willow Run; Jesse Ormondroyd, Co-ordinator of Basic Research; J. E. Corey, Reports Office Supervisor, Willow Run; Research Physicists Boyd, Chang, Enns, Geiger, Hagelbarger, Welch, Wolfe; Research Chemists Evans, Toribara; Research Mathematicians Brown, Faulkner, Piranian, Reade; Research Engineers Agruss, Allen, Allured, Bartman, Battey, Biasell, Black, Blocher, Boden, Bradfield, Chaney, Clark, Cline, Courtney, daRosa, Doty, Driggers, Early, Felder, Fredericks, W. W. Fredericks, Freeman, Frisk, Garby, Hok, Jacob, Jones, Keene, Krugler, Limouze, Lothrop, Martens, Martin, May, McDonald, McLaughlin, Mills, Morrison, Neill, Ohlsson, T. E. Quinsey, Ristow, Ross, Rumpf, Sattinger, Schaefer, Schultz, Schumacher, Spencer, Stapleton, Strand, Theobald, Theofil, Therkelsen, Tieman, Weinberg; Research Associates Brown, Coleman, Crows, Curry, Dorrance, Dougherty, Fledderman, Glass, Grover, Hanson, Hennessy, Kiessel, Latham, Leite, Lirette, Liskow, Malik, Mathews, Mazurkiewicz, Orr, Rand, Reynolds, Riley, Roberts, Robinson, Spath, Thomas, Wenk, Wheatley, Willits, Wilson, Wolfson; Research Assistants Albright, Aldrich, Boutelle, Browne, Buck, Bush, Collins, Consiglio, Curtis, Duncan, Dunlap, Edict, Gault, Gumprecht, Horton, Johnson, Kessler, Levy, Lewis, Mooshy, Pantek, Perry, Rabson, Shields, Thompson, Wright.

The Engineering Research Institute was originally established as the Department of Engineering Research in October, 1920. It affords an official channel through which the research facilities of the College of Engineering and the other physical science divisions of the University are made available to the governmental, civic, and industrial interests of the state and nation for sponsored research. No course work is offered by the Institute, but many of its researches afford opportunities for students to do remunerative work which has instructional and experience value.

The Institute administers the projects sponsored through it. The technical direction of the work is usually assigned to members of the faculty and most of the work is done in the laboratories of the instructional departments with which they are associated.

PART III

PROFESSIONAL DEPARTMENTS

The following curriculums offered in the professional departments were accredited by the Engineers' Council for Professional Development on October 1, 1937: Aeronautical, Chemical, Civil, Electrical, Marine, Mechanical, and Metallurgical Engineering, and Engineering Mechanics and Naval Architecture.

64. THE GROUP SYSTEM OF ELECTIVE STUDIES

The system provides that of the 140 hours of credit required for graduation, about 125 hours are prescribed and fifteen hours may be elective. These elections may be made from announced groups of study or from other courses approved by the head of the department.

The group system allows the student to receive his instruction in the advanced subjects from a specialist. It also permits a student desiring to take up a fifth year of study to specialize in some particular branch of engineering. A student in any group will be allowed to elect work in the other departments of engineering or in the other colleges or schools of the University, subject to the approval of the head of the department. A student desiring to obtain special scientific knowledge or special business training by building on the fundamental subjects of engineering may be allowed to elect scientific courses or courses in economics or business administration under the direction and approval of the head of the department.

The Roman numeral indicates the semester in which the course is given: the first semester—I, the second semester—II, summer session—S.S. The italic numeral enclosed in parentheses indicates the number of hours credit for the course: (*3*) denotes three hours credit.

65. AERONAUTICAL ENGINEERING

Professors Conlon, Kuethe, and Nelson; Associate Professors Lesher, Schetzer, and Nichols; Assistant Professors Morkovin, Schneyer, and Luecht.

The work in the Department of Aeronautical Engineering has been arranged to cover all problems entering into the design and construction of aircraft. This includes a study of general aerodynamics, the determination of the strength of structures, and the general design of components of aircraft. Studies in the field of propulsion include the aerodynamic design of propellers and turbo and ram jet motors, and the design of rocket motors.

The courses offered by the department are arranged to cover the essentials of aerodynamics necessary for the proper understanding of the behavior of airfoils and propulsion devices and of problems connected with stability and maneuvering; and to form the basis for the application of such studies to the design, construction, and analysis of performance of all types of aircraft.

Each student may choose from among three programs of study. By a proper choice of electives, the student may specialize in aerodynamics, propulsion, structures, or design.

Preparatory courses in mathematics, theory of structures, hydromechanics, and mechanical engineering are essential. In the design of aircraft, the student is given an opportunity to apply such studies so as to obtain the best solution to any given set of conditions.

The aerodynamic and structural laboratories offer facilities for experimental work and are available for research work for advanced students.

AERONAUTICAL LABORATORIES. The Department of Aeronautical Engineering provides laboratories for instruction and research in aerodynamics, instrumentation, propulsion, and structures. Most of the laboratories are situated on the campus and others are at the Aeronautical Research Center at Willow Run Airport. The new East Engineering Building wing houses aerodynamics, instrumentation, propulsion, and structures laboratories.

Campus facilities for work in aerodynamics include two subsonic wind tunnels, a small supersonic jet, and hot-wire apparatus for turbulence studies. The larger of the two wind tunnels has a working section 5 by 8 feet and a maximum wind speed of 120 miles per hour. A six-component balance and equipment for special tests are available. The smaller tunnel has a throat 20 by 30 inches and a maximum speed of 110 miles per hour. The supersonic jet has a cross section of one square inch and attains a Mach number around 2. The Structures Laboratory is designed for test work on full-scale or scaled models of aircraft components. The equipment includes a 120,000-pound tension or compression testing machine and a special drop test apparatus used in the investigation of landing gear shock struts. Strain measuring equipment includes extremely sensitive optical strain gages and a 48-gage recording unit for use with electrical strain gages. The Instrumentation Laboratory is equipped for studies of the fundamentals of aeronautical instrumentation and has special apparatus for optical observation of air flow, vibration measurement, guidance and control of guided missiles, studies of upper atmospheric phenomena and telemetry. The Propulsion Laboratory provides facilities for studies on flame propagation and heat transfer and for carrying out small scale experimentation in aerothermodynamics as related to propulsion problems.

Laboratories at the Aeronautical Research Center are provided for aerodynamics and propulsion research. A supersonic wind tunnel capable of attaining Mach numbers of 4.5 is in operation. This tunnel is of the intermittent type and has a working section eight by thirteen inches. A strain gage balance and equipment for optical studies of supersonic flows are included. The Propulsion Laboratory equipment includes a regular service type turbo jet engine, test stands for various types of jet and rocket motors, and a variety of equipment for investigations relating to problems of fluid flow and combustion.

ADVICE TO STUDENTS of other colleges and universities, with regard to planning their courses before coming to the University, is given in section 14.

MILITARY AND NAVAL SCIENCE. The attention of prospective students in aeronautical engineering is called to the Reserve Officers' Training Corps. Students in aeronautical engineering are particularly well qualified to take the work offered in preparation for air service. Those who consider taking military or naval science are urged to enroll at the beginning of their course. For further details see sections 59 and 62.

METEOROLOGY. Courses in meteorology are offered in the Department of Geology. See section 56.

AIR NAVIGATION. Courses in air navigation are offered in the Departments of Astronomy and Mathematics and are described under sections 49 and 70.

CURRICULUM IN AERONAUTICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Aeronautical Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 36.

	Hours
a) *Preparatory Courses*	
English 11 (1), 21 (2), 12 (3), and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical electives	6
Economics 53, 54	6
*Mathematics 13, 14, 53, 54	16
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 1 and Ch. and Met. Eng. 1	5
Metal Proc. 5	2
Total	68
b) *Secondary Courses*	
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
Civil Eng. 21 (2), Theory of Structures	3
†Mathematics 150, Advanced Mathematics for Engineers	4
Mech. Eng. 82 (2), Elements of Machine Design	3
Mech. Eng. 105 (5), Thermodynamics	3
‡Mech. Eng. 17 (7), Laboratory	2
Mech. Eng. 160 (60), Aircraft Power Plants	3
Elec. Eng. 5 (2*a*), Electric Apparatus and Circuits	4
Aero. Eng. 1, General Aeronautics	3
Aero. Eng. 110 (2), Fundamentals of Aerodynamics	3
Aero. Eng. 111 (3), Theory and Design of Propellers	3
Aero. Eng. 130 (4), Basic Airplane Structures	3

* Outstanding students may elect, by special permission of the Mathematics Department, the sequence Math. 17, 18, 54 in place of the sequence Math. 13, 14, 53, 54.

† In unusual cases students may, with special permission of the Aeronautical Engineering Department, elect an advanced technical course in place of Math. 150.

‡ Students may elect, with special permission of the Aeronautical Engineering Department, Aero. Eng. 172 in place of Mech. Eng. 17.

	Hours
Aero. Eng. 112 (6), Experimental Aerodynamics	1
Aero. Eng. 101 (5), Airplane Design	3
Aero. Eng. 132 (26), Airplane Structure Laboratory	1
Aero. Eng. 113 (25), Aircraft Performance	3
Total	56

Summary:

Preparatory courses	68
Secondary and technical courses	56
Group options and electives	16
Total	140

c) *Group Options.* Students in aeronautical engineering may elect one of the following groups of courses according to their interest.

AERODYNAMICS

Required

Aero. Eng. 114 (27), Applied Aerodynamics	3
Aero. Eng. 131 (23), Airplane Structures	3
Total	6

Elect a minimum of five hours from this group

Aero. Eng. 105 (11), Dynamics of the Airplane (2)
Aero. Eng. 106, Aero-Elastic Loads (3)
Aero. Eng. 115 (15), Theoretical Aerodynamics (3)
Aero. Eng. 116 (20), Advanced Fluid Mechanics (3)
Aero. Eng. 117 (21), Advanced Theory of Propellers and Fans (2)
Aero. Eng. 118 (24), Advanced Experimental Aerodynamics (2)
Aero. Eng. 165, Aircraft Propulsion I (3)
Aero. Eng. 172, Engineering Measurements and Research Techniques (3)

Total	5
Free Electives	5
Total	16

STRUCTURES AND DESIGN

Required

Aero. Eng. 114 (27), Applied Aerodynamics	3
Aero. Eng. 131 (23), Airplane Structures	3
Total	6

Elect a minimum of five hours from this group

Aero. Eng. 102 (13), Advanced Design (2)
Aero. Eng. 106, Aero-Elastic Loads (3)
Aero. Eng. 134, Materials and Structures (3)
Metal Proc. 115, Advanced Course in Metal Processing (2)
Aero. Eng. 165, Aircraft Propulsion I (3)

Aero. Eng. 172, Engineering Measurements and Research Techniques (3)
Civ. Eng. 124 (*7h*), Rigid Frame Structures (3)
Eng. Mech. 123 (9 and 19), Advanced Theory of Strength (4)
Eng. Mech. 125 (*13b*), Theory of Thin Elastic Plates (3)

Total	5
Free Electives	5
Total	16

AIRCRAFT PROPULSION

Required

Aero. Eng. 165, Aircraft Propulsion I	3
Mech. Eng. 115 (15). Advanced Internal-Combustion Engines	3
Total	6

Elect a minimum of five hours from this group
Mech. Eng. 161 (61), Aircraft Power Plants—Experimental Tests (3)
Mech. Eng. 162 (62), Design of Aircraft Engines (3) First semester only.
Mech. Eng. 164. Gas Turbines and Jet Propulsion (3)
Aero. Eng. 116 (20), Advanced Fluid Mechanics (3)
Aero. Eng. 117 (21), Advanced Theory of Propellers and Fans (2)

Total	5
Free Electives	5
Total	16

FIRST-YEAR PROGRAM

For uniform first-year program see section 47.

SECOND YEAR

	Hours		*Hours*
*Math. 53	4	*Math. 54	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Nontech. electives	3	Aero. Eng. 1	3
Mil. or Nav. Science	(1)	Mil. or Nav. Science	(1)
	17 or (18)		17 or (18)

SUMMER SESSION

	Hours
Eng. Mech. 3	3
Elec. Eng. 5 (2*a*)	4
	7

* See footnotes on page 74.

THIRD YEAR

	Hours		Hours
*Math. 150	4	Mech. Eng. 82 (2)	3
Civil Eng. 21	3	Econ. 53	3
Eng. Mech. 4	3	Metal Proc. 5	2
Aero. Eng. 111	3	Aero. Eng. 110 (2)	3
*Mech. Eng. 17 (7)	2	Aero. Eng. 130	3
Mech. Eng. 105	3	Mech. Eng. 160 (60)	3
	18		17

FOURTH YEAR

Engl. (Group III)	2		
Aero. Eng. 113 (25)	3	Aero. Eng. 101 (5)	3
Aero. Eng. 132 (26)	1	Aero. Eng. 112 (6)	1
Econ. 54	3	Nontech. electives	3
Prof. or free electives	7	Prof. or free electives	9
	16		16

COURSES IN AERONAUTICAL ENGINEERING

1. GENERAL AERONAUTICS. *Prerequisite: Math. 53 and Phys. 45.* I and II. *(3).*

The essentials of aeronautics as applied to the airplane and other modern means of flight. Lectures and recitations. Open to all students except freshmen.

101 (5). AIRPLANE DESIGN. *Prerequisite: preceded or accompanied by Aero. Eng. 113 and 130.* I and II. *(3).*

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

102 (13). ADVANCED DESIGN. I and II. *(To be arranged).*

Continuation of Aero. Eng. 101 (5), taking up some of the more complex or special problems. Open primarily to graduates.

103 (32). AIRPLANE DESIGN PRACTICE II. *Prerequisite: Aero. Eng. 113 (25).* I and II. (2).

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.

104 (31). AIRCRAFT VIBRATIONS. *Prerequisite: Aero. Eng. 110 (2) and Aero. Eng. 130 (4).* I and II. (2).

Vibrations and other dynamic problems occurring in aircraft structures.

105, 105*a* (11, 11*a*) DYNAMICS OF THE AIRPLANE. *Prerequisite: Aero. Eng. 110 (2), 113 (25), and Math. 150.* (2).

The theory of the dynamic stability of the airplane as a rigid body is studied and compared with experience. Stability criteria and current requirements are discussed for stick-fixed as well as stick-free flight.

106. AERO-ELASTIC LOADS. *Prerequisite: Aero. Eng. 114 and preceded or accompanied by Aero. Eng. 113. (3).*

Loads on an airplane considered as a rigid body and as an elastic body are studied. Maneuvering and gust loads, elementary flutter theory, landing loads, and other dynamic loading conditions are investigated.

* See footnotes on page 74.

110 (2). FUNDAMENTALS OF AERODYNAMICS. *Prerequisite: preceded or accompanied by Math. 150 and Eng. Mech. 4.* I and II. *(3).*

A development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Lectures and recitations.

111 (3). THEORY AND DESIGN OF PROPELLERS. *Prerequisite: preceded by Eng. Mech. 2 and Aero. Eng. 1.* I and II. *(3).*

The aerodynamic theories of the propeller and its strength. The selection of propellers for specific conditions is discussed. Lectures and recitations.

112 (6). EXPERIMENTAL AERODYNAMICS. *Prerequisite: Aero. Eng. 110 (2).* I and II. *(1).*

Modern methods for obtaining experimental aerodynamic data are discussed and illustrated. Lectures and laboratory. Open only to seniors and graduates.

113 (25). AIRCRAFT PERFORMANCE. *Prerequisite: Aero. Eng. 110 (2) and 111 (3).* I and II. *(3).*

Methods for estimating performance, stability, and maneuverability as required for airplane design are studied. The relationships between engine and airplane, and between control and stability are treated in detail.

114 (27). APPLIED AERODYNAMICS. *Prerequisite: Aero. Eng. 110 (2) and Math. 150.* I and II. *(3).*

Applies theoretical aerodynamics and modifications based on experiment to the calculation of actual air loads on the airplane.

115 (15). THEORETICAL AERODYNAMICS *Prerequisite: Aero. Eng. 110 (2) and Math. 150. (3).*

A summary of the fundamentals of the mathematical theory of hydrodynamics and its application to modern aerodynamics. The theory of the geometry and dynamics of airfoil sections is treated in considerable detail.

116 (20). ADVANCED FLUID MECHANICS. *Prerequisite: Aero. Eng. 110 or equivalent. (3).*

An advanced course in fluid mechanics dealing mainly with the physical aspects of various problems of viscosity and compressibility and their application in aeronautical as well as other branches of engineering.

117 (21). ADVANCED THEORY OF PROPELLERS AND FANS. *Prerequisite: Aero. Eng. 110 (2), 111 (3), and Mech. Eng. 105 (5). (2).*

A critical study of the fundamental aerodynamic and strength theories of the propeller; viscosity and compressibility effects; the theory and performance of axial and centrifugal blowers, with application to superchargers and jet propulsion systems.

118 (24). ADVANCED EXPERIMENTAL AERODYNAMICS. *Prerequisite: preceded or accompanied by Aero. Eng. 116. (2).*

Covers the work presented in Aero. Eng. 112 (6), but with considerably more attention to detail and a more elaborate discussion of the advanced theories and methods used in this field. Lectures and laboratory.

119 (29). MECHANICS AND FLUID RESISTANCE. *Prerequisite: Aero. Eng. 115 (15). (2).*

The problems of resistance in fluid motion are treated in a broad way.

consideration being given to viscous fluid resistance, wave resistance, and resistance due to fluid compressibility.

120. FANS AND DUCT SYSTEMS. *Prerequisite: Eng. Mech. 4, Mech. Eng. 105 (5).* (2).
Airfoil theory applied to fan design; theoretical performance, fan losses and dimensions; viscosity and compressibility effects; experimental results; losses in straight pipes, nozzles, diffusers, and around corners.

130 (4). BASIC AIRPLANE STRUCTURES. *Prerequisite: preceded or accompanied by Aero. Eng. 1 and preceded by Civil Eng. 21* (2). I and II. (*3*).
An introduction to the elementary problems of airplane stress analysis. Lectures and recitations on the applications of the topics covered in mechanics and strength of materials to airplane structures, such as beam deflection, moment distribution, unsymmetrical bending, combined stresses, and tension field beams.

131 (23). AIRPLANE STRUCTURES. *Prerequisite: Aero. Eng. 130 (4) or by special arrangement for students from other departments.* I and II. (*3*).
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, and an introduction to the solution of indeterminate structures.

132 (26). AIRPLANE STRUCTURES LABORATORY. *Prerequisite: preceded or accompanied by Aero. Eng. 130.* (*1*).
The lectures and 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 (30). ADVANCED AIRPLANE STRUCTURES. *Prerequisite: Aero. Eng. 131 (23).* (*3*).
Special airplane stress analysis problems of an advanced nature. Shear lag, rigid frame analyses, torsional bending, the analysis of circular shell supported frames, and the general relaxation theory are covered, with a complete discussion of various recent publications.

134. MATERIALS AND STRUCTURES. *Prerequisite: Aero. Eng. 130 or Civil Eng. 21.* (*3*).
The 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.

140 (17). AIRCRAFT, MATERIALS OF CONSTRUCTION. See Metal Proc. 110.

141. PROPERTIES OF AIRCRAFT MATERIALS. See Ch. and Met. Eng. 108.

150 (18). HELICOPTERS AND AUTOGIROS. *Prerequisite: Aero. Eng. 110* (2).

160 (12). 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 most desirable.

161 (14). RESEARCH. *Prerequisite: Aero. Eng. 112 (6).* I and II. (*To be arranged*).
Continuation of Aero. Eng. 112 (6) offering an opportunity for students to pursue experimental investigations.

162 (19). ANALYTICAL RESEARCH. *(To be arranged).*

A theoretical investigation of problems in aeronautical engineering which are particularly suited to treatment by analytical and mathematical methods.

165. AIRCRAFT PROPULSION I. *Prerequisite: Mech. Eng. 105. (3).*

Review of those phases of thermodynamics used in the analysis of compressible flow and propulsion systems. The turbo jet, ram jet, and aeropulse will be briefly analyzed.

165*a*. REVIEW OF THERMODYNAMICS AND INTRODUCTION TO AIRCRAFT PROPULSION. *Prerequisite: Mech. Eng. 105. (3).*

The fundamental principles of thermodynamics and their general application to propulsion problems.

171. GUIDANCE OF PILOTLESS AIRCRAFT. *Prerequisite: taken concurrently with Elec. Eng. 221 and Aero. Eng. 105 and 170 (3).*

Remote controlled beam rider, homing and navigational guidance; proximity fusing, detonation devices, servomechanism, gyroscopes, collision courses.

172. ENGINEERING MEASUREMENTS AND RESEARCH TECHNIQUES. *Prerequisite: Eng. Mech. 3 and Elec. Eng. 5. (3).*

Treatment of experimental data and errors. Seismic instruments, optical instruments in fluid flow, pressure instruments, strain gages, electromechanical pickups.

173. FUNDAMENTALS OF AERONAUTICAL INSTRUMENTS AND RESEARCH TECHNIQUES. *Prerequisite: Aero. Eng. 172. (3).*

Continuation of Aero. Eng. 172, including a 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 instrumented flight in aerodynamic and systems research.

174. NUCLEAR ENERGY FOR AIRCRAFT PROPULSION. *Prerequisite: Aero. Eng. 165. (3).*

The engineering problems involved with the utilization of nuclear energy for the propulsion of aircraft. Primarily intended for graduate students enrolled in the guided missiles course.

176. FLIGHT TESTING. *Prerequisite: Aero. Eng. 113 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.

201. DYNAMICS OF VISCOUS FLUIDS. *Prerequisite: Aero. Eng. 116 (20). (3).*

The 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. 116 (20). (3).*

An 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, transsonic and supersonic airfoil theory.

203. DYNAMICS OF PERFECT FLUIDS. *Prerequisite: Aero. Eng. 115 (15), Math. 110 and 176 or equivalent. (3)*

A continuation of Aero. Eng. 115 (15), in which theoretical methods are applied to three-dimensional flow and to unsteady flows of frictionless incompressible fluids. The forces and moments on an oscillating airfoil as they apply to the flutter of aircraft are derived and discussed.

204. AIRCRAFT PROPULSION II. *Prerequisite: Aero. Eng. 165. (3).*

Analysis of various propulsion systems, including ram jets and rocket motors, with special emphasis on the characteristics which govern the selection of a propulsion system for a specific installation.

66. CHEMICAL AND METALLURGICAL ENGINEERING

Professors G. G. Brown, A. E. White, Brier, Upthegrove, Wood, Katz, Schneidewind, Carrick, Thomassen, Siebert, Foust, and R. R. White; Associate Professors Freeman, McCready, and Townsend; Assistant Professors Monroe, Rote, Moesel, Brownell, Martin, Sinnott, Sliepcevich, and Williams; Mr. York, Mr. Banchero, Mr. Young, Mr. Myers, and Mr. Thatcher.

"Chemical engineering is that branch of engineering concerned with the development and application of manufacturing processes in which chemical or certain physical changes of materials are involved." The chemical engineer is, therefore, 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 heat transfer, evaporation, filtration, distillation, crushing, extracting, and drying are common to the processing of different materials and industries. Any manufacturing process with which the chemical engineer deals is made up of a sequence of such operations. His knowledge of these unit operations and their commercial applications is one characteristic which distinguishes him from the chemist. Only by being thoroughly grounded in the principles of chemistry, physics, and mathematics, and their application to industrial processes, is it possible for the chemical engineer to make his proper contribution to the development and commercial production of the amazing multiplicity of new products from modern industry.

Almost all that has been said of the chemical engineer applies in an equal degree to the metallurgical engineer, although the metallurgical engineer is more concerned with metals than with engineering materials. The activities of the metallurgical engineer cover the extraction of metals from their ores, their melting, refining, alloying, casting, fabrication, and heat treatment, and their utilization in the various industries. He finds his work not only in the industries involved directly in the production of metals and metal products, but also to an ever-increasing extent in the industries utilizing, and dependent for their existence on, metals and metal products. Diminishing supplies of high-grade ores and an increasing demand for new alloys of superior qualities make this field one of ever-growing importance.

Materials used in the construction of plants and also in the fabrication of consumer goods are becoming more varied and complex, and there is an increasing demand for engineers familiar with the chemical and physical properties of materials. Because of the possibility of substituting one material, such as a plastic, for a different material, such as metal, these "material engineers" must have a broad fundamental background, including organic synthetics, metals, protective coatings, and their properties. This represents an important development in chemical and metallurgical engineering which has been hastened by the necessities of the recent war.

Industry is becoming more technical, and the modern executive needs an understanding of the science of engineering which governs the operations of his plant as well as the principles of management and executive control.

The programs of study are designed to prepare the student for each of these various activities and to take his place as a responsible citizen and active member of a complex society.

GRADUATE WORK

The fact that chemical and metallurgical engineering involves application of chemistry in addition to mathematics and physics, which are the basis of other branches of engineering, indicates the importance of more than four years' study. This is definitely recognized by many of the larger corporations, which prefer a man with a master's or a doctor's degree to one with a bachelor's degree on the grounds that the man with postgraduate training advances faster and farther than an equally able man without such training. Graduate work should be undertaken only by those students whose undergraduate record clearly indicates superior scholastic ability. All students who desire to become candidates for a graduate degree must present substantially the equivalent of the undergraduate program required for the bachelor's degree in chemical or metallurgical engineering at the University of Michigan. Students whose undergraduate training has not been adequate will be required to make up the work which is lacking. A superior student who is well prepared may complete the requirements for a master's degree in two semesters, but usually it is desirable to spend more time than this minimum. All graduate students are enrolled in the Horace H. Rackham School of Graduate Studies, and the *Announcement* of that school should be consulted for further information.

FACILITIES

The Chemical and Metallurgical Engineering Department is situated in the East Engineering Building, where it co-operates closely with the foundry and forge shop of the Metal Processing Laboratories, the cement and asphalt work of the highway laboratories, and the Engineering Research Institute.

The departmental library is housed with others in the East Engineering Library and includes over six thousand volumes and about one hundred journals dealing with chemical and metallurgical engineering.

THE CHEMICAL AND METALLURGICAL OPERATIONS LABORATORY occupies four floors in the north wing of the building and is well equipped for pilot-plant work and studies of the unit operations and their integration into processes. All students in chemical and metallurgical engineering are required to elect Ch. and Met. 129 (29) in Engineering Operations. The laboratory includes special equipment of adequate size to give the student a proper perspective of the factors influencing the operation of commercial scale equipment.

The evaporator equipment includes a conventional vertical tube or basket evaporator, a forced circulation evaporator, and a long tube vertical evaporator complete with accessories for making all possible tests and for conducting research work.

Heat transfer equipment includes double pipe heat exchangers and various types of multipass condensers and heat exchangers offering a wide variety of opportunities for instruction and research.

Distillation equipment includes special columns constructed of cast iron units eighteen inches in internal diameter and equipped with various types of bubble-cap and perforated trays for studying the effect of column design on its performance. The cast iron sections are equipped with glass windows for making visual observations and are so designed that the students can put the sections together to construct columns of different plate spacings and of different internal design. A special type of column of high capacity, known as a cascade column, is available in the same diameter. A glass bubble-cap fractionating column and two packed columns are also available for tests and research.

Refrigeration equipment includes an ammonia compression plant, an ammonia absorption plant, and a three-ton methyl chloride compressor unit complete with controls for use as an air-conditioning unit.

Filtration equipment includes a small plate and frame filter press and a two-foot by one-foot rotary vacuum filter complete with all accessories. Also available are a ten-inch portable centrifuge and special equipment for the study of the characteristics of various filter cakes.

The Operations Laboratory is also well equipped with tanks, piping, pumps, blowers, and scales, and crushing, grinding, screening, flotation, and other equipment representing the operations studied by the chemical or metallurgical engineer.

THE METALLURGICAL ENGINEERING LABORATORIES are situated adjacent to the foundry and metal-working laboratories of the Department of Metal Processing.

The metallographic laboratory includes rooms for the preliminary grinding and preparation of metallographic specimens, polishing rooms, metallographic microscopes, metallographic cameras, and the necessary darkroom facilities for complete and thorough instruction in all phases of metallographic work.

The melting and heat-treating laboratory includes a number of electric and gas-fired furnaces. A 35 KVA Ajax Northrup frequency converter is available for use with a number of different types of furnaces for carrying out a large variety of melting operations, including the determination of the gas content of metals.

Physical properties may be determined by standard equipment for hardness testing, dimensional changes, and tensile, impact, and fatigue tests. A special laboratory for the study of the properties of metals at elevated temperatures is also available.

The X-ray laboratory has modern equipment for both radiography and crystal diffraction investigations. It is used not only for inspection, but also for studies of the structure in metals and other materials. Available to advanced students is a Geiger X-ray spectrometer with automatic recording, which measures directly and instantaneously the intensity of diffracted X rays for both the powder and single crystal methods.

THE CHEMICAL ENGINEERING LABORATORIES also include special laboratories devoted to the problems in particular industries, among which the following may be mentioned:

The petroleum laboratories include equipment for testing petroleum products and for research on the phase equilibria of petroleum hydrocarbons at high temperature and pressure. Special equipment is available for determining the thermal and physical properties of petroleum oils and gases and pilot plants for studying the processes used in this industry. The laboratories also include a CFR-ASTM test engine for conducting research in motor fuels.

The gas engineering laboratory contains furnaces for the manufacture of gas and for studying the catalytic conversion of gas, which is the current research project of the Michigan Gas Association.

The paint and varnish laboratories provide facilities for the study of the manufacture and application of paints and varnishes, lacquers, and other finishing material. In addition to regular laboratory facilities, the equipment includes grinding apparatus, washed air dryer, and baking and spray gun equipment for the application of various kinds of finishing materials.

Electrochemical equipment includes a 650-ampere, sixteen-volt generator and a thirty-ampere, twelve-volt generator, and a number of precision potentiometers, pH meters, and other research equipment. Facilities for anodizing aluminum with either direct or alternating current are provided.

The paper laboratory includes a beater, sheet-forming machine, and supplemental equipment for the making of test or experimental sheets of paper. A room, in which the temperature and humidity can be controlled, houses complete equipment for standard testing and evaluating of paper sheets.

The plastics laboratory is equipped for making a majority of the basic synthetic resins. There is equipment for compounding rubbers and plastics and for forming these compounds into final articles.

Other special laboratories are available to deal with the problems of particular industries as suggested under Ch. and Met. 210. By making suitable elections from among the advanced courses, it is possible for the advanced student to obtain expert special instruction in a chosen field of specialization. In research work the student becomes an associate of the teacher, who is himself learning new relationships of a fundamental scientific nature or more sound or economical ways of applying knowledge for the promotion of industry and human welfare. This is the best means of acquiring an understanding of the profession.

VISITS OF INSPECTION. The educational value of visits of inspection is recognized, and inspection trips are made regularly in connection with the various courses. The great industrial development of the cities within easy reach of Ann Arbor allows a wide range of industries to be visited at small expense. The opportunities are so abundant that the list varies from year to year.

SUMMER EMPLOYMENT. Each student is urged to obtain employment in a factory for at least one summer, in order that he may appreciate somewhat the viewpoint of the worker in an industrial organization. He also may acquire some professional knowledge and recognition of industrial problems and methods.

Student chapters of the American Institute of Chemical Engineers, established in 1922, and the American Institute of Mining and Metallurgical Engineering, established in 1938, hold meetings for discussion of topics of professional interest. Convenient and pleasant clubrooms are provided adjoining the seminar room in the East Engineering Building.

MILITARY AND NAVAL SCIENCE. The College of Engineering contains units of both Army and Naval Reserve Officers' Training Corps. Students completing the required work may obtain commissions as reserve officers. The ordnance unit is especially attractive to chemical and metallurgical engineers, and there is sufficient flexibility in the program so that they may obtain the necessary military credits without increasing the time of residence, provided they take one summer in a military camp. See sections 59 and 62 for further details. Students considering taking military or naval science should enroll at the beginning of their courses.

CURRICULUMS IN CHEMICAL AND METALLURGICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering are required to complete the preparatory courses detailed below and in addition, the secondary and technical courses detailed for the desired degree, making a total of 140 hours in each case. For the definition of an hour of credit, see section 36.

a) Preparatory Courses	*Hours*
English 11 (1), 21 (2), 12 (3), Groups II and III	10
Nontechnical Electives	6
Econ. 153, 173	6
*Math. 13, 14, 53, 54	16
Physics 45, 46	10
Chem. 5E, 21E	9
Drawing 1, 2, 3	8
Eng. Mech. 2, 6	8
Ch. and Met. 1 and Metal Proc. 1	5
Ch. and Met. 2, Engineering Calculations	3
Total	81

* See note, section 47, studies of the first year, or see note, section 70, pertaining to possible substitution in early mathematics course.

b) Candidates for the degree of Bachelor of Science (Chemical Engineering) are required to complete the following secondary and technical courses:

	Hours
Chem. 41, Analytical Chemistry	4
Chem. 67E, 169E, Organic Chemistry	8
Chem. 83E, Physical Chemistry	4
Mech. Eng. 107	3
Elec. Eng. 5 (2*a*), Electrical Apparatus and Circuits	4
Ch. and Met. 16, Measurements	3
Ch. and Met. 111 (11), Thermodynamics	3
Ch. and Met. 113, 115 (13, 15), Unit Operations	7
Ch. and Met. 117 (17), Metals and Alloys	3
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 121, Design	2
Ch. and Met. 129 (29), Engineering Operations Laboratory	3
Ch. and Met. 130 (34), Process Design	3
Electives	9
Total	59

c) Candidates for the degree of Bachelor of Science (Metallurgical Engineering) are required to complete the following secondary and technical courses:

Chem. 41, Analytical Chemistry	4
Chem. 53, Organic Chemistry	4
Chem. 83E, Physical Chemistry	4
Mech. Eng. 107	3
Elec. Eng. 5 (2*a*), Electrical Apparatus and Circuits	4
Ch. and Met. 9, Cast Metals	2
Ch. and Met. 16, Measurements	3
Ch. and Met. 111 (11), Thermodynamics	3
Ch. and Met. 114, 119, Operations	8
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 121, Design	2
Ch. and Met. 124 (44), X Rays	2
Ch. and Met. 127, 128 (27, 28), Physical Metallurgy	6
Ch. and Met. 129 (29), Engineering Operations Laboratory	3
Electives	8
Total	59

d) Candidates for the two degrees, Bachelor of Science in Engineering (Chemical Engineering) and Bachelor of Science in Engineering (Metallurgical Engineering), are required to complete the preparatory courses listed in paragraph *a* and the following secondary and technical courses for a total of 152 hours.

	Hours
Chem. 41, Analytical Chemistry	4
Chem. 67E, 169E, Organic Chemistry	8
Chem. 83E, Physical Chemistry	4
Mech. Eng. 107	3
Elec. Eng. 5 (2*a*), Electrical Apparatus and Circuits	4
Ch. and Met. 9, Cast Metals	2
Ch. and Met. 16, Measurements	3
Ch. and Met. 111 (11), Thermodynamics	3
Ch. and Met. 113 (13), 115 (15), 119 (19), Operations	11
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 121, Design	2
Ch. and Met. 124 (44), X Rays	2
Ch. and Met. 127 (27), 128 (28), Physical Metallurgy	6
Ch. and Met. 129 (29), Engineering Operations Laboratory	3
Ch. and Met. 130 (34), Process Design	3
Electives	10
Total	71

Students who are also candidates for a degree in mathematics are permitted to make the following substitutions:

1. In the mathematics curriculum, substitute three hours of chemistry (beyond 5E) for Eng. Mech. 3.
2. In the chemical and metallurgical curriculum, substitute three hours of advanced mathematics for Economics 173.

COMBINED CURRICULUM IN CHEMISTRY AND CHEMICAL ENGINEERING

A thorough understanding of chemistry is of the greatest importance to chemical engineers who enter the chemical industry or are planning a career in research. An integrated program leading to the two degrees, Bachelor of Science in Chemistry and Bachelor of Science in Engineering (Chemical Engineering), which can be completed in ten semesters is available to students in either the College of Engineering or the College of Literature, Science, and the Arts. Information may be obtained from the assistant dean of the College of Literature, Science, and the Arts; or from the Department of Chemical and Metallurgical Engineering.

PROGRAMS IN CHEMICAL ENGINEERING AND IN METALLURGICAL ENGINEERING

FIRST YEAR

See section 47 for program common to first-year engineering students. Students in chemical or metallurgical engineering should take Chem. 5E in the first semester and may then elect Chem. 21E, four hours, instead of English Group II in the second semester and take English Group II later, making it possible to complete the requirements in eight semesters without a summer session by advancing subsequent courses marked x to an earlier semester.

Attention is also called to the note in section 70 regarding possible substitution in mathematics.

SECOND YEAR

FIRST SEMESTER	Hours	SECOND SEMESTER	Hours
Math. 53, Calculus I	4	Math. 54, Calculus II	4
Draw. 3, Adv. Eng. Drawing	2	Ch. and Met. 2, Eng. Cal.	3
Physics 45, Mech. Sound and Heat	5	Physics 46, Electricity and Light	5
xChem. 21E, Gen. and Anal. Chem.	4	xChem. 41, Quan. Analysis	4
Electives	2	Mil. or Nav. Science	(1)
Mil. or Nav. Science	(1)		
	17 or (18)		16 or (17)

SUMMER SESSION

Eng. Mech. 6	4
Chem. 83E	4
	8

FIFTH SEMESTER

CHEMICAL ENGINEERING		METALLURGICAL ENGINEERING	
xChem. 67E	3	xChem. 53	4
Ch. and Met. 16	3	Ch. and Met. 16	3
Ch. and Met. 111 (11)	3	Ch. and Met. 111 (11)	3
Ch. and Met. 113 (13)	4	Ch. and Met. 9	2
Eng. Mech. 2	4	Eng. Mech. 2	4
		Electives	2
	17		18

SIXTH SEMESTER

xChem. 169E	5	xCh. and Met. 114	4
Ch. and Met. 115 (15)	3	xCh. and Met. 118	3
Ch. and Met. 118	3	Ch. and Met. 127 (27)	3
Econ. 173	3	Econ. 173	3
Mech. Eng. 107	3	Mech. Eng. 107	3
	17		16

SEVENTH SEMESTER

Ch. and Met. 117 (17)	3	Ch. and Met. 128 (28)	3
Ch. and Met. 129 (29)	3	Ch. and Met. 119 (19)	4
Elec. Eng. 5 (2*a*)	4	Elec. Eng. 5 (2*a*)	4
Econ. 153	3	Econ. 153	3
Electives	3 or 4	Electives	2 or 3
	16 or 17		16 or 17

EIGHTH SEMESTER

	Hours		Hours
Ch. and Met. 121	2	Ch. and Met. 121	2
Ch. and Met. 130 (34)	3	Ch. and Met. 129 (29)	3
Engl. Group III	2	Ch. and Met. 124 (44)	2
Electives	8 or 9	Engl. Group III	2
		Electives	6 or 7
	15 or 16		15 or 16

ELECTIVES

The undergraduate curriculums in chemical and metallurgical engineering are designed to develop in the student an understanding of the fundamentals of his profession and a power in their application that fits him to enter almost any industry. The application of these basic principles to specific industries is covered in many of the advanced courses, which may be elected by the student who has particular interest in a special field. These courses may be included among the electives of the undergraduate program, taken as additional work, or included in a postgraduate program for an advanced degree. The members of the staff, particularly the student classifiers, are available for consultation in regard to the selection of elective courses to fit the needs of the individual student.

The following groups suggest the way in which special fields may be covered by advanced students:

SUGGESTED ELECTIVE GROUPS

1. *Materials*

Ch. and Met. 125 (25), Colloids—Amorphous Materials
Ch. and Met. 233 (125), Plastics
Ch. and Met. 236 (136), Paints, Varnishes, and Lacquers
Ch. and Met. 221 (121), Design of Equipment
Ch. and Met. 229, Engineering Laboratory
Ch. and Met. 217, Corrosion and High-Temperature Resistance of Metals
Ch. and Met. 258, Electrochemical Operations
Ch. and Met. 124 (44), Application of X Rays to Engineering Materials
Mech. Eng. 182, Process Equipment Selection and Design
Mech. Eng. 282, Superpressure Process Equipment and Technique
Chem. 291, Colloid Chemistry
Math. 161, 162, Statistical Methods for Engineers
Metal Proc. 111, Gaging
Eng. Mech. 131 (12), Vibration

2. *Process Design*

Ch. and Met. 211 (105), Chemical Engineering Thermodynamics
Ch. and Met. 213 (113), Advanced Unit Operations
Ch. and Met. 215 (115), Mass Transfer Operations
Ch. and Met. 216 (152), Pyrometry and Furnace Control
Ch. and Met. 217, Corrosion and High-Temperature Resistance of Metals
Ch. and Met. 221 (121), Design of Chemical Engineering Equipment

Ch. and Met. 229, Engineering Laboratory
Ch. and Met. 231, Explosives
Ch. and Met. 235 (155), 251 (151), 254, or 258
Ch. and Met. 315 (215), Azeotropic Distillation
Chem. 255 or 256, Organic Chemistry
Chem. 291, Colloid Chemistry
Mech. Eng. 182, Design of Process Equipment
Mech. Eng. 282, Design of Superpressure Equipment
Math. 109, Graphical Methods
Math. 161, 162, Statistical Methods for Engineers
Math. 150, Advanced Mathematics

3. *Process Metallurgy*

Ch. and Met. 211 (105), Chemical Engineering Thermodynamics
Ch. and Met. 240 (141), Manufacture of Iron and Steel
Ch. and Met. 241 (149), Cast Iron and Steel
Ch. and Met. 216 (152), Pyrometry and Furnace Control
Ch. and Met. 219, Metallurgical Operations
Ch. and Met. 229, Engineering Laboratory
Ch. and Met. 258, Electrochemical Operations
Ch. and Met. 251 (151), Furnace Design
Physics 181, Heat
Chem. 291, Colloid Chemistry
Mech. Eng. 120 (19), Materials Handling and Factory Transportation
Mech. Eng. 182, Process Equipment Selection and Design
Mech. Eng. 135 (35), Factory Management or
Bus. Ad. 141, Production Management
Math. 161, 162, Statistical Methods for Engineers

4. *Petroleum Refinery Engineering*

Ch. and Met. 211 (105), Chemical Engineering Thermodynamics
Ch. and Met. 213 (113), Advanced Unit Operations
Ch. and Met. 215 (115), Mass Transfer Operations
Ch. and Met. 217, Corrosion and High-Temperature Resistance of Metals
Ch. and Met. 221 (121), Design of Chemical Engineering Equipment
Ch. and Met. 235 (155), Petroleum Refining
Ch. and Met. 315 (215), Azeotropic Distillation
Ch. and Met. 335 (255), Petroleum Refinery Engineering
Ch. and Met. 355 (254), Petroleum Production Engineering
Chem. 255 or 256, Organic Chemistry
Physics 165, Electron Tubes
Elec. Eng. 181 (83), Industrial Electronics
Math. 161, 162, Statistical Methods for Engineers
Math. 150, Advanced Mathematics

5. *Petroleum Production Engineering*

Ch. and Met. 211 (105), Chemical Engineering Thermodynamics
Ch. and Met. 213 (113), Advanced Unit Operations

Ch. and Met. 215 (115), Mass Transfer Operations
Ch. and Met. 217, Corrosion and High-Temperature Resistance of Metals
Ch. and Met. 235 (155), Petroleum Refining
Ch. and Met. 335 (254), Petroleum Production Engineering
Chem. 276, Heterogeneous Equilibrium
Chem. 291, Colloid Chemistry
Physics 196, Atomic Structure
Geol. 145, Petroleum Geology
Geol. 146, The Stratigraphy of Petroliferous Areas
Math. 150, Advanced Mathematics
Math. 147 or 152, Operational Mathematics

6. *Protective Coatings*

Ch. and Met. 124 (44), X-ray Studies of Engineering Materials
Ch. and Met. 236 (136), Materials, Paints, Varnishes, and Lacquers
Ch. and Met. 266, Paint, Varnish, and Lacquer Laboratory
Ch. and Met. 336, Paint, Varnish, and Lacquer Formulation
Chem. 255, Organic Chemistry
Chem. 291, Colloid Chemistry
Chem. 292, Advanced Colloid and Surface Chemistry
Chem. 294, Colloid and Surface Chemistry Laboratory
Physics 186, Light
Physics 188, Light Laboratory
Math. 109, Graphical Methods
Math. 161, 162, Statistical Methods for Engineers

7. *Plastics*

Ch. and Met. 124 (44), X-ray Studies of Engineering Materials
Ch. and Met. 232 (172), The Cellulose Studies
Ch. and Met. 233 (125), Plastics and High Molecular Weight Polymers
Ch. and Met. 236 (136), Paints, Varnishes, and Lacquers
Chem. 255, Organic Chemistry
Chem. 256, Organic Chemistry
Chem. 277, Statistical Mechanics in Chemistry
Chem. 291, Colloid Chemistry
Physics 171, Mechanics of Solids
Physics 172, Mechanics of Fluids
Metal Proc. 107, Metal Stamping, Die Casting, and Plastic Molding
Math. 109, Graphical Methods
Math. 161, 162, Statistical Methods for Engineers

8. *Physical Metallurgy*

Ch. and Met. 211 (105), Thermodynamics
Ch. and Met. 216 (152), Pyrometry and Furnace Control
Ch. and Met. 224 (144), X-ray Studies of Engineering Materials II
Ch. and Met. 228 (143), Metallography of the Nonferrous Metals
Ch. and Met. 241 (149), Cast Iron and Steel

Ch. and Met. 242 (150), Alloy Steels
Chem. 276, Heterogeneous Equilibria
Physics 181, Heat
Physics 196, Atomic and Molecular Structure
Math. 161, 162, Statistical Methods for Engineers

9. *Pulp and Paper*

Ch. and Met. 125 (25), Colloid and Amorphous Materials
Ch. and Met. 232 (172), The Cellulose Industries
Ch. and Met. 233 (125), Plastics and High Molecular Weight Polymers
Ch. and Met. 236 (136), Paints, Varnishes, and Lacquers
Chem. 255, Organic Chemistry
Chem. 256, Organic Chemistry
Chem. 291, Colloid Chemistry
Chem. 292, Advanced Colloid and Surface Chemistry
Forestry 162, Foundation of Wood Technology
Civil Eng. 152 (31), Water Supply Engineering
Mech. Eng. 109 (9), Power Plants
Mech. Eng. 128 (18), Heating and Ventilation
Math. 109, Graphical Methods

COURSES IN CHEMICAL AND METALLURGICAL ENGINEERING

1. Engineering Materials and Processes. *Prerequisite: an acceptable high-school course in chemistry or Chem. 3. (5).*

Metals, alloys, cement, clay products, protective coatings, fuels, and water. An introductory course. Two lectures, three recitations, and three hours of laboratory. Required of all engineering students.

2. Engineering Calculations. *Prerequisite: general chemistry and Physics 45. (3).*

Material and energy balances and their application to chemical and metallurgical problems. Lectures and recitations.

3. Cast Metals (Metal Proc. 3). *Prerequisite: Ch. and Met. Eng. 1 and Metal Proc. 1. (4).*

The principles and practice of producing gray iron, malleable iron, steel, brass, bronze, and aluminum castings, including the constitution and properties of molding sands and core sands, metallographic and x-ray inspection, welding and heat treatment of the castings. Two recitations, and two three-hour laboratory periods a week.

9. Cast Metals (Metal Proc. 9). *(2).*

A short course similar to Ch. and Met. Eng. 3 for students in metallurgy.

10. Fuels. *(1).*

Laboratory testing of fuels, gases, oils, and water, and interpretation of results. Is scheduled with Mech. Eng. 17 (7).

16. Measurements Laboratory. *Prerequisite: Chem. 41, preceded or accompanied by Chem. 83E. (3).*

Physical-chemical measurements and determination of properties. Laboratory, computation, and reports.

100 (20). Plant Work. *(1)*.

Credit is given for a satisfactory report on some phase of work done in a plant. The nature of the problem and registration must be approved before entering upon the work.

101 (21). 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.

105. Jet and Rocket Motor Fuels. *(3)*.

Preparation, supply, handling, and properties of materials used or usable for rocket propellants. Open only to those students having U.S.A.A.F. approval.

107 (7). Metals and Alloys. *Prerequisite: Ch. and Met. Eng. 1. (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. May not be elected by chemical or metallurgical engineers.

108. Properties of Aircraft Materials (Aero. Eng. 141). *Prerequisite: Ch. and Met. Eng. 1. (3)*.

Structure and properties of materials used in aircraft. Light alloys, heat treatment, plywood, plastics, etc.

111 (11). 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 (13). Unit Operations. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 111 (11). (4)*.

Equipment and theory of unit operations and their application.

114. Unit Operations. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 111 (11) or Mech. Eng. 105 (5) or preceded by a course in physical chemistry. (4)*.

A short course in the equipment and theory of the unit operations.

115 (15). Unit Operations Design. *Prerequisite: Ch. and Met. Eng. 113 (13). (3)*.

Theories of heat and mass transfer operations and their application in calculations for equipment design. Lectures and recitations.

117 (17). 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. 83E. (3)*.

Atomic structure, radioactivity, and artificial nuclear reactions. 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. Lectures and recitations.

119 (19). METALLURGICAL PROCESS DESIGN. *Prerequisite: Ch. and Met. Eng. 113 (13) or 114. (4).*

Application of principles involved in the extraction of metals from ores, the production of alloys and their commercial shapes or forms to process design. Lectures and recitations.

121. DESIGN OF PROCESS EQUIPMENT. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 129 or 130. (2).*

The student designs and estimates cost of selected equipment. Conferences, reports, and design.

124 (44). X-RAY STUDIES OF ENGINEERING MATERIAL. *Prerequisite: Ch. and Met. Eng. 16 and 117 (17) or 127 (27). (2).*

Principal methods. Lectures, recitations, and laboratory.

127 (27). PHYSICAL METALLURGY I. *Prerequisite: Ch. and Met. Eng. 2, 16, and 118. (3).*

Structures and properties of metals as related to composition and thermal and mechanical treatment. Lectures, recitations, and laboratory.

128 (28). PHYSICAL METALLURGY II. *Prerequisite: Ch. and Met. Eng. 127 (27). (3).*

Surface hardening, hardenability, hardening, tempering, isothermal transformation, related properties of iron and steel.

129 (29). ENGINEERING OPERATIONS LABORATORY. *Prerequisite: Ch. and Met. Eng. 16 and 115 (15) or 119 (19). (3).*

Laboratory determination of actual operating data of equipment for chemical and metallurgical operations. Laboratory, conferences, and reports.

130 (34). CHEMICAL PROCESS DESIGN. *Prerequisite: Ch. and Met. Eng. 115 (15) and 117 (17). (3).*

Application of chemistry and the unit operations to the design of chemical processes.

207. METALS AT HIGH TEMPERATURES. *Prerequisite: Ch. and Met. Eng. 107, 117 (17), or 127 (27). (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.

210 (110). SPECIAL RESEARCH AND DESIGN PROBLEMS. Laboratory and conferences. *(To be arranged).*

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, and electro deposition. The student writes a final report on his project.

211 (105). Engineering Thermodynamics. *Prerequisite: Ch. and Met. Eng. 111 (11). (3).*

Principles of the laws of energy as applied to chemical and metallurgical engineering problems. Lectures and recitations.

213 (113). Advanced Unit Operations. *Prerequisite: Ch. and Met. Eng. 115 (15). (4).*

Fluid flow, heat transfer, evaporation, filtration, and sedimentation.

215 (115). The Mass Transfer Operations. *Prerequisite: Ch. and Met. Eng. 213 (113). (4).*

An advanced study of distillation, absorption, extraction, leaching, and allied operations. Lectures and recitations.

216 (152). Pyrometry and Furnace Control. *Prerequisite: Ch. and Met. Eng. 16. (3).*

Theory, construction, calibration, and use of commercial pyrometers; the methods of thermal analysis and the means of temperature control in furnaces. Recitation and laboratory.

217. Corrosion and High-Temperature Resistance of Metals. *Prerequisite: Ch. and Met. Eng. 117 (17) or 127 (27). (3).*

Lectures and recitations.

219. Metallurgical Operations. *Prerequisite: Ch. and Met. Eng. 119 (19) and 127 (27). (3).*

Rolling, forging, extrusion, piercing, drawing, and straightening.

220. Operation and Management of Chemical Plants. *Prerequisite: Ch. and Met. Eng. 130 (34) or special permission of the instructor. (3).*

Lectures and recitations.

221 (121). Advanced Design of Process Equipment. *Prerequisite: Ch. and Met. Eng. 121. (3).*

The student selects some piece of chemical machinery and makes a complete set of drawings that would be required for its actual construction. Conferences and drafting.

224 (144). X-Ray Studies of Engineering Materials II. *Prerequisite: Ch. and Met. Eng. 124 (44). (3).*

Application of X-ray methods to the study of age hardening, cold working, and annealing.

225. Plastics. *Prerequisite: Chem. 53 or Chem. 169E and Ch. and Met. Eng. 118. (3).*

Chemistry and properties of plastic materials and applications. Lectures, recitations, and laboratory.

228 (143). Metallography of the Nonferrous Metals. *Prerequisite: Ch. and Met. Eng. 128 (28). (3).*

Ternary systems, solution and precipitation, plastic deformation, recrystallization grain growth. Lectures, recitations, and laboratory.

229. Engineering Laboratory. *Prerequisite: Ch. and Met. Eng. 129 (29). (4)*
Students work in small groups on development projects involving the design, construction, and operation of pilot plant scale equipment. Laboratory, conferences, and reports.

231 (171). Explosives. *Prerequisite: Chem. 169E and Ch. and Met. Eng. 130 (34). (4).*
Manufacture of commercial and military explosives and pyrotechnic materials; their properties and uses. Lectures and recitations.

232 (172). The Cellulose Industries. *Prerequisite: Chem. 83E and Ch. and Met. Eng. 125 (25). (3).*
Manufacture of pulp and paper, cellulose fibers, and plastics; their properties and uses. Lectures and recitations.

233 (125). Plastics and High Molecular Weight Polymers. *Prerequisite: Ch. and Met. Eng. 125 (25). (3).*

235 (155). Petroleum Refining. *Prerequisite: Ch. and Met. Eng. 115 (15). (4).*
Design of process and plant used in the manufacture of petroleum products and natural gasoline. Lectures and recitations.

236 (136). Paints, Varnishes, and Lacquers. *Prerequisite: Chem. 53 or 169E. (4).*
Their manufacture, properties, and uses. Lectures and recitations.

237. Synthetic Resins and Emulsions. *Prerequisite: organic and physical chemistry. (4).*
Their manufacture, properties, and uses. Lectures and recitations.

239. Food Processing. *Prerequisite: organic chemistry and Ch. and Met. Eng. 115. (3).*
The chemistry of food, food processing methods, and field trips.

240 (141). Manufacture of Iron and Steel. *Prerequisite: Ch. and Met. Eng. 119 (19). (3).*
Design and operation of the blast furnace and steel-making processes.

241 (149). Cast Iron and Steel. *Prerequisite: Ch. and Met. Eng. 117 (17) or 127 (27)* or *107 (7). (3).*
Solidification, structures, and properties of cast ferrous metals.

242 (150). Alloy Steels. *Prerequisite: Ch. and Met. Eng. 128 (28). (3).*
Theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel. Lecture and recitations.

251 (151). Furnace Design and Construction. *Prerequisite: Ch. and Met. Eng. 128 (28). (3).*
Including a study of furnace atmosphere, refractory materials, and their application. Lectures and recitations.

[254. Heavy Chemicals. *Prerequisite: Ch. and Met. Eng. 129 (29) and 130 (34). (3).* Omitted in 1949–50.]

258. Electrochemical Operations. *Prerequisite: Chem. 83E or a course in electrochemistry. (3).*
The design and operation of plants for cleaning, anodizing, electrorefining, electrowinning, and electroplating. Lectures, recitations, and laboratory.

266. Paint, Varnish, and Lacquer Laboratory. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 236 (136). (5).*

Their analysis, physical testing, and manufacture. Conferences and laboratory.

311 (205). Applied Thermodynamics. *Prerequisite: Ch. and Met. Eng. 211 (105). (3).*

An advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics. Conferences and recitation.

312. Advanced Process Design. *Prerequisite: Ch. and Met. Eng. 211 and 215. I. (3).*

Process design calculation with primary emphasis on the application of rate data for homogeneous and heterogeneous reaction.

315 (215). Azeotropic and Extractive Distillation. *Prerequisite: Ch. and Met. Eng. 215 (115). (3).*

The design of processes used in operations involving nonideal solutions. Lectures and recitations.

328 (241). Physical Metallurgy Seminar. *Prerequisite: Ch. and Met. Eng. 228 (143). (2).*

335 (255). Petroleum Refinery Engineering. *Prerequisite: Ch. and Met. Eng. 235 (155). (4).*

Conferences and recitations.

336 (245). Paint, Varnish, and Lacquer Formulation. *Prerequisite: Ch. and Met. Eng. 236 (136). (5).*

A study of their economic formulation, manufacture, and uses. Lectures and recitations.

340 (245). Metallurgical Reactions. *Prerequisite: Ch. and Met. Eng. 211 (105) and 240 (141). (2).*

355 (254). Petroleum Production Engineering. *Prerequisite: Ch. and Met. Eng. 235 (155). (4).*

Petroleum gases and liquids under high pressure, the production of natural gases and crude oil, and process design of separation plants. Lectures and recitations.

363. Heat Transfer Seminar. *(To be arranged).*

365. Mass Transfer Seminar. *(To be arranged).*

67. CIVIL ENGINEERING

Professors Boyce, Cissel, Morrison, Wisler, Sherlock, Bouchard, Sadler, Crawford, and Maugh; Associate Professors Emmons, Housel, Alt, Brater, and Young; Assistant Professors McFarlan, Bleekman, Kohl, King, Kerkhoff, Legatski, and Borchardt; Mr. Harris and Mr. Boyd.

The civil engineer is trained to plan, design, and build the many structural projects necessary for public works, civic improvements, and industrial development. This requires an understanding of the fundamental scientific principles underlying other branches of engineering as well as an appreciation of the social and economic significance of the changes associated with engineering development. The civil engineering curriculum provides a broad foundation for professional careers in the many special fields included in this branch of engineering. The major electives offered in the senior year permit a limited amount of undergraduate specialization in the following fields:

CONSTRUCTION ENGINEERING. The methods and techniques of modern construction. Fundamental principles of construction applicable to all types of engineering structures. Principles of business management as applied in the field of engineering contracting.

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

HIGHWAY TRAFFIC ENGINEERING. Methods of increasing the efficiency and safety of traffic movement. Traffic surveys, geometrical design of urban and rural highways, traffic control devices and other means of regulating and controlling highway use.

HYDRAULIC ENGINEERING. 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. Laboratory facilities and instruction are offered for students who engage in research work both in hydrology and hydraulics leading to advanced degrees.

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

SANITARY ENGINEERING. The planning, construction, and operation of waterworks, 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 for the ventilation of buildings, and for working under compressed air.

STRUCTURAL ENGINEERING. The theory, design, and construction of structures, such as bridges, buildings, dams, retaining walls, involving the use of steel, reinforced concrete, and lumber.

MAJOR ELECTIVES. As early as practicable the student should select that division of civil engineering in which he may have a major interest and confer with the professor in charge of the division relative to the completion of his program.

GRADUATE STUDY

Graduate work leading to advanced degrees is offered to those whose undergraduate records indicate adequate preparation. Master of Science in Engineering degree programs leading to a degree in sanitary engineering and in municipal engineering administration (in co-operation with the Institute of Public Administration) are offered in addition to the degree in civil engineering. Conditions under which such work may be undertaken are described in the

Announcement of the Horace H. Rackham School of Graduate Studies of the University.

FELLOWSHIPS of interest to students in civil engineering are described in section 43.

THE TRANSPORTATION LIBRARY offers unusual opportunities for research. It contains many rare books and pamphlets relating to the origin, history, and development of the various transportation systems as well as complete files of current magazines and reports.

HIGHWAY LABORATORIES. Through a co-operative arrangement between the University and the State Highway Department, the testing of materials for use in state highways and bridges is done at the University. The work of the state is, in general, done in the rooms used for student work, so that students secure the benefits to be derived from observing the work of trained state employees.

CAMP DAVIS. The University of Michigan was the pioneer in the establishment and maintenance of a camp for field work in surveying. The camp was organized under the supervision of the late Professor J. B. Davis in 1874. Several sites were occupied in Michigan until 1929, when the University purchased lands in Jackson's Hole, Wyoming, for the location of the present camp.

Camp Davis is situated in the valley of the Hoback River, twenty miles southeast of the town of Jackson, Wyoming, and seventy-five miles south of Yellowstone National Park. The elevation of the camp, over six thousand feet above sea level, the nature of the surrounding area, and the climate combine to make this location nearly ideal for a summer surveying camp.

A summary of the necessary preparatory training, with an outline of the work covered at the camp, and other information, is contained in a special circular which may be obtained upon application to the Camp Director, Professor Harry Bouchard, 209 West Engineering Building.

ADVICE TO STUDENTS of other colleges and universities, with regard to planning their courses before coming to the University, is given in section 14.

MILITARY AND NAVAL SCIENCE. The attention of prospective students in civil engineering is called to the Reserve Officers Training Corps. Those who consider taking military or naval science are urged to enroll at the beginning of their course. For further details see sections 59 and 62.

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

The Regents by action taken in June, 1947, authorized the College of Engineering and the College of Literature, Science, and the Arts to conduct a combined curriculum which, at the end of five years and a summer session, will lead to the degrees of Bachelor of Science in Engineering (Civil Engineering) and Bachelor of Arts. The curriculum provides for prescribed courses in civil engineering for a total of 140 hours, and in addition there will be required a total of 31 hours in the liberal arts; the degrees will be granted on completion of the prescribed curriculum, with the understanding that if military science is elected, it must be carried in addition to the 171 semester hours of the regular curriculum. Additional information may be obtained from the Assistant Dean of the College of Literature, Science, and the Arts.

CURRICULUM IN CIVIL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Civil Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 36.

a) *Preparatory Courses*	*Hours*
English 11 (1), 21 (2), 12 (3), and a course from Group II	8
English 136 (6)	2
Nontechnical electives	6
Mathematics 13, 14, 53, 54	16
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2	6
Geology 11 or 39	4
Ch. and Met. Eng. 1 and Metal Proc. 1	5
*Economics 153, 173	6
Total	68

b) *Secondary and Technical Courses*	
Civil Eng. 1, 2, 3 (Surv. 1, 2, 3)	11
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 (2*a*), Electrical Apparatus and Circuits	4
Mech. Eng. 13 (3), Heat Engines	4
Civ. Eng. 20 (1), Structural Drafting	2
Civ. Eng. 22 (2*c*), Theory of Structures	3
Civ. Eng. 23 (5*a*), Elementary Design of Structures	3
Civ. Eng. 121 (3), Reinforced Concrete	3
Civ. Eng. 140 (10), Hydrology	3
Civ. Eng. 141, Hydraulics	2
Civ. Eng. 180 (26), Specifications and Contracts	2

* Econ. 53 and 54 may be elected instead of Econ. 153 and 173. This election is recommended for students taking the construction option.

	Hours
Civ. Eng. 50, Fundamentals of Sanitary Engineering	2
Civ. Eng. 151, Water Supply and Sewerage	3
Civ. Eng. 60 (40), Highway Engineering	2
Civ. Eng. 30 (120), Concrete Mixtures	1
Civ. Eng. 70 (50), Railroad Engineering	2
Total	61

c) *Electives*

Major and free	11

Summary:

Preparatory courses	68
Secondary and technical courses	61
Electives	11
Total	140

ELECTIVES

a) *Major Electives:*

One of the following groups, each including a design course, must be selected as a major. Substitution for any other than the design course is subject to the approval of the Chairman of the Civil Engineering Department.

Construction Engineering	*Hours*
Civ. Eng. 131, Cost Analysis and Estimating	2
Civ. Eng. 132, Construction Methods and Equipment	3
Choice of a Civil Engineering Design course	3
One of the following courses:	
Civ. Eng. 135 (125) (6), Applied Soil Mechanics	3
Bus. Ad. 2, Introduction to Business Management	3
Civ. Eng. 181, Legal Aspects of Engineering	3
Highway Traffic Engineering	
Civ. Eng. 169, Highway Design	3
Civ. Eng. 165, Highway Traffic Control	2
Civ. Eng. 166, Highway Traffic Surveys	2
Highway Engineering	
Civ. Eng. 169, Highway Design	3
Civ. Eng. 161, Highway Materials	3
Civ. Eng. 167, Highway Economics	3
Hydraulic Engineering	
Civ. Eng. 146 (16), Hydraulic Engineering Design	3
Civ. Eng. 142 (12), Water-Power Engineering	2
Civ. Eng. 144 (14), Hydraulic Structures	3

Railroad Engineering	*Hours*
Civ. Eng. 173, Terminal Design	3
Civ. Eng. 176, Economics of Railroad Construction and Operation	2
Civ. Eng. 172, Railroad Maintenance	2
Sanitary Engineering	
Civ. Eng. 156, Sanitary Engineering Laboratory	2
Civ. Eng. 154, Sanitary Engineering Design	3
Bacteriology 51	4
Structural Engineering	
Civ. Eng. 123 (5*b*), Design of Structures	3
Civ. Eng. 122 (4), Advanced Theory of Structures	3
Choice of either—	
Civ. Eng. 135 (125)(6), Applied Soil Mechanics	3
Civ. Eng. 124 (7*h*), Rigid Frame Structures	3

b) *Free Electives*

The remaining elective hours may be filled by courses offered by any department in the University, subject to the approval of the Chairman of the Civil Engineering Department.

NOTE.—Students completing military or naval science (advanced group) as part of their elective requirement will be required to elect not less than five hours from one of the above groups, and such elections shall include a design course.

PROGRAM

For uniform first-year program see section 47.

NOTE.—See section 32 for ruling on freshmen repeating subjects graded D.

SECOND YEAR

	Hours		*Hours*
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Civ. Eng. 1 (Surv. 1)	3	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Civ. Eng. 20 (1)	2	Civ. Eng. 2 (Surv. 2)	4
Mil. or Nav. Science	(1)	Mil. or Nav. Science	(1)
	17 or (18)		18 or (19)

SUMMER SESSION
(at Camp Davis)

	Hours
Civ. Eng. 3	4
Geol. 11 or 39	4
	8

THIRD YEAR

	Hours		Hours
Civ. Eng. 30 (120)	1		
Eng. Mech. 3	3	Civ. Eng. 50	2
Eng. Mech. 4	3	Econ. 173	3
Civ. Eng. 22 (2*c*)	3	Civ. Eng. 121 (3)	3
Civ. Eng. 60 (40)	2	Civ. Eng. 23 (5*a*)	3
Civ. Eng. 70 (50)	2	Civ. Eng. 140 (10)	3
Electives	3	Electives	3
	17		17

FOURTH YEAR

Civ. Eng. 151	3	Civ. Eng. 180 (26)	2
Civ. Eng. 141 (11)	2	Mech. Eng. 13 (3)	4
Elec. Eng. 5 (2*a*)	4	Engl. 136 (6)	2
Econ. 153	3	Electives	6
Electives	5		
			14
	17		

COURSES IN CIVIL ENGINEERING

1 (SURV. 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 (SURV. 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 coordinate systems. Earth-work computations including mass diagram. Controlled planimetric map from aerial photographs. Map making. Theory of instrument adjustment. Problems and field exercises.

3 (SURV. 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 (SURV. 4). SURVEYING. *Prerequisite: Math. 14.* I and II. (2).

Care and use of surveying instruments and equipment. Differential and profile leveling; establishing grade; traverse surveys and computations. For noncivils. Theory, problems, and field exercises.

12 (SURV. 12). SURVEYING. *Prerequisite: Math. 13.* (*4*).

Similar to Civ. Eng. 1 (Surv. 1) with drawing work added. Designed for forestry students. Lectures, text, recitations, field.

13 (SURV. 13). SURVEYING. *Prerequisite: Civ. Eng. 12 (Surv. 12).* (*4*).

Similar to Civ. Eng. 2 (Surv. 2). Designed for forestry students. Lectures, text, two recitations, and two four-hour field or drawing periods.

20 (1). STRUCTURAL DRAFTING. *Prerequisite: Draw. 2.* (*2*).

Graphical methods of presenting and recording civil engineering data. Lectures, text, and laboratory.

21 (2). THEORY OF STRUCTURES. *Prerequisite: Eng. Mech. 2.* (*3*).

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. Not open to civil engineering students.

22 (2*c*). THEORY OF STRUCTURES. *Prerequisite: Eng. Mech. 2.* (*3*).

Analysis of stresses in simple structures. Calculation of reactions, 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 (5*a*). ELEMENTARY DESIGN OF STRUCTURES. *Prerequisite: preceded by Civ. Eng. 20 (1) and preceded or accompanied by Civ. Eng. 22 (2c).* (*3*).

Theory of beams and plate girders, and elements of design of simple structures. Computations, drawing work.

30 (120). CONCRETE MIXTURES. (*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. (*2*).

The 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 (40). HIGHWAY ENGINEERING. I and II. (*2*).

Historical development; economics; preliminary investigations; design of road and street systems and the individual highway; construction and maintenance of roads and pavements.

70 (50). RAILROAD ENGINEERING. I and II. (*2*).

Elements of the location, design, construction, maintenance, and operation of railways. Open to juniors and seniors.

FOR UNDERGRADUATES AND GRADUATES

101 (GEOD. 1). GEODESY. *Prerequisite: Civ. Eng. 3 (Surv. 3).* (*3*).

Introductory course; history; elements of modern practice and its application of several branches of surveying. Lectures, text, recitation.

102 (GEOD. 2). GEODESY. *Prerequisite: Civ. Eng. 101 (Geod. 1).* (*2*).

Methods employed and field covered by the United States Coast and Geodetic Survey. Lectures, reference work.

105 (SURV. 5). LEAST SQUARES. *Prerequisite: Math. 54. (2).*

Theory of least squares; adjustment and comparison of data. Lectures, text, problems, and recitations.

106 (SURV. 6). ADVANCED SURVEYING. S.S. *(2–8).*

Special advanced work can be provided for those who have received credit in Civ. Eng. 3 (Surv. 3). Given only at Camp Davis.

107 (SURV. 7). MUNICIPAL SURVEYING. *Prerequisite: Civ. Eng. 3 (Surv. 3). (2).*

Surveys for streets, grades, paving, sewers, property lines, subdivisions. Lectures, text, drawing, field period.

109 (SURV. 9). RAILWAY SURVEYING. *Prerequisite: Civ. Eng. 3 (Surv. 3), except for students in transportation. (2).*

Text, field, track problems. One recitation and one four-hour field period.

111 (SURV. 21). PHOTOGRAPHY—BASIC COURSE. *Prerequisite: elementary chemistry and physics. (3).*

Fundamental theory and practice. Lectures, reference work, and laboratory period.

112 (SURV. 22). ADVANCED PHOTOGRAPHY. *Prerequisite: Civ. Eng. 111 (Surv. 21). (2).*

Continuation of Civ. Eng. 111 (Surv. 21). Lectures, reference work, laboratory period.

113 (SURV. 23). AERIAL PHOTOGRAPHY AND MAPPING. (2).

Map projections and map making from aerial photographs. Lectures, reference work, recitations, problems, and laboratory.

114 (SURV. 34). REGISTRATION OF LAND TITLES. *Prerequisite: Civ. Eng. 3 (Surv. 3). (3).*

Torrens Act of Australia and modifications as adapted to conditions of other countries. Lectures, reference work.

115 (SURV. 35). BOUNDARY SURVEYS. *Prerequisite: Civ. Eng. 3 (Surv. 3). (3).*

Problems relating to the establishment of boundaries. Lectures, reference work.

120. FUNDAMENTALS OF EXPERIMENTAL RESEARCH. (2).

The scientific method, its elements and procedures. The research project; outline, bibliography, design of experiments, selecting materials, instrumentation, analysis of data, inferences and conclusions. Preparation for publication. Seminar, problems, laboratory.

121 (3). REINFORCED CONCRETE. *Prerequisite: preceded or accompanied by Civ. Eng. 22 (2c). (3).*

Properties of materials; analysis of stresses in plain and reinforced concrete structures.

122 (4). ADVANCED THEORY OF STRUCTURES. *Prerequisite: Civ. Eng. 22 (2c). (3).*

A continuation of Civ. Eng. 22 (2c). Analysis of stresses in advanced types of trusses; statically indeterminate structures; arches. Lectures, texts, problems.

123 (5*b*). DESIGN OF STRUCTURES. *Prerequisite: Civ. Eng. 121, 23 (3 and 5a). (3).*

Design of reinforced concrete and steel structures. Computations, drawing.

124 (7*h*). Rigid Frame Structures. *Prerequisite: preceded or accompanied by Civ. Eng. 121 (5b).* (*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 (7*d*). Timber Construction. *Prerequisite: Civ. Eng. 23* (*5a*). S.S. and 1. (*1*)

Physical characteristics of structural woods; grading rules; design of timber structures.

128 (5*c*). Design of Arc-Welded Steel Structures. *Prerequisite: Civ. Eng. 23.* (*1*).

Elastic behavior of welded structures; designing for continuity and elastic-frame action; stress distribution in joints; expansion, contraction, distortion, and residual stresses; welding technic, methods, and equipment.

130. Physical Properties of Concrete Masonry. (2).

The design of concrete mixtures to obtain specified physical properties, including strength, elasticity, plasticity, impermeability, durability, and economy. Seminar, problems, laboratory.

131 (9). Cost Analysis and Estimating I. (2).

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. Open to seniors and graduates.

132 (130) (8). Construction Methods and Equipment II. (*3*).

Contractors' organizations; plant selection and layout; equipment studies; methods of construction. Lectures, class discussion, seminar. Open to seniors and graduates.

135 (125) (6). Applied Soil Mechanics. *Prerequisite: Civ. Eng. 121. Should be accompanied by Civ. Eng. 136.* I and II. (*3*).

Soil as an engineering material; pressure distribution; determination of physical properties; bearing capacity; design of substructures, pile foundations, and underground structures; earth-pressure theories. Lectures and references.

136 (126) (42*d*). Soil Mechanics Laboratory. *Prerequisite: preceded or accompanied by Civ. Eng. 135.* I and II. (*1*).

Laboratory soil tests; demonstrations and analysis of field tests; soil surveys; soil classification.

140 (10). Hydrology. (*3*).

The relationship between rainfall and runoff. Two recitations and one three-hour laboratory period.

141. Hydraulics. *Prerequisite: Eng. Mech. 4.* (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 (12). WATER-POWER ENGINEERING. *Prerequisite: preceded or accompanied by Civ. Eng. 140 (10). (2).*

Hydraulics of turbines and fundamental principles of water-power development. Lectures, recitations, problems. Open only to seniors and graduates.

143. ADVANCED HYDRAULICS. *Prerequisite: Civ. Eng. 141. (3).*

Flow in open channels; nonuniform flow; critical depth; channels of variable width; flow at high velocities; translatory waves; dimensional analysis; hydraulic similitude; hydraulic models. Lectures and demonstrations.

144 (14). HYDRAULIC STRUCTURES. *Prerequisite: Civ. Eng. 140 (10). (3).*

Dams, head gates, canals, flumes, pipes, breakwaters, and other structures; principles of irrigation, drainage, and harbor design.

145 (15). HYDRAULIC MODELS. (2).

The use of hydraulic models; principles of dimensional analysis and hydraulic similitude and applications to hydraulic problems. Open to advanced seniors and graduate students.

146 (16). HYDRAULIC ENGINEERING DESIGN. *Prerequisite: preceded by Civ. Eng. 121 (3), and preceded or accompanied by Civ. Eng. 141 (11). (3).*

Design of hydraulic structures; dams; regulating works, etc. Lectures, computations, 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. The design of works for the collection, purification, and distribution of water for municipal use. Requirements for municipal sewerage system. Fundamentals of design of sewage treatment plants. Lectures, problems. Open to seniors and graduates.

152 (31). WATER SUPPLY ENGINEERING. *Prerequisite: Civ. Eng. 50 and 151.* I. *(2).*

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. Lectures, library reading, and visits to municipal water purification plants. Open to seniors and graduates.

153 (33). SEWERAGE AND SEWAGE DISPOSAL. *Prerequisite: Civ. Eng. 151.* II. *(3).*

A broad survey of the 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. Open to seniors and graduates.

154 (35). SANITARY ENGINEERING DESIGN. *Prerequisite: preceded by Civ. Eng. 121 (3), and accompanied or preceded by either Civ. Eng. 152, 153, or 155 (31, 33, or 34).* II. *(3).*

Computations and drawing-board design of typical structures related to water supply, water purification, sewerage, and sewage disposal. Drawing room and visits to plants and work under construction.

155 (34). MUNICIPAL AND INDUSTRIAL SANITATION. I. *(3).*

The scientific foundations of public sanitation, in particular relation to closely built-up areas and to industrial environments. Lectures, library readings. Open to seniors and graduates.

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 Environmental Health 225 or consent of instructor.* II. (*2*).

The 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 (41). ADVANCED HIGHWAY ENGINEERING. (*2*).

A seminar course dealing with special phases in which the individual student may be particularly interested. Assigned reading, reports, consultation at stated intervals.

161 (42*a*). HIGHWAY MATERIALS. *Prerequisite: preceded or accompanied by Civ. Eng. 60 (40).* I. (*3*).

Sources, production, and testing of highway materials; specifications; minor research problems. Lectures, text, laboratory.

162 (42*b*). BITUMINOUS MATERIALS AND PAVEMENTS. *Prerequisite: Civ. Eng. 60 (40).* II. (*2*).

Selection of bituminous materials for various uses; pavement types; design of mixtures; construction and maintenance methods. Lectures, text, laboratory.

163 (43). SOILS IN HIGHWAY ENGINEERING. *Prerequisite: Civ. Eng. 135 and 136.* II. (*2*).

Physical properties of soil as they affect the design and construction of highways. Soil surveys and highway design; drainage, frost action, stabilization; mechanics of flexible surfaces; fills; embankments; swamp construction.

164 (44). HIGHWAY TRANSPORT. (*2*).

Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers; management of transportation companies. Open to seniors and graduates.

165 (45). HIGHWAY TRAFFIC CONTROL. I. (*2*).

Causes of and remedies for street traffic congestion and accidents. Open to seniors and graduates.

166 (47). HIGHWAY TRAFFIC SURVEYS. *Prerequisite: preceded or accompanied by Civ. Eng. 165 (45).* II. (*2*).

Traffic studies for highway planning and for the facilitation and safeguarding of traffic flow. Assigned reading and field work. Open to seniors and graduates.

167 (46). HIGHWAY AND RAILWAY ECONOMICS. II. (*3*).

Economics of highway and railway location, construction, and operation. Highway and railway finance. Effect on cost of grades, curves, and distance. Open to seniors and graduates.

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 (54). RAILWAY LOCATION DESIGN. (*3*).

Field and office practice of location and construction. Computation and design.

171 (56). ADVANCED RAILROAD LOCATION. *Prerequisite: Civ. Eng. 170.* I and II. (*3*).

The design of a railroad division, including paper location, selection of rolling stock, operating schedules, and appropriate facilities.

172 (52). RAILROAD MAINTENANCE. *Prerequisite: Civ. Eng. 70 (50).* II. (*2*).

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 (53). TERMINAL DESIGN. I and II. (*3*).

Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities. Text, problems, drawing work.

174 (53*a*). AIRPORT DESIGN AND CONSTRUCTION. *Prerequisite: Civ. Eng. 135,* I and II. (*3*).

Location and size of airports; design of runways; materials, types of construction for paved areas. Lectures, assigned reading, problems.

175 (55). 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 movement and transfer of passengers and freight.

176 (51). ECONOMICS OF RAILROAD CONSTRUCTION AND OPERATION. *Prerequisite: Civ. Eng. 70.* II. (*2*).

Statistical analysis of operating expenses. A general study of curve, grade, and train resistances, ruling grades, rise and fall, and virtual profiles. Study of line changes, grade reductions, and elimination of grade crossings. Lectures, text, problems. Open to seniors and graduates.

177 (57). RAILROAD ADMINISTRATION. (*3*).

Nature of the railroad organization; the various departmental and divisional functions; employee relationships; public relations; intercarrier traffic agreements. Open to seniors and graduates.

178 (58). TRANSPORTATION. (*2*).

History of transportation; relation of highway, waterway, railway, and airway transportation. Lectures, library research, seminar.

180 (26). SPECIFICATIONS, CONTRACTS, AND PROFESSIONAL CONDUCT. I and II. (*2*).

Engineering relations; ethics; war and civil contracts, and specifications. Lectures, reading, discussion.

181 (20). LEGAL ASPECTS OF ENGINEERING. I and II. (*3*).

Agency, partnership, private and municipal corporations, rights in land, mechanics' liens, workmen's compensation, and sales. Cases, lectures, discussion.

182 (21). Patent Law for Engineers. II. (*3*).

The 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, discussions.

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

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

PRIMARILY FOR GRADUATES

220 (239) (65). 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. Open only to graduates.

221. Advanced Theory of Reinforced Concrete. *Prerequisite: Civ. Eng. 121.* (*3*).

Design and analysis of special types of reinforced concrete structures. Lectures, text, 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. II and S.S. (*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.

227 (7*a*). Bridge Engineering. *Prerequisite: Civ. Eng. 123.* (*2*).

The selection of the proper bridge structure for a given location; economics of bridge types; determination of water ways; erection methods.

228 (7*c*). Bridge Design. *Prerequisite: Civ. Eng. 123.* (*3*).

The design of reinforced concrete and steel highway and railway bridges. Lectures, computations, drafting.

229 (7*i*). Mechanical Methods of Stress Analysis. *Prerequisite: preceded or accompanied by Civ. Eng. 124.* II. (*1*).

The mechanical analysis of stresses in statically indeterminate structures by means of models. The 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 (223). Precast and Prestressed Reinforced Concrete. *Prerequisite: Civ. Eng. 30 and 123.* (*2*).

Shrinkage, plastic flow, bond, precast beams, cast in place floors forming T beams, and prestressed reinforced concrete, precast members.

235 (225). Foundations and Underground Construction. *Prerequisite: Civ. Eng. 135 and preceded or accompanied by Civ. Eng. 136.* I and II. (*2*).

Design of substructures to meet various soil conditions; investigation of overloaded foundations; earth pressure in the deep underground; excavation problems; tunnel construction and design, critical diameter of tunnels and shafts, subsidence and legal aspects of damage due to subsurface construction.

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. Open only to graduates.

239 (65). 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. Open only to graduates.

240 (61). HYDROLOGICAL RESEARCH. *Prerequisite: Civ. Eng. 140 (10). (To be arranged).*

Assigned work on some special problem in the field of hydrology. An enormous amount of data is available for such studies. Open only to graduates.

241 (64). HYDRAULIC ENGINEERING RESEARCH. *Prerequisite: Civ. Eng. 141 (11). (To be arranged).*

Assigned work in hydraulic research; a wide range of matter and method permissible. Open only to graduates.

250 (60). 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. Open to graduates.

251 (36). PUBLIC WATER SUPPLY. *(3).*

Some of the broader aspects of public water supply, such as the conservation and protection of sources of supply, accepted water supply standards, purposes and results of water purification, legal rights and responsibilities of public water supply departments, and waterworks administration. Text, lectures, library reading.

252 (37). STATE HEALTH DEPARTMENT ENGINEERING PRACTICE. *(2).*

A critical and analytical study of the jurisdictions, 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).*

The functional design of sanitary engineering structures and typical plant layouts. Drafting room and field studies. Preparation of design reports.

255. SANITARY ENGINEERING SEMINAR. II. *(1).*

Preparation and presentation of reports covering assigned topics.

260 (66). HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT RESEARCH. *(To be arranged).*

Assigned work in the fields of highway engineering, highway transport, or highway traffic control. To obtain credit a thesis must be prepared which would be acceptable for publication. Open only to graduates.

270 (67). RAILROAD ENGINEERING RESEARCH. (*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. Open only to graduates.

280 (63). CIVIL ENGINEERING RESEARCH. (*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. Open only to graduates.

68. ELECTRICAL ENGINEERING

Professors Lovell, Cannon, Moore, Attwood, Stout, Dow, Holland, and Gault; Associate Professors Bull and Carey; Assistant Professors Martin and Hedrich; Mr. Cline, Mr. Gomberg, Mr. Needle, Mr. Kazda, Mr. Talpey, Mr. Brown, Mr. Hegler, Mr. Connor, Mr. Rogers, Mr. Deutsch, Mr. Kerr, Mr. Folkert, and Lecturer Hok.

Electrical engineers practice in a field of such great breadth that complete classification of subject matter and functional duties is difficult. The main subdivisions in which training is offered by the department may be mentioned briefly. Electrical power engineering has to do with the theoretical and practical phases of power generation, distribution, and utilization. Electrical communication deals with the transmission of signals, speech, music, and pictures by open-wire lines, by cable, and by radio. Illumination engineering is concerned with the problems arising in the production and utilization of light in accordance with correct principles of physics, economics, physiology, psychology, and art. Design involves the application of the fundamentals of electricity and heat to the production of new or improved electrical apparatus. Electronics deals with the individual and statistical behavior of electrons, ions, and atoms in various types of electrical equipment, in order to permit a rational analysis of the action in electron tubes, switches, rectifiers, welding processes, etc. Industrial electrical engineering includes the study of applications and control of electricity in industrial plants.

The Electrical Engineering Department recognizes the diversity of work to be performed by electrical engineers by offering two basic programs, one centered in electronics and communications and the other in electrical machinery and power. A student may adapt one or the other of these programs to a somewhat more specific purpose by the choice of appropriate elective courses, to the extent that time permits. Extensive specialization, however, is neither possible nor desirable in undergraduate curriculums and should be reserved for graduate study.

The course requirements are identical for the first three years in the electronics-communication and the machinery-power programs. A student must decide by the end of his junior year which of the two curriculums he wishes to follow, and thereafter may change his election only with the consent of the head of the department.

FACILITIES

THE ELECTRICAL ENGINEERING LABORATORIES include electrical machinery laboratories, communication laboratories, a photometric laboratory, electronics laboratories, servomechanisms laboratory, measurements and instrumentation laboratories, and a heat-transfer laboratory.

The electrical machinery laboratories are fully equipped with direct- and alternating-current motors, generators, and control of various types, and include the necessary complement of meters and oscillographs. The communication laboratories are well equipped with oscillators, vacuum-tube voltmeters, impedance bridges, cathode-ray oscillographs, microwave equipment, and artificial telephone lines and cables. The photometric laboratory provides facilities for class exercises and research work in the characteristics of light sources and in the study of models of the interior lighting of buildings. The electronics laboratories contain a seventy-thousand-volt surge generator, a sixty-thousand-volt cathode-ray oscillograph needed to study electric-arc behavior, transient features of igniter rods and controlled rectifiers, etc. The electrical measurements laboratories are provided with standards of resistance, inductance, and capacitance, standard cells, and other equipment needed to calibrate meters and instrument transformers and to make various types of bridge measurements. The heat transfer laboratory offers a beginning in heat transfer study, and is unique in possessing a Hydrocal—a hydrodynamic device for solving heat transfer problems.

The servomechanisms laboratory is equipped for the study of the wide variety of components employed in modern control. Hydraulic, electric, and electronic units are included, together with appropriate measuring devices and controlled power supplies.

REQUIRED COURSES

The required courses offered by the department are designed to give every student a thorough basic training in the principles of electrical engineering. The aim is to develop well-rounded engineers rather than narrow technicians. The staff of the Department of Electrical Engineering, by constant study and revision of course content and teaching method, aims to offer such work as will react to the ultimate benefit of the student rather than to his immediate gain. Throughout, the teaching of theory and its modifications by practice, the development of analytic judgment, and the acquiring of a fundamental scientific background are emphasized. The acquisition of specific factual knowledge is left, except when necessary to sound pedagogy, to the training in actual experience through which every electrical graduate must go during his first years out of school.

In special cases, for good and sufficient reasons, some substitutions for regular courses may be permitted.

Scholarships and fellowships are available at the University for assignment to students of outstanding ability and high scholastic standing. Any student desiring to ascertain the possibilities in this respect, or to make application, should consult the chairman of the Electrical Engineering Department. Application for a Graduate School fellowship must be made before March 1. See sections 43 and 44.

CHOICE OF ELECTIVE WORK

With regard to electives in the nontechnical group, the student is advised to select such courses in the arts and sciences as will contribute to a broad, liberal education. Students feeling the lack of sufficient facility in the use of English are strongly urged to elect advanced courses in this subject, for the ability to speak and write good English is essential to a broad education in general, as well as to the highest success in the engineering profession.

The following elective groups are presented to help the student plan a consistent and unified program of the greatest possible value. It is recognized that only a small part of the courses listed in any group can be elected in the undergraduate curriculum, and that the major specialization must come later. A year or more of graduate work is recommended for able students, and such students should begin as early as possible to plan the graduate with the undergraduate program. Members of the staff are always pleased to aid a student in his choice of elective courses.

SUGGESTED ELECTIVE COURSES

Electrical Power Engineering

Elec. Eng. 102 (31), Symmetrical Components
Elec. Eng. 155 (33), Industrial Electrical Engineering
Elec. Eng. 158 (8), Electric Traction
Elec. Eng. 181 (83), Industrial Electronics
Elec. Eng. 196 (16), Electrical Rectification
Elec. Eng. 240 (19), Study of Design—Power Plants
Elec. Eng. 241 (20), Study of Design—Transmission and Distribution
Elec. Eng. 242 (36), Electric Rates and Cost Analysis
Elec. Eng. 255 (34), Servomechanisms
Elec. Eng. 280 (82), Theory of Gaseous-Conducting Electronic Apparatus
Mech. Eng. 105 (5), Thermodynamics
Mech. Eng. 113 (13), Steam Turbines
Mech. Eng. 140 (16), Water Turbines
Civ. Eng. 142 (12), Water Power

Illumination

Elec. Eng. 173 (15), Advanced Lighting
Elec. Eng. 174 (70), Electrical Distribution, Wiring and Control for Lighting
Elec. Eng. 175 (74), Lighting Equipment
Elec. Eng. 194 (73), Photoelectric Cells
Elec. Eng. 271 (71), Interior Illumination—Study of Design
Elec. Eng. 280 (82), Theory of Gaseous-Conducting Electronic Apparatus
Physics 186, Light
Physics 187, Geometrical Optics
Physics 188, Laboratory Work in Light

Fine Arts 82, History of Art
Psychology 31, Introductory Psychology
Psychology 160, Psychology of Vision
Design 4, Theory of Color
Arch. 15, History of Architecture

Electrical Engineering Design

Elec. Eng. 151, Advanced Theory of Alternating-Current Machinery
Elec. Eng. 201, Transients
Elec. Eng. 210 (25), 211 (25*a*), Electromagnetic Field Theory
Elec. Eng. 212 (27), Electric and Magnetic Properties of Materials
Elec. Eng. 255 (34), Servomechanisms
Elec. Eng. 260 (52), Heat Problems in Electrical Design
Advanced courses in mathematics and physics

Communication

Elec. Eng. 103, Electroacoustics
Elec. Eng. 196 (16), Electrical Rectification
Elec. Eng. 201 (26), Transients
Elec. Eng. 210 (25), 211 (25*a*), Electromagnetic Field Theory
Elec. Eng. 220, Microwave Engineering
Elec. Eng. 221, Radiation and Propagation
Elec. Eng. 225 (22*b*), Television
Elec. Eng. 285 (81), Theory of Thermionic Vacuum Tubes
Elec. Eng. 286, Microwave Electron Tubes

General Theory and Measurement

Elec. Eng. 101 (10), Advanced Theory of Electrical Circuits
Elec. Eng. 102 (31), Symmetrical Components
Elec. Eng. 135, Methods of Instrumentation
Elec. Eng. 201 (26), Transients
Elec. Eng. 210 (25), 211 (25*a*), Electromagnetic Field Theory
Elec. Eng. 212 (27), Electric and Magnetic Properties of Materials
Elec. Eng. 255 (34), Servomechanisms
Elec. Eng. 280 (82), Theory of Gaseous-Conducting Electronic Apparatus
Elec. Eng. 285 (81), Theory of Thermionic Vacuum Tubes
Elec. Eng. 286, Microwave Electron Tubes

Electronics

Elec. Eng. 194 (73), Photoelectric Cells and Their Applications
Elec. Eng. 196 (16), Electrical Rectification
Elec. Eng. 201 (26), Transients
Elec. Eng. 210 (25), 211 (25*a*), Electromagnetic Field Theory
Elec. Eng. 212 (27), Electric and Magnetic Properties of Materials
Elec. Eng. 280 (82), Theory of Gaseous-Conducting Electronic Apparatus
Elec. Eng. 285 (81), Theory of Thermionic Vacuum Tubes
Elec. Eng. 286, Microwave Electron Tubes
Physics 166, High-Frequency Measurements

Physics 265, Conduction of Electricity through Gases
Physics 196, Atomic and Molecular Structure

Industrial Electrical Engineering

Elec. Eng. 155 (33), Industrial Electrical Engineering
Elec. Eng. 181 (83), Industrial Electronics
Elec. Eng. 242 (36), Electric Rates and Cost Analysis
Mech. Eng. 135 (35), Factory Management
Mech. Eng. 136 (36), Factory Management
Econ. 71, Principles of Accounting I
Econ. 72, Principles of Accounting II
Bus. Ad. 142, Industrial Relations
Bus. Ad. 111, Industrial Cost Accounting
Bus. Ad. 62, Financial Principles
Bus. Ad. 161, Financial Policies

Electrical Engineering 199 (9) or 299 (18) may be added to any of the programs. These courses cover individual research problems which may be selected in accordance with the wishes of the student, and which may be conducted by laboratory or library work, or by analytical study. The election may be for any number of hours approved by the instructor involved, with consideration of the suitability to the student's program. Electrical Engineering 199 (9) is intended for undergraduates, and involves rather close faculty supervision. Electrical Engineering 299 (18), intended for graduates, involves independent work with little supervision and requires a report in the form of a thesis.

Advice to students of other colleges and universities with regard to planning their courses before coming to the University is given in section 14.

Military and Naval Science. The attention of prospective students in electrical engineering is called to the Reserve Officers' Training Corps. Work offered in the Signal Corps group is of special interest to students in electrical engineering for they are well qualified for it. Those who consider taking military or naval science are urged to enroll at the beginning of their course. For further details see sections 59 and 62.

CURRICULUMS IN ELECTRICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Electrical Engineering) are required to complete either the machinery-power curriculum or the electronics-communication curriculum detailed below. For the definition of an hour of credit see section 36.

MACHINERY—POWER

a) *Preparatory Courses*	*Hours*
English 11 (1), 21 (2), 12 (3), and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical electives	6
Mathematics 13, 14, 53, 54, 57	18
Physics 45, 46	10

	Hours
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 1 and Ch. and Met. Eng. 1	5
Economics 53, 54	6
Total	68

b) *Secondary and Technical Courses*

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
Civ. Eng. 21 (2), Theory of Structures	3
Mech. Eng. 82 (2), Elements of Machine Design	3
Mech. Eng. 13 (3), Heat Engines	4
Mech. Eng. 14 (3*a*), Laboratory	1
Elec. Eng. 2, D.C. Apparatus and Circuits	4
Elec. Eng. 3, A.C. Circuits	4
Elec. Eng. 10 (1), Principles of Electricity and Magnetism	4
Elec. Eng. 100 (17), Electromechanics	4
Elec. Eng. 130 (Physics 147), Electrical Measurements	3
Elec. Eng. 140 (11), Power Plants, Transmission, and Distribution	5
Elec. Eng. 150 (4), A.C. Apparatus	4
Elec. Eng. 151 (4*a*), Electrical Machinery or 155 (33), Industrial Electrical Engineering	3
Elec. Eng. 160 (5), Fundamentals of Electrical Design	4
Elec. Eng. 170 (7), Illumination and Photometry	2
Elec. Eng. 180 (12), Electronics and Electron Tubes	4
Total	66

Summary:

Preparatory Courses	68
Secondary and Technical Courses	66
Electives	6
Total	140

ELECTRONICS—COMMUNICATION

a) *Preparatory Courses*

English 11 (1), 21 (2), 12 (3) and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical electives	6
Mathematics 13, 14, 53, 54, 57	18
Physics 45, 46	10

	Hours
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 1 and Ch. and Met. Eng. 1	5
Economics 53, 54	6
Total	68

b) *Secondary and Technical Courses*

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. 82 (2), Elements of Machine Design	3
Mech. Eng. 13 (3), Heat Engines	4
Elec. Eng. 2, D.C. Apparatus and Circuits	4
Elec. Eng. 3, A.C. Circuits	4
Elec. Eng. 10 (1), Principles of Electricity and Magnetism	4
Elec. Eng. 100 (17), Electromechanics	4
Elec. Eng. 101 (10), Advanced Theory of Electrical Circuits	3
Elec. Eng. 120 (22), Radio Communication	4
Elec. Eng. 121 (22*a*), Advanced Radio Communication, or 126 (41), Telephone Communication, or 181 (83), Industrial Electronics	4
Elec. Eng. 130 (Physics 147), Electrical Measurements	3
Elec. Eng. 141 (11*a*), Economic Applications in Electrical Engineering	2
Elec. Eng. 150 (4), A.C. Apparatus	4
Elec. Eng. 160 (5), Design of Electrical Machinery	4
Elec. Eng. 180 (12), Electronics and Electron Tubes	4
Total	65

Summary:

Preparatory Courses	68
Secondary and Technical Courses	65
Electives	7
Total	140

PROGRAMS

Students who earn an average grade of B, 3.0 average, on the first-semester program may complete the requirements in eight semesters. See Rules Governing Election of Studies, section 27*b*.

For uniform first-year program see section 47.

NOTE.—See section 32*m* for ruling on freshmen repeating subjects graded D.

SECOND YEAR

	Hours		Hours
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Drawing 3	2	Elec. Eng. 2	4
Eng. Mech. 1	3	Nontechnical electives	3
Nontechnical electives	3	Mil. or Nav. Science	(1)
Mil. or Nav. Science	(1)		16 or (17)
	17 or (18)		

THIRD YEAR

Elec. Eng. 10 (1)	4	Elec. Eng. 150 (4)	4
Elec. Eng. 3	4	Elec. Eng. 180 (12)	4
Eng. Mech. 2	4	Elec. Eng. 100 (17)	4
Eng. Mech. 2*a*	1	Elec. Eng. 130 (Physics 147)	3
Eng. Mech. 3	3	English (Group III)	2
Math. 57	2		17
	18		

MACHINERY—POWER

SUMMER

	Hours
Mech. Eng. 13 (3)	4
Eng. Mech. 4	3
Mech. Eng. 14 (3*a*)	1
	8

FOURTH YEAR

	Hours		Hours
Elec. Eng. 151 or 155 (33)	3	Elec. Eng. 160 (5)	4
Elec. Eng. 140 (11)	5	Elec. Eng. 170 (7)	2
Mech. Eng. 82 (2)	3	Civ. Eng. 21 (2)	3
Econ. 53	3	Econ. 54	3
Elective	3	Elective	3
	17		15

ELECTRONICS—COMMUNICATION

SUMMER

	Hours
Mech. Eng. 13 (3)	4
Eng. Mech. 4	3
	7

FOURTH YEAR

	Hours		Hours
Elec. Eng. 101 (10)	3	Elec. Eng. 160 (5)	4
Elec. Eng. 120 (22)	4	Elec. Eng. 141 (11*a*)	2
Mech. Eng. 82 (2)	3	Elec. Eng. 121 (22*a*), or 126 (41), or 181 (83)	4
Econ. 53	3	Econ. 54	3
Elective	3	Elective	4
	—		—
	16		17

CO-OPERATIVE COURSE IN ELECTRICAL ENGINEERING AND INDUSTRY (FIVE YEARS)

The co-operative plan enables a student who is permitted to enter the course to work for fifteen months, divided into four periods, with some industrial concern, where he is rotated through various departments as a cadet engineer. Upon completion of the industrial work and of the University credit requirements of 132 hours, the student will receive eight credit hours. About five calendar years are required for the course.

Permission to enter the course is granted only to those students who have received at least one semester's University credit with a grade average distinctly above the passing requirement, and for whom definite arrangments have been made with some particular industrial concern. While with the concern the co-operating student receives wages which are satisfactory for a training course but are not intended to be sufficient to enable the student to work his way through the University. If mutually agreeable to the co-operating student and industrial concern, this course may lead to permanent employment.

Co-operative relation is established only with such industries as are able and willing to offer a definite program of work of educational value. No credit, therefore, is given for industrial work except as arranged under the co-operative plan.

COURSES IN ELECTRICAL ENGINEERING

2. DIRECT-CURRENT CIRCUITS AND MACHINERY. *Prerequisite: preceded or accompanied by Physics 46. (4).*

Electric circuit theory, measuring instruments, and elementary treatment of motor and generator theory. Three lectures and one four-hour laboratory period.

3. ALTERNATING-CURRENT CIRCUITS. *Prerequisite: Elec. Eng. 2 or 5 (2a). (4).*

Alternating-current circuits, including single-phase series and parallel connections, polyphase circuits, balanced and unbalanced; e.m.f.'s in generator windings; transformers. Two lectures, one four-hour computing period, and one four-hour laboratory period.

5 (2*a*). DIRECT- AND ALTERNATING-CURRENT APPARATUS AND CIRCUITS. *Prerequisite. Math. 54 and Physics 46. (4).*

Characteristics of direct- and alternating-current motors and generators; problem work on these and on electric circuits. A general course for nonelectrical students. Not open to electrical engineering students. Required of all other students in engineering. Three lectures and one four-hour laboratory period.

7. MOTOR CONTROL AND ELECTRONICS. *Prerequisite: Elec. Eng. 5. (4).*

Study of direct- and alternating-current motors and control equipment suited to particular applications; electronic tubes and circuits including industrial types. Three lectures and one four-hour laboratory period. Not open to electrical engineering students.

10 (1). 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.

100 (17). ELECTROMECHANICS. *Prerequisite: Elec. Eng. 3. (4).*

Analysis of complex alternating-current waves; average and effective values; meaning of power factor; the method of the complex variable in a.c. problems; the application of differential equations to 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 (10). ADVANCED THEORY OF ELECTRICAL CIRCUITS. *Prerequisite: Elec. Eng. 100 (17). (3).*

General network analysis; artificial lines, attenuators, filters, equalizers. Transmission of electric waves on lines; reflections at terminals. Lectures and problems.

102 (31). CIRCUIT ANALYSIS BY SYMMETRICAL COMPONENTS. *Prerequisite: preceded or accompanied by Elec. Eng. 100 (17). (2).*

Representation of unbalanced polyphase currents and voltages by component symmetrical sets; solution of unbalanced circuit problems by use of symmetrical components; faults on power systems. Lectures, recitations, and problems.

103. ELECTROACOUSTICS. *Prerequisite: Math. 57 and Elec. Eng. 100 or permission of instructor.* I. (2).

Derivations of the equations for propagation of sound in gases, liquids, and solids. Standing-wave phenomena; resonant systems. Electric-circuit analogs of mechanical and acoustical systems; equivalent electrical networks. Electrostatic, electromagnetic, electrodynamic, and piezoelectric transducers. Systems for electric transmission, recording, and reproduction of sound; distortions and noise of acoustic origin. Lectures and problems.

120 (22). RADIO COMMUNICATION. *Prerequisite: Elec. Eng. 100 (17) and 180 (12) 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 (22*a*). ADVANCED RADIO COMMUNICATION. *Prerequisite: Elec. Eng. 120 (22). (4).*
Wide-band amplifiers; radio-frequency amplification; modulation and detection; transmitting and receiving circuits; radio-frequency transmission lines. Lectures and laboratory.

126 (41). TELEPHONE COMMUNICATION. *Prerequisite: preceded or accompanied by Elec. Eng. 101 (10). (4).*
Telephone circuits, networks, and apparatus. Lectures and laboratory.

130 (PHYSICS 147). ELECTRICAL MEASUREMENTS. *Prerequisite: preceded or accompanied by Elec. Eng. 100 (17). (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.

135. METHODS OF INSTRUMENTATION—A. *Prerequisite: Elec. Eng. 100 (17) and 180 (12). (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 (2a). (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.

140 (11). POWER PLANTS AND TRANSMISSION SYSTEMS—ECONOMICS OF DESIGN. *Prerequisite: Elec. Eng. 3 or 5 (2a). (5).*
Economic features of power-plant design; economic decay, obsolescence, load division between units, plant location, conductor section, selection of circuit breakers and reactors. Lectures, recitations, and problems.

141 (11*a*). ECONOMIC APPLICATIONS IN ELECTRICAL ENGINEERING. *Prerequisite: Elec. Eng. 3. (2).*
Corporate finance, cost of exchanges, economic decay, obsolescence, plant location, and conductor section. Problems with special application to the communication field. Lectures and recitations.

150 (4). ALTERNATING-CURRENT MACHINERY. *Prerequisite: Elec. Eng. 3. (4).*
Theory and operating characteristics of polyphase synchronous and induction machines; various types of single-phase motors; selsyn devices. Lectures, computing period, and laboratory.

151. ADVANCED THEORY OF ALTERNATING-CURRENT MACHINERY. *Prerequisite: Elec. Eng. 150 (4). (3).*
Design and performance of polyphase and single-phase machines, especially induction motors. Lectures and computing period.

155 (33). INDUSTRIAL ELECTRICAL ENGINEERING. *Prerequisite: preceded by Elec. Eng. 5 (2a) or Elec. Eng. 150 (4). (3).*
Motors and control equipment suited to particular applications; amplidyne and similar control; electronic motor control. Lectures and laboratory.

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

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

160 (5). Fundamentals of Electrical Design. *Prerequisite: Elec. Eng. 3 and 10 (1).* (*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 (7). 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 three-hour laboratory period.

171 (*7a*). Building Illumination. (*1*).

Proper illumination for typical interiors such as schools, offices, and residences. Designed to acquaint students of public health, factory administration, and architecture with criteria for determining whether the lighting is good or harmful to the eyes. One illustrated lecture each week and one or two demonstration periods during the semester. Not open to electrical engineering students.

172 (*7b*). Electric Lighting and Distribution. (*2*).

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

173 (15). Advanced Lighting. *Prerequisite: preceded by Elec. Eng. 3 and 170 (7).* (*3*).

Selection by the student of a topic, with instructor's approval, for continued and intensive study; short oral reports by each student to the class each week; written report and bibliography presented to instructor at end of course.

174 (70). Electrical Distribution, Wiring, and Control for Lighting. *Prerequisite: Elec. Eng. 3 and 170 (7).* (*2*).

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

175 (74). Lighting Equipment. *Prerequisite: Elec. Eng. 3 and 170 (7).* (*2*).

Analysis of design and performance of lamps, reflectors, refractors, diffusers, and other light-control media, and of complete luminaires. Lectures and problems.

180 (12). Electronics and Electron Tubes. *Prerequisite: preceded by Elec. Eng. 3 and preceded or accompanied by Elec. Eng. 10 (1).* (*4*).

Amplifier gain, distortion, coupling; oscillators; thermionic emission; space charge control, cathode ray tubes, vacuum tube voltmeters. Energy-level diagrams, ionization and excitation potentials. Three lectures and one three-hour laboratory period.

181 (83). INDUSTRIAL ELECTRONICS. *Prerequisite: Elec. Eng. 100 (17) and 180 (12). (4).*

An applicational study of electronic circuits, methods, and problems in the manufacturing and electric power industries. Three lectures and one four-hour laboratory period.

194 (73). PHOTOELECTRIC CELLS AND THEIR APPLICATIONS. *Prerequisite: permission of instructor. (2).*

Study of operating characteristics of photoelectric cells; amplifying circuits and relays; industrial applications; photoelectric photometers. Lectures and laboratory work.

196 (16). ELECTRICAL RECTIFICATION. *Prerequisite: preceded by Elec. Eng. 180 (12) and preceded or accompanied by Elec. Eng. 100 (17). (2).*

Equipment and circuits used for rectification; study of wave forms in circuits composed of resistance, inductance, capacitance, and batteries. Transformer connections, single phase and polyphase. Lectures and recitations.

199 (9). 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. 299 (18) in that the instructor is in close touch with the work of the student. Elec. Eng. 199 (9) may be elected by seniors who have suitable preparation. Elec. Eng. 299 (18) is for graduates.

201 (26). TRANSIENTS. *Prerequisite: Elec. Eng. 100 (17). (2).*

Advanced theory of electrical circuits. Operational methods of solution for transients in circuits with lumped constants; circuits with distributed constants; long lines; cables. Lectures and discussions.

210 (25). ELECTROMAGNETIC FIELD THEORY. *Prerequisite: Elec. Eng. 3 and 10 (1). (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 (25a). ENGINEERING APPLICATION OF ELECTROMAGNETIC FIELD THEORY. *Prerequisite: Elec. Eng. 210 (25). (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 (27). ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS. *Prerequisite: Elec. Eng. 180 (12), 210 (25), and 211 (25a). (3).*

The 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 (22a). (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 AND PROPAGATION. *Prerequisite: Elec. Eng. 120. (3).*

Fundamental theory. Simple antennas; arrays and reflecting systems. Ionosphere. Reflection, refraction, and diffraction. Tropospheric propagation. Lectures.

225 (22*b*). TELEVISION. *Prerequisite: preceded or accompanied by Elec. Eng. 121 (22a). (2).*

Basic principles, cathode-ray scanning devices, and television receivers and transmitters. Lectures.

240 (19). STUDY OF DESIGN—POWER PLANTS. *Prerequisite: Elec. Eng. 140 (11) and 100 (17). (2).*

Modern power station design and performance. Detailed study of electrical equipment. Special problems of interconnection, frequency control, stability, single-phase short-circuit study through use of symmetrical components.

241 (20). STUDY OF DESIGN—ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEMS. *Prerequisite: Elec. Eng. 140 (11) and 100 (17). (2).*

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 (36). ELECTRIC RATES AND COST ANALYSIS. *Prerequisite: Elec. Eng. 140 (11).* II. *(1).*

Capitalization; fair return on investment; 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.

255 (34). SERVOMECHANISMS. *Prerequisite: Elec. Eng. 201 (26) or Math. 147. Elec. Eng. 155 (33) recommended. (3).*

Study of automatic controller design and application, including mathematical theory. Two lectures and one three-hour laboratory period.

260 (52). HEAT PROBLEMS IN ELECTRICAL DESIGN. *Prerequisite: permission of the 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 Elec. Eng. 160. (3).*

Includes calculations for machines of given ratings, use of design sheets, practical limits for many items of design, calculation of performance and use of ventilation. Computating period.

271 (71). INTERIOR ILLUMINATION, STUDY OF DESIGN. *Prerequisite: Elec. Eng. 170 (7) 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.

280 (82). GASEOUS-CONDUCTING ELECTRONIC APPARATUS. *Prerequisite: Elec. Eng. 180 (12). (3).*

Current conduction, ignition, and extinction in thermionic and mercury-arc rectifiers, thyratrons, ignitrons, ionized gas light sources, circuit breakers, and spark gaps. Two lectures and one four-hour laboratory period.

284. INTRODUCTION TO ELECTRICAL FLUCTUATION PHENOMENA. *Prerequisite: Elec. Eng. 100, Math. 57, and preceded or accompanied by Math. 152.* S.S., 1949. (*2*).

Generation of common types of random fluctuation: shot noise in vacuum tubes, thermal noise in conductors, random errors in servo systems, i.e. radar tracking. Description of fluctuation phenomena as superposition of a large number of transients with random distribution in time. Correlation, power spectrum. Response of linear and nonlinear circuits to excitation by noise. Statistical properties of currents produced by noise and of currents produced by communication signals. Outline of information theory. Lectures.

285 (81). THEORY OF THERMIONIC VACUUM TUBES. *Prerequisite: Elec. Eng. 180 (12).* (*3*).

Electromagnetic fields and electron flow in high-vacuum tubes; thermionic electron emission; noise level analysis, transit time and circuit effects at very high frequencies. Two lectures and one four-hour laboratory period.

286. MICROWAVE ELECTRON TUBES. *Prerequisite: Elec. Eng. 180 (12).* (*3*).

Theory and operation of ultra-high-frequency electron tubes, including klystrons, magnetrons, triodes, and tetrodes. Two lectures and one four-hour laboratory period.

287 (84). ELECTRON BEAM TUBES. *Prerequisite: Elec. Eng. 180 (12).* (*3*).

Electron optics; electronic principles of cathode-ray, image, and pickup, electron-multiplier, beam-switching and beam deflection tubes; secondary emission and phosphors. Two lectures and one four-hour laboratory period.

299 (18). RESEARCH WORK IN ELECTRICAL ENGINEERING. *Prerequisite: permission of head of department. (To be arranged).*

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 a report in the form of a thesis.

69. ENGINEERING MECHANICS

Professors Eriksen, Menefee, Van den Broek, Ormondroyd, and Dodge; Associate Professors Swinton, Olmsted, Hansen, Wojtaszak, Liddicoat, and Everett; Assistant Professor Hagerty; Mr. Chenea, Mr. G. Hess, Mr. R. Hess, Mr. Hunter, Mr. Corson, Mr. Thomson, Mr. Pattison, Mr. Yates, and Mr. Essenberg.

Engineering mechanics is the subject which, probably more than any other, tests the student's ability to use the technical training given him in preceding courses and at the same time prepares him for what is to follow.

No definition of engineering, from whatever angle given, is complete without some reference to forces. It is in mechanics that the student is given the engineer's conception and methods of handling forces. This is accomplished by:

a) A general, required three-hour course in fundamentals, definitions, and conceptions, of the ways in which mathematics, analytical and graphical, may be used with the laws of equilibrium, to solve problems dealing with forces, followed by:

b) A required four-hour course on strength and elasticity of materials. This course is supplemented by a one-hour laboratory course.

c) A required three-hour course in dynamics, supplemented by a one-hour elective course in the laboratory.

d) A required three-hour course in fluid mechanics. The principles of fluid flow are demonstrated in the fluids laboratory.

LIBRARY. The general engineering library has books for collateral reading and study in mechanics.

THE PHYSICAL TESTING LABORATORY occupies 102 West Engineering Building. The equipment comprises a series of universal testing machines with capacities from 50,000 to 200,000 pounds, a 230,000-inch-pound torsion machine, impact testing machines, fatigue testing machines, Brinell and Rockwell hardness testers, and other equipment for conducting standard A.S.T.M. tests.

The special accessory equipment includes one six-element telemeter strain gage, Huggenberger extensometers, Martens mirror strain gages, electrical micrometer gages, contact micrometer gages, Berry gages, S-R 4 electric strain gages with auxiliary equipment, and one vertical and one horizontal portable seismograph.

THE FLUID FLOW LABORATORY has an area about 24 by 50 feet. It has a pump and piping connected with a sump and constant head tank, which, with scales and weighing tanks, make possible tests of small meters, nozzles, and orifices. Among other equipment are manometers, viscometers, Hele-Shaw apparatus, and a small balance for the study of lift, drag, and torque on small bodies. There is extensive equipment for visualizing flow patterns by projection on a screen and for demonstrating the flow of both air and water. The space and equipment are adaptable to use for studying special advanced problems in flow of fluids as well as for undergraduate work.

CURRICULUM IN ENGINEERING MECHANICS AND REQUIREMENTS FOR GRADUATION

The following curriculum leading to the degree of Bachelor of Science in Engineering (Engineering Mechanics) has been provided to meet the increasing demand from industry for graduates with the thorough theoretical grounding in mechanics and mathematics needed to cope with difficult engineering problems of research type.

a) *Preparatory Courses*	*Hours*
English 11 (1), 21 (2), 12 (3), and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical electives	6
Mathematics 13, 14, 53, 54	16

	Hours
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 1 and Ch. and Met. Eng. 1	5
Economics 53 and 54	6
Total	66

b) *Secondary Courses*

Civ. Eng. 4 (Surv. 4)	2
Eng. Mech. 1, 2, 2a, 3, 4	14
Elec. Eng. 5 (2*a*)	4
Civ. Eng. 21 (2)	3
Mech. Eng. 13 (3)	4
Total	27

c) *Advanced Courses*

Technical group, in some specified technical engineering department, including an advanced design course; approximately	13
Eng. Mech. 124, 131, 141, plus advanced electives	16
Mathematics 103, 147, 150	9
Elec. Eng. 135	3
Electives	6
Grand total	140

The number of hours in the technical, mathematics, and elective groups is subject to variation on the advise of the Chairman of the Department.

COURSES IN ENGINEERING MECHANICS

1. STATICS. *Prerequisite: must be 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, and centroids. Recitations, lectures, problems.

2. STRENGTH AND ELASTICITY OF MATERIALS. *Prerequisite: preceded by Eng. Mech. 1 and preceded or accompanied by Math. 54.* I and II. (*4*).

The application of the 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.

2*a*. LABORATORY IN STRENGTH OF MATERIALS. *Prerequisite: preceded or accompanied by Eng. Mech. 2.* I and II. (*1*).

Familiarizes the student with the behavior of engineering materials under load in both the elastic and the plastic ranges. Includes the use and calibrating of testing machines and their accessories. The strain measuring equipment ranges through the mechanical, optical, and electrical. Approximately twenty experiments are performed in which all the testing machines and strain gages are employed. In addition to the usual tests such as tension, compression, torsion, bending, impact, hardness, and columns, a photoelastic experiment is performed.

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.

3*a*. EXPERIMENTAL DYNAMICS. *Prerequisite: preceded or accompanied by Eng. Mech. 3.* (*1*).

Experiments with acceleration, vibration, balancing, critical speeds, and gyroscopics. One-hour laboratory period, with report, each week.

4. FLUID MECHANICS. *Prerequisite: Eng. Mech. 2 and Math. 54.* I and II. (*3*).

Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids, Mach's number; dynamical similitude and Pi theorem. Recitations, lectures, demonstrations.

4*a*. 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.

6. STATICS AND DYNAMICS. *Prerequisite: Phys. 45, preceded by Math. 54.* (*4*).

Fundamental principles of mechanics and their application to engineering problems. Forces, components, vectors, moments, couples, friction, centroids, motions of a particle, dynamics of moving bodies, Newton's laws, simple harmonic motion, elementary vibration problems, balancing, impulse, momentum, work and energy. Recitations, lectures, problems. Open only to chemical and metallurgical engineers.

100. SEMINAR IN ENGINEERING MECHANICS. (*To be arranged.*)

110 (10). RESEARCH IN STRENGTH OF MATERIALS. I and II. (*To be arranged*).

Study and experimental investigation of the behavior of metals under working conditions, including discussions of fatigue, influences of surface conditions, creep, wear, corrosion, inelastic properties and effect on dynamic strength, stress concentrations, analytically and experimentally. Special problems involving laboratory tests and application of theory in Eng. Mech. 2, 2*a*, and 3.

120 (10*a*). Research in Theory of Elasticity. *(To be arranged).*

Special problems involving application of theory and experimental investigation, including photoelastic analysis.

121 (10*b*). Research in Theory of Structures. *(To be arranged).*

Special problems in the theory of structures, concerning the determination of stresses, strains and displacements, elastic stability, impact effect and vibration of engineering structures such as buildings, pressure vessels, aircraft structures, machine frames, and bridges.

122 (7). Research in Testing Materials. *Prerequisite: Eng. Mech. 2. (To be arranged).*

123 (9 and 18). Advanced Theory of Strength. *Prerequisite: Eng. Mech. 2. (4).*

Analysis of redundant structures by the theory of elastic energy and by the theory of limit design, with special emphasis on the determination of strength based on limiting strain rather than on limiting stress. The analysis of columns is given particular attention.

124 (13*a*). Applied Elasticity. *Prerequisite: Eng. Mech. 2 and 3 and Math. 103, 150. (3).*

Fundamentals of the theory of elasticity and its application to engineering problems. Analysis of the stress, strain, and displacement of elastic bodies. General equations of equilibrium and compatibility. Applications to the bending of curved and prismatic bars, torsion of noncircular bars, and problems involving plane stress and plane strain, including the determination of stress concentration factors. Intended as an introduction to the advanced stress analysis of elastic materials.

125 (13*b*). Theory of Thin Elastic Plates. *Prerequisite: Eng. Mech. 2 and 3 and Math. 103, 150, 152. (3).*

General equation for deflection of thin plates. Bending of circular plates under various loading conditions; bending of rectangular plates. Application in design of tubular built-up sections and girders. Plates on elastic foundation.

126 (14). Advanced Stress Analysis. *Prerequisite: Eng. Mech. 2 and Math. 103. (2).*

Stress concentration in tension and compression produced by fillets and holes. Application of hydrodynamic, electrical, and membrane analogies to the study of stress concentration. Stresses in shafts of variable cross-sections; stresses due to shrinkfit pressure; stresses in curved bars and springs of various types. Design of proving rings and diaphragms. Stresses in flywheels, rotating disks, and rotors.

127 (15). Theory of Structures in Ship Design. *Prerequisite: Eng. Mech. 2 and Math. 103 or equivalent. (3).*

Statically indeterminate structures in general. The 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 (25). Stability of Elastic Structures. *Prerequisite: Eng. Mech. 2 and 3 and Math. 103, 147, 150. (3).*

Bending of bars under the action of lateral and direct load. Buckling of slender bars. Effect of eccentricity and initial curvature. Practical applications of the design of columns. Stability of I-beams; stability of thin plates under compression and shear; stability of thin-walled structures.

130 (10*c*). 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. These investigations may also deal with the fundamentals of mechanics, such as the study of friction and internal hysteresis of materials.

131 (12). FUNDAMENTAL VIBRATION ANALYSIS. *Prerequisite: Eng. Mech. 3, Math. 103. (3).*

The theory of vibration of single and multiple mass systems with or without damping in translation and rotation; the impedance or mobility methods in analysis of complex vibratory systems; vibration of distributed mass systems (strings, beams, and shafts); self-induced vibration (stability).

132 (8). ADVANCED DYNAMICS. *Prerequisite: Eng. Mech. 131, Math. 103, 147, 150. (2).*

Advanced dynamics of rigid bodies in systems of engineering interest. Lagrange's equations.

133 (21). HISTORY OF DYNAMICS. *Prerequisite: Eng. Mech. 3 and Math. 103. (2).*

A review of the important publications in which the fundamental principles of dynamics were developed. *Mechanical Questions,* Aristotle. The influence of astronomical theories on the development of dynamics. *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 (8). 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. 131 and Math. 147 and 152. (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.

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, photo-viscosity, secondary flow in conduits and channels, stability of modes of fluid flow.

141. ADVANCED FLUID MECHANICS. *Prerequisite: Eng. Mech. 4, Math. 103, 150. (3).*

Equations of viscous fluid motion; solution of special problems; dimensional analysis, the pi-theorem, flow in closed conduits, velocity distribution, roughness, boundary layer, mechanics of turbulent flow.

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.

221. THEORY OF PLASTICITY. *Prerequisite: Eng. Mech. 124. (3).*

Fundamentals of the theory of plasticity and their application; study of finite deformations and strain; stress and strain referred to Eulerian and Lagrangian co-ordinates; stress and strain invariants; equilibrium conditions; work done during plastic deformation; stress-strain relations in the elastic and plastic states; stress and strain deviations; yield conditions; strain velocities; isotropic strain hardening; applications to torsional problems; flow through dies, and drawing of metals.

225. THEORY OF SHELLS. *Prerequisite: Eng. Mech. 125. (3).*

The fundamental theory of deformation of thin shells in which bending stresses may be neglected (membrane theory); an introduction to the general theory of bending of cylindrical shells; stresses in shells in the form of surfaces of revolution such as domes, containers, pressure vessels, tanks, and fuselages.

226. PHOTOELASTICITY. *Prerequisite: Eng. Mech. 124. (2).*

Lectures and laboratory experiments involving the fundamental principles of the photoelastic method of stress determination. The subject matter will cover 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 will be made. Several methods of separating the principal stresses will be studied.

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.

70. MATHEMATICS

Professors Hildebrandt and Churchill; Associate Professors Hopkins, Rainville, Dushnik, and Hay; Assistant Professors Rouse, Kaplan, Rothe, Bartels, Coburn, Reade, Young, Piranian, and Dolph; Mr. Kazarinoff, Dr. Kincaid, Dr. Tornheim. Dr. Wiegmann, Dr. Leisenring, Dr. Hahn, Dr. Harary, Mr. Ritt, Dr. Scott, and Dr. Stanton.

The object of the work in this department in the College of Engineering is not only to impart to the student the mathematical knowledge requisite for the study of the various branches of engineering, but also to train his mind in methods of precise reasoning and to accustom him to the proper application of general principles to particular cases.

Much time is devoted to the solution of problems in order to combine a fair knowledge of the elementary principles of higher mathematics with the necessary facility in applying these principles to concrete cases. The classes are divided into sections as small as practicable, so as to make it possible for the instructor to give his individual attention to the students.

The required work is practically the same for all students of engineering and extends throughout the first two years. The first year is devoted to advanced algebra and plane and solid analytic geometry, with an introduction to calculus; the second, to differential and integral calculus. An introduction to differential equations is required in certain departments. Students who do not have credit in solid geometry and trigonometry are required to complete these subjects in their first semester.

For students who desire to pursue their mathematical studies beyond the required work, a considerable number of advanced elective courses are offered. Courses which are of particular interest to students in engineering are listed below. Complete offerings of the Department of Mathematics are given in the *Announcement* of the College of Literature, Science, and the Arts and in that of the Horace H. Rackham School of Graduate Studies.

There is an increasing demand in the engineering industries and in the faculties of technical schools for graduates who have taken considerably more mathematics and mechanics than is required in the other engineering curriculums. To meet this demand, the following program has been provided:

CURRICULUM IN MATHEMATICS AND REQUIREMENTS FOR GRADUATION

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

a)	*Preparatory Courses*	*Hours*
	English 11 (1), 21 (2), 12 (3), and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Nontechnical electives (preferably French or German)	8
	Mathematics 13, 14, 53, 54	16
	Physics 45, 46	10
	Chemistry 5E	5
	Drawing 1, 2	6
	Metal Proc. 1 and Ch. and Met. Eng. 1	5
	Total	60
b)	*Secondary Courses*	
	Eng. Mech. 1, 2, 3 (or Math. 141 and 142 in place of Eng. Mech. 1 and 3)	10

	Hours
Elec. Eng. 5 (2*a*)	4
Mech. Eng. 13 (3)	4
Total	18

c) *Advanced Courses*

Options in mathematics including a course in differential equations and 151 or 150	12
Options in engineering	10
Electives in astronomy, chemistry, economics, engineering, drawing, mathematics, metal processing, natural science, physics, and surveying	20
Free electives	20
Total	62

Summary:

Preparatory courses	60
Secondary courses	18
Advanced courses	62
Total	140

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 make the following substitutions:

1. In the mathematics curriculum, substitute three hours of chemistry (beyond 5E) for Eng. Mech. 3 and Eng. Mech. 6 for Eng. Mech. 1.

2. In the chemical or metallurgical curriculum, substitute three hours of advanced mathematics for Economics 173.

All students who are candidates for the degree in mathematics must consult with and have their elections approved by the departmental adviser, Professor Churchill or Hay, for this degree.

Since this curriculum leads to fields other than engineering, it is not listed for accrediting with the Engineers' Council for Professional Development.

COURSES IN MATHEMATICS

*6. SOLID EUCLIDEAN GEOMETRY. *Prerequisite: one year of plane geometry.* I and II. (*No credit*).

Postulates; basic constructions and propositions; original exercises; mensuration.

*7. ALGEBRA AND TRIGONOMETRY. I and II. (2).

Review of elementary operations; linear equations; exponents; radicals;

* Students entering with credit in trigonometry will take Math. 13. Students entering without trigonometry will take Math. 7 except that those whose high-school records show unusual proficiency in mathematics may take Math. 13 and 8 instead. Permission to do this must be obtained from the Department of Mathematics at the time of classification. Students entering without credit in solid geometry will take Math. 6 without credit.

quadratic equations; simultaneous quadratics; progressions; binomial theorem. Trigonometry—the same as in Math. 8.

*8. TRIGONOMETRY. I and II. (*2*).

Trigonometric ratios; trigonometric identities and equations; inverse functions; reduction and addition formulas; laws of sines, cosines, and tangents; theory and use of logarithms; solution of triangles.

*13. ALGEBRA AND ANALYTIC GEOMETRY. I and II. (*4*).

Review of exponents, radicals, quadratic equations; theory of equations; determinants; complex numbers; curve tracing and locus problems in Cartesian and polar co-ordinates; straight line; circle; conic sections.

14. PLANE AND SOLID ANALYTIC GEOMETRY. I and II. (*4*).

Properties of conics involving tangents and asymptotes; parametric equations; surface tracing and locus problems in space; plane; straight line; quadric surfaces; space curves; introduction to calculus; differentiation of algebraic functions.

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. *Prerequisite: permission of the chairman of the department and the student's classifier.* 17, I; 18, II. (*4 each*).

Particularly designed for students outstanding in mathematics. The material covered will be that included in Math. 13, 14, and 53, so that students who have completed these two courses are prepared to take 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.

52. CALCULUS I. I and II. (*5*).

To be elected by students who have not had an introduction to calculus in their freshman course. Starts from the beginning of calculus, taking up differentiation of algebraic functions and then the material of Math. 53. It is to be followed by Math. 54.

53. CALCULUS I. I and II. (*4*).

Functions; limits; continuity; derivative; differentiation of trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; integration.

54. CALCULUS II. *Prerequisite: Math. 53 or equivalent.* I and II. (*4*).

Definite integral; definite integral as the limit of a sum; centroids; moments of inertia; infinite series; Maclaurin's series; Taylor's series; partial differentiation; multiple integrals; introduction to differential equations.

* See footnote p. 134.

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*).

An elementary course in ordinary differential equations, including more detailed treatment of the topics listed in Math. 57, together with the study of more general linear and nonlinear equations.

109. Differential Equations with Applications to Chemical Engineering. *Prerequisite: one year of calculus.* I. (*3*).

An elementary course in ordinary differential equations with applications to geometry, mechanics, and special emphasis on problems in applied chemistry and chemical engineering. Students cannot receive credit for both 103 and 109.

113. Introduction to Matrices. *Prerequisite: Math. 62 or consent of instructor.* I and II. (*3*).

Polynomials; symmetric functions; transformations and matrices; equivalence of matrices and forms; linear spaces; functional matrices and canonical forms; application to linear differential equations.

141. Statics. *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. Dynamics. *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.

[143. Application of Mathematics to Engineering Problems. Omitted in 1949–50.]

145, 146. Celestial Mechanics. 145, I; 146, II. (*2 each*).

Rectilinear motion of a particle; central forces; potential and attraction of bodies; problem of two, three, and *n* bodies; applications of relativity; mechanical quadrature; stellar constitution; introduction to periodic orbits.

147. Modern Operational Mathematics. *Prerequisite: elementary differential equations or advanced calculus* (*or Math.* 150). I and II. (*2*).

The 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.

[149. Exterior Ballistics. Omitted in 1949–50.]

150. Advanced Mathematics for Engineers. *Prerequisite: Math. 54. Required in aeronautical engineering.* I and II. (*4*).

Topics in advanced calculus including infinite series, Fourier series, partial derivatives, directional derivatives, line integrals, Green's theorem, vector analysis. Introduction to differential equations. 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 valued 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 151 or their equivalents.* II. (*3*).

Linear equations of the second order. Solutions by power series. The generalized Riccati equation, the hypergeometric equation, and the confluent hypergeometric equation. Use of divergent summable series.

161. STATISTICAL METHODS FOR ENGINEERS I. *Prerequisite: one year of calculus.* I. (*3*).

Statistical methods of quality control. The normal, binomial, and Poisson distributions. The Shewhart control chart. Sampling methods for scientific acceptance inspection. Math. 161 and 162 together form an introductory course especially designed for the needs of engineers in both experimental work and the flow of production.

162. STATISTICAL METHODS FOR ENGINEERS II. *Prerequisite: Math. 161 or 163.* 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. (*3*).

Averages and moment characteristics of frequency distributions. Frequency functions.

164. THEORY OF STATISTICS II. *Prerequisite: Math. 163.* I and II. (*3*).

Correlation and sampling theory.

165. SIGNIFICANCE TESTS. *Prerequisite: Math. 163 and 164 or equivalent.* I. (*2*).

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. (*2*).

Theory and application of the analysis of variance and covariance. The 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.

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*).

A study of the formal processes of vector analysis, followed by applications to problems in mechanics and geometry.

242. PROBLEMS IN HEAT CONDUCTION AND DIFFUSION. *Prerequisite: permission of instructor.* I. (*2*).

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

246. HYDRODYNAMICS. *Prerequisite: Math. 103, 151 (or 150), and 155.* II. (*3*).

General equations of motion of a fluid; irrotational motion of an incompressible fluid, two- and three-dimensional flow problems; transformation theory and adiabatic flow; viscosity.

[247. MATHEMATICAL ELASTICITY I. Omitted in 1949–50.]

[248. MATHEMATICAL ELASTICITY II. Omitted in 1949–50.]

249. METHODS IN PARTIAL DIFFERENTIAL EQUATIONS. II. (*3*).

Theory and application of the solution of boundary value problems in the partial differential equations of engineering and physics by various methods: orthogonal functions, Laplace transformation, other transformation methods, Green's functions.

250. TOPICS IN MATHEMATICAL PHYSICS. I. (*3*).

Boundary value problems and initial value problems. Elliptic, hyperbolic, and parabolic equations. Method of integral equations, expansion in characteristic functions, Green's function. Variational methods.

[251. MODERN TOPICS IN MATHEMATICAL PHYSICS. Omitted in 1949–50.]

257. SPECIAL FUNCTIONS IN CLASSICAL ANALYSIS. II. (*3*).

Functions of Bessel, Legendre, Mathieu, elliptic functions, and others as treated in Whittaker and Watson, *Modern Analysis.*

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.

347, 348. SEMINAR IN APPLIED MATHEMATICS. I and II. (*1*).

MECHANICAL ENGINEERING

Professors Hawley, Lay, Keeler, Gordy, Vincent, Nickelsen, Good, and Marin; Associate Professors Lloyd, Calhoon, Kessler, Porter, Schwartz, Bolt, Nichols, Edmonson, and Vines; Assistant Professors Watson, Epple, and Flindt; Mr. Alvord, Mr. Colby, Mr. Page, Mr. Morrison, Mr. Vesper, Mr. Farquharson, and Mr. Lett.

MECHANICAL ENGINEERING includes the fields of heat, power, design of machinery, management, and industrial problems. It may be divided into thermodynamics, steam power, internal-combustion engines, hydromechanics, heating, ventilation, air-conditioning, refrigeration, automobile, aircraft power, machine design, and industrial engineering, and covers theory, design, and laboratory work in these fields.

THE DEPARTMENT OF MECHANICAL ENGINEERING stresses a thorough training in the basic courses of mathematics, physics, chemistry, drawing, English, economics, and mechanics, followed by required fundamental courses in thermodynamics, heat engines, power, laboratory practice, hydraulics, machine design, and management to supplement the foundation courses. Opportunity is given for elective courses in special fields. Graduate study is encouraged and a number of courses are outlined especially for graduate students.

FACILITIES FOR INSTRUCTION

Physical equipment in the form of laboratory apparatus for demonstration and testing is an important adjunct to classroom instruction.

THE MECHANICAL ENGINEERING LABORATORY situated in the West Engineering Building is devoted to experimental work in connection with engines, turbines, boilers, fuels, pumps, fans, air compressors, hydraulic machinery, and special equipment.

THE AUTOMOTIVE AND INTERNAL COMBUSTION LABORATORY, situated in the West Engineering Annex, includes twenty-five or more internal-combustion engines of several types, together with complete test equipment in the form of dynamometers, brakes, etc. Both laboratories have facilities for research work. A small laboratory for testing aircraft motors is situated at the Ann Arbor Airport.

THE INDUSTRIAL-MECHANICAL LABORATORY, a building adjacent to the West Engineering Building, contains projectors, films, and other equipment for detailed work in the field of motion and time study.

ADVICE TO STUDENTS of other colleges and universities, with regard to planning their courses before coming to the University, is given in section 14.

MILITARY AND NAVAL SCIENCE. Students who plan to take courses in military or naval science are urged to enroll at the beginning of the freshman year, and in doing so should consult with the officer in charge of this department, and also with the head of the department in which they propose to take their degree. For information regarding the work see sections 59 and 62.

CURRICULUM IN MECHANICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Mechanical Engineering) are required to complete the following curriculum.

For the definition of an hour of credit see section 36.

		Hours
a)	*Preparatory Courses*	
	English 11 (1), 21 (2), 12 (3), and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Nontechnical electives	6
	Mathematics 13, 14, 53, 54	16
	Physics 45, 46	10
	Chemistry 5E	5
	Drawing and Descriptive Geometry 1, 2, 3	8
	Metal Proc. 1 and Ch. and Met. Eng. 1	5
	Metal Proc. 3, Foundry	4
	Metal Proc. 5, Machine Shop	2
	Economics 53, 54	6
	Total	72
b)	*Secondary and Technical Courses*	
	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
	Mech. Eng. 1, Introduction to Mech. Eng.	1
	Mech. Eng. 17 (7), Laboratory, First Course	2
	Mech. Eng. 80 (1*a*), Mechanism	2
	Mech. Eng. 82 (2), Machine Design	3
	Mech. Eng. 86 (6), Advanced Machine Design	3
	Mech. Eng. 104 (4), Hydraulic Machinery	3
	Mech. Eng. 105, Thermodynamics I	3
	Mech. Eng. 106. Thermodynamics II	3
	Mech. Eng. 107, Applied Energy Conversion	3
	Mech. Eng. 108 (8), Laboratory, Second Course	3
	Mech. Eng. 114, Internal Combustion Engines	3
	Mech. Eng. 125, Heating and Air Conditioning	3
	Civil Eng. 21 (2), Theory of Structures	3
	Elec. Eng. 5 (2*a*), D.C. and A.C. Apparatus and Circuits	4
	Elec. Eng. 7, Electronics and Motor Controls	4
	Ch. and Met. Eng. 10, Utilization of Fuels	1
	Total	58

Summary:

	Hours
Preparatory courses	72
Secondary and technical courses	58
Selected electives	10
Total	140

CHOICE OF ELECTIVE COURSES

a) *Nontechnical Electives*

For the selection of the six hours of nontechnical electives, the student is referred to section 29 of this *Announcement.* Courses in English, psychology, philosophy, geography, foreign language, history, etc., are particularly desirable for this requirement.

b) *Selected Electives*

These may be chosen from mechanical engineering theory, design, or laboratory courses in the series numbered 100, which are not in the required group, or from courses offered by any department in the Engineering College or by any college or school in this University to which the student is eligible, subject to the approval of the Mechanical Engineering Department. The student is urged to broaden his background by making elections in other departments of work, and should consult freely with the members of the mechanical engineering staff.

PROGRAM IN MECHANICAL ENGINEERING

FIRST YEAR

For uniform first-year program see section 47.

SECOND YEAR

FIRST SEMESTER	Hours	SECOND SEMESTER	Hours
Math. 53	4	Math. 54	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Mech. Eng. 1	1	Mech. Eng. 80 (1*a*)	2
Mil. or Nav. Science	(1)	Mil. or Nav. Science	(1)
	15 or (16)		16 or (17)

SUMMER SESSION

	Hours
Elec. Eng. 5 (2*a*)	4
Metal Proc. 3	4
	8

THIRD YEAR

	Hours		Hours
Mech. Eng. 17 (7) and Ch. and Met. 10	3	Mech. Eng. 82 (2)	3
Mech. Eng. 105	3	Mech. Eng. 106	3
Econ. 53	3	Econ. 54	3
Elec. Eng. 7	4	Eng. Mech. 4	3
Eng. Mech. 3	3	Metal Proc. 5	2
Electives	2	Electives	3
	18		17

FOURTH YEAR

Mech. Eng. 86 (6)	3	Mech. Eng. 107	3
Mech. Eng. 104 (4)	3	Mech. Eng. 108 (8)	3
Mech. Eng. 125 (25)	3	Mech. Eng. 114	3
Civil Eng. 21 (2)	3	Engl., Grp. III	2
Electives	5	Electives	6
	17		17

CURRICULUM IN INDUSTRIAL-MECHANICAL ENGINEERING*

The following curriculum is available to those students whose main interests lie in the industrial phases of engineering and leads to the degree of Bachelor of Science in Engineering (Industrial-Mechanical).

For the definition of an hour of credit, see section 36.

	Hours
a) *Preparatory Courses*	
Same as listed in Curriculum in Mechanical Engineering. Total hours	72
b) *Secondary and Technical Courses*	
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 1, Introduction to Mech. Eng.	1
Mech. Eng. 17 (7), Mech. Laboratory	2
Mech. Eng. 80 (1*a*), Mechanism	2
Mech. Eng. 82 (2), Machine Design	3

* Graduates of this program are eligible to apply for admission to the Graduate School as candidates for the Master of Science in Industrial Engineering. For this degree a minimum of 30 credit hours is required in a selected group of courses. Graduates are also eligible to apply for admission to the School of Business Administration as candidates for the degree of Master of Business Administration (M.B.A.). The courses marked with an asterisk are applicable to the sixty hours required for the M.B.A. and may be counted as advanced standing toward that degree. The elective courses may be considered likewise, if chosen in the field of business administration. Math. 161 may be substituted for Bus. Ad. 124 for students who later elect Math. 162.

	Hours
Mech. Eng. 86 (6), Advanced Machine Design	3
Mech. Eng. 105, Thermodynamics I	3
Mech. Eng. 106, Thermodynamics II	3
Ch. and Met. Eng. 10, Fuel Testing	1
Elec. Eng. 5 (2*a*), D.C. and A.C. Apparatus and Circuits	4
Elec. Eng. 7, Electronics and Motor Controls	4
Total	39

c) *Industrial Courses*

*Bus. Ad. 11, Accounting	4
*Bus. Ad. 12, Accounting	4
*Bus. Ad. 124, Business Statistics	3
Metal Proc. 107, Metal Stamping, or 108, Jigs, Fixtures, and Machining Tools	2
Mech. Eng. 130 (20), Materials Handling	2
*Mech. Eng. 135 (35), Factory Management	3
*Mech. Eng. 136 (36), Motion and Time Study	3
Total	21

d) *Selected Electives*	8
Total	140

CHOICE OF ELECTIVE COURSES

a) *Nontechnical Electives*

For the selection of the six hours of nontechnical electives, the student is referred to section 29 of this *Announcement.* Courses in English, psychology, philosophy, geography, foreign language, history, etc., are particularly desirable for this requirement.

b) *Selected Electives*

The following courses are particularly suitable as electives in this field:

	Hours
Mech. Eng. 123, Industrial Air Conditioning	2
Mech. Eng. 131, Design of Hoisting and Conveying Machinery	3
Civ. Eng. 181, Legal Aspects of Engineering	3
*Math. 161, Statistical Methods for Engineers	3
Metal Proc. 106, Foundry Costs and Organization	2
Metal Proc. 108, Jigs, Fixtures, and Machining Tools	2

Other courses offered by any department in the Engineering College or by any school or college in this University to which the student is eligible may also be elected, subject to the approval of the Mechanical Engineering Department.

* See footnote on p. 142.

PROGRAM IN INDUSTRIAL-MECHANICAL ENGINEERING

For uniform first-year program see section 47.

SECOND YEAR

FIRST SEMESTER	Hours	SECOND SEMESTER	Hours
Math. 53	4	Math. 54	4
Econ. 53	3	Econ. 54	3
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 1	3
Mech. Eng. 1	1	Mech. Eng. 80 (1*a*)	2
Mil. or Nav. Science	0 or (1)	Mil. or Nav. Science	0 or (1)
	15 or (16)		17 or (18)

SUMMER SESSION

	Hours
Eng. Mech. 2	4
Met. Proc. 3	4
	8

THIRD YEAR

Mech. Eng. 17 (7) and Ch.-Met. Eng. 10	3	Mech. Eng. 106	3
Mech. Eng. 82 (2)	3	Eng. Mech. 3	3
Mech. Eng. 105	3	Bus. Ad. 12	4
Bus. Ad. 11	4	Elec. Eng. 5 (2*a*)	4
Met. Proc. 5	2	Electives	3
Electives	3		17
	18		

FOURTH YEAR

Mech. Eng. 135 (35)	3	Mech. Eng. 86 (6)	3
Bus. Ad. 124	3	Mech. Eng. 130 (20)	2
Eng. Mech. 4	3	Mech. Eng. 136 (36)	3
Elec. Eng. 7	4	Met. Proc. 107 or 108	2
English, Gp. III	2	Electives	5
Electives	3		15
	18		

COURSES IN MECHANICAL ENGINEERING

Some of the advanced elective courses are offered only in alternate semesters. Students are advised to consult the *Time Schedule* for each semester.

1. INTRODUCTORY COURSE IN MECHANICAL ENGINEERING. *Prerequisite: completion of freshman year in engineering.* I and II. (*1*).

Intended to acquaint the student with the field of mechanical engineering. Lectures, bluebooks, and written assignments. Two one-hour periods a week.

13 (3). HEAT ENGINES. *Prerequisite: Phys. 45 and Math. 53.* I and II. (*4*).

Elementary thermodynamics, fuels and combustion, and the principles involved in the application of heat to the various forms of heat engines, including the steam boiler, the steam engine, the steam turbine, the internal-combustion engine, and plant auxiliaries. Lectures, recitations, problems. For nonmechanical students.

14 (3*a*). MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Mech. Eng. 13* (*3*). I and II. (*1*).

Elective for students who are not required to take Mech. Eng. 17 (7). Intended to give an insight into methods of testing and to exemplify some of the principles of power engineering.

17 (7). MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Eng. Mech. 1, preceded or accompanied by Mech. Eng. 105 and accompanied by Ch. and Met. Eng. 10.* I and II. (*2*).

First course. Elementary testing of a steam engine, steam turbine, oil engine, power pump, and steam boiler; the use and calibration of instruments, and the calculation and interpretation of results. Laboratory, computation, and reports. Two periods of four and one-half hours a week.

80 (1*a*). MECHANISM. *Prerequisite: Phys. 45 and Drawing 2.* I and II. (*2*).

Elementary course covering linkages, cams and followers, gear trains, wrapping connectors, and other mechanisms. Two two-hour periods a week.

82 (2). ELEMENTS OF MACHINE DESIGN. *Prerequisite: Drawing 3, Eng. Mech. 2, and Mech. Eng. 80* (*1a*). I and II. (*3*).

Application of the theory of strength and rigidity to machine elements, and a study of the transmission of power by them. Three one-hour recitations a week.

86 (6). ADVANCED MACHINE DESIGN. *Prerequisite: Mech. Eng. 82* (2). I and II. (*3*).

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

104 (4). HYDRAULIC MACHINERY. *Prerequisite: preceded or accompanied by Eng. Mech. 4.* I and II. (*3*).

General consideration of the theory, construction, and operation of the principal types of hydraulic machinery. Lectures, problems, and written recitations.

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

A 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*).

A second course in engineering thermodynamics. 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).*

The 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. A variety of power plant problems are assigned.

108 (8). MECHANICAL ENGINEERING LABORATORY. *Prerequisite: Mech. Eng. 17 (7) and preceded or accompanied by Mech. Eng. 106.* I and II. *(3).*

Second course. Experimental study of a steam turbine, Diesel engine, fan, steam injector, air compressor, 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.

109 (9). POWER PLANTS. *Prerequisite: Mech. Eng. 106.* I and II. *(3).*

Engineering, operation, and economics of power plants. Lectures, recitations, and problems.

110 (9*a*). DESIGN OF POWER PLANTS. *Prerequisite: Mech. Eng. 109 (9) and Eng. Mech. 4. (3).*

Type, capacity, and arrangement of equipment to meet the requirements of a modern steam-power plant. The 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 (11). STEAM-GENERATING EQUIPMENT. *Prerequisite: Mech. Eng. 106. (3).*

Commercial types of boilers, stokers, and superheaters; principles of boiler economy and operation; combustion of fuels; theory of heat transference; purchase of coal by specification; storage of coal; feed-water treatment; problems of design. Lectures, recitations, problems.

112 (11*a*). DESIGN OF STEAM-GENERATING EQUIPMENT. *Prerequisite: Mech. Eng. 82 (2) and 111 (11). (3).*

The design of boilers of different types, including calculations and drawing of important details. Drawing problems; two four-hour periods a week.

113 (13). STEAM TURBINES. *Prerequisite: Mech. Eng. 106. (3).*

Application of the laws of thermodynamics, fluid flow and kinetic effects to the steam turbine. Various types and forms of turbines, and different applications, including electric generation and marine propulsion, are considered together with general principles of governing. Lectures, recitations, problems.

114. INTERNAL-COMBUSTION ENGINES. *Prerequisite: preceded or accompanied by Mech. Eng. 106.* I and II. *(3).*

Engine types and characteristics of operation, thermodynamic analysis, combustion and flame propagation, detonation, carburetion and injection systems, compression and spark ignition engines, supercharging, automotive gas turbines.

115 (15). ADVANCED INTERNAL-COMBUSTION ENGINES. *Prerequisite: preceded by Eng. Mech. 3 and Mech. Eng. 106.* I and II. (*3*).

Theory of Otto and Diesel engines; thermodynamics; fuel; combustion; carburetion; ignition; injection; cooling; lubrication; starting; performance; engine mechanics; balancing and vibration. Discussions, problems.

*116 (15*a*). DESIGN OF INTERNAL-COMBUSTION ENGINES. *Prerequisite: Mech. Eng. 82 (2), and preceded or accompanied by Mech. Eng. 115 (15).* 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 (19). REFRIGERATION AND AIR CONDITIONING. *Prerequisite: Mech. Eng. 106.* (*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.* (*2*).

A study of 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.

125 (5). HEATING AND AIR CONDITIONING. *Prerequisite: Mech. Eng. 105.* (*3*).

Theory, design, and installation of hot-air, direct- and indirect-steam, hot-water, and fan-heating systems; central heating; air conditioning; temperature control. Lectures, recitations.

126 (25*a*). DESIGN OF HEATING AND AIR-CONDITIONING SYSTEMS. *Prerequisite: Mech. Eng. 125 (25).* (*3*).

The student is given the usual data furnished the heating and ventilating engineer. He then makes a layout of piping, ducts, and auxiliary apparatus, with computations for the size of principal equipment. Two four-hour periods a week.

127 (26). AIR-CONDITIONING LABORATORY. *Prerequisite: Mech. Eng. 108 (8) and 125 (25).* (*2–3*).

Advanced experimental study in the field of air conditioning.

128 (18). HEATING AND VENTILATION. (*2*).

Theory, design, and construction of hot-air, direct- and indirect-steam, hot-water, and fan-heating systems, air conditioning, and temperature control. Lectures, recitations. For architects only.

130 (20). MATERIALS HANDLING AND FACTORY TRANSPORTATION. *Prerequisite: Mech. Eng. 82 (2).* (*2*).

Materials-handling equipment and its application in modern industrial plants. Considerable time is devoted to the economics involved in the use of mechanical-handling equipment and also to the effect on labor. Lectures, recitations, problems, reports, and plant inspection.

* Only one of the following courses may be taken for credit toward a degree: Mech. Eng. 116, 152, 163, 173.

131 (20*a*). DESIGN OF HOISTING AND CONVEYING MACHINERY. *Prerequisite: Mech. Eng. 82 (2). (3).*

Calculations and layout work on hoists, cranes, and conveyors. Two four-hour periods a week.

135 (35). FACTORY MANAGEMENT. I and II. *(3).*

Management problems and methods involved in the operation of manufacturing institutions, including location, layout, equipment investment, 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.

136 (36). FACTORY MANAGEMENT—MOTION AND TIME STUDY. *Prerequisite: Mech. Eng. 135 (35).* I and II. *(3).*

Operating methods, work-center layout according to the laws of motion economy, and time-study technique. Recitations, problems, and laboratory exercises constitute the work of this course.

142 (17). PUMPING MACHINERY. *Prerequisite: Mech. Eng. 104 (4). (3).*

Theory and operation of reciprocating and centrifugal pumps, application of pumps to definite pumping problems, economic considerations, and graphical methods. Lectures, recitations, problems.

143 (17*a*). DESIGN OF PUMPING MACHINERY. *Prerequisite: Mech. Eng. 82 (2) and 104 (4) and Mech. Eng. 142 (17). (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.

150 (29). AUTOMOBILES AND MOTOR TRUCKS. *Not open to students below senior level except by permission of instructor. (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 (30). AUTOMOBILE AND TRUCK ENGINES. *Prerequisite: Mech. Eng. 82 (2) and 150 (29). (3).*

The student selects the type of car or truck; makes expectancy curves for engine performance; and computes the dimensions and sketches principal parts. Lectures, problems, drawing. Two four-hour periods a week.

†152 (30*a*). DESIGN OF AUTOMOBILE AND MOTOR-TRUCK ENGINES. *Prerequisite: Mech. Eng. 151 (30). (3).*

Continuation of Mech. Eng. 151 (30). Lectures, assembly drawing, and details. Two four-hour periods a week.

153 (31). DESIGN OF AUTOMOBILE AND MOTOR-TRUCK CHASSIS. *Prerequisite: Mech. Eng. 82 (2) and 150 (29). (3).*

* Only one of the following courses may be taken for credit toward a degree: Mech. Eng. 151, 162, 172.

† See footnote in connection with Mech. Eng. 116.

The student selects the type of engine for assumed conditions, then computes the dimensions and sketches the principal parts of the chassis. Lectures, problems, drawing.

154 (31*a*.) DESIGN OF AUTOMOBILE AND MOTOR-TRUCK CHASSIS. *Prerequisite: Mech. Eng. 153 (31). (3).*

Continuation of Mech. Eng. 153 (31). Lectures, assembly drawings, and details.

155 (32). AUTOMOTIVE LABORATORY. *Prerequisite: Mech. Eng. 17 (7) and 150 (29) or 115 (15).* I and may be elected for II. *(3).*

An 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.

160 (60). AIRCRAFT POWER PLANTS. *Prerequisite: Mech. Eng. 13 (3) or 105. (3).*

Construction and operation of aircraft engines and their auxiliaries. A descriptive course including critical discussion of the reasons for the various types of construction now in service.

161 (61). AIRCRAFT POWER PLANTS—EXPERIMENTAL TESTS. *Prerequisite: Mech. Eng. 17 (7) and 160 (60). (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 (62). DESIGN OF AIRCRAFT ENGINES. *Prerequisite: Mech. Eng. 82 (2) and preceded or accompanied by Mech. Eng. 115 (15).* (2).

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 three-hour periods a week.

†163 (63). DESIGN OF AIRCRAFT ENGINES. *Prerequisite: Mech. Eng. 162 (62).* (2).

Continuation of Mech. Eng. 162 (62). Further design and sketching of parts, including proposed layout of accessories, followed by the complete layout of final design. Lectures, drawing. Two three-hour periods a week.

164. GAS TURBINES AND JET PROPULSION. *Prerequisite: Mech. Eng. 106.* II. *(3).*

Thermodynamics, theoretical cycles of combustion, fuels, and gas turbine cycle, regenerators, compressors, turbines, and blading; fundamentals of the jet engine. Lectures, recitations, and problems.

170 (70). DIESEL POWER PLANTS. *Prerequisite: Mech. Eng. 105.* (2).

Descriptive of the construction and operation of Diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries.

*172 (72). DESIGN OF DIESEL ENGINES. *Prerequisite: Mech. Eng. 82 (2) and preceded or accompanied by Mech. Eng. 115 (15).* (2).

* See footnote in connection with Mech. Eng. 151.
† See footnote in connection with Mech. Eng. 116.

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

*173 (73). DESIGN OF DIESEL ENGINES. *Prerequisite: Mech. Eng. 172 (72). (2).*

Continuation of Mech. Eng. 172. Further design and sketching of parts, including proposed layout of accessories, followed by the complete layout of final design. Lectures, drawing. Two three-hour periods a week.

181 (21*a*). DESIGN OF MACHINE TOOLS. *Prerequisite: Mech. Eng. 82 (2). (3).*

Layout and manufacturing drawings of a modern machine tool including a study of bearings, clutches, controls, etc., computations for strength and rigidity of parts; and the design of power transmission for speeds and feeds. Two four-hour periods a week.

[182. PROCESS EQUIPMENT SELECTION AND DESIGN. *Prerequisite: Eng. Mech. 2 and Mech. Eng. 82 (2) or Ch. and Met. 113 (13). (3).* Open to seniors and graduate students only. Not offered in 1949–50.]

PRIMARILY FOR GRADUATES

204 (104). RESEARCH IN HYDROMECHANICAL ENGINEERING. *Prerequisite: Mech. Eng. 104 (4) and 108 (8).* I and may be elected for II. *(2–3).*

Opportunity for advanced study in the hydromechanical field. Theory, design, equipment performance, or laboratory research.

205 (14). ADVANCED THERMODYNAMICS. *Prerequisite: Mech. Eng. 106 and 108 (8). (3).*

A continuation of Mech. Eng. 106, consisting of the application of principles to advanced problems in heat engines, air compressors, and refrigerating machines, together with lectures dealing with both engineering phases and the relation of the laws of thermodynamics to modern physical concepts of matter and energy.

208 (108). RESEARCH IN HEAT-POWER ENGINEERING. *Prerequisite: Mech. Eng. 106 and 108 (8)*. I and may be elected for II. *(2–3).*

Opportunity for 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 Eng. Mech. 4. (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.

215 (137). RESEARCH IN INTERNAL-COMBUSTION ENGINEERING. *Prerequisite: Mech. Eng. 115 (15). (To be arranged).*

Opportunity for investigation of the theory, design, and construction of internal-combustion engines, and for laboratory research.

* See footnote in connection with Mech. Eng. 116.

228 (27). STUDIES IN NATURAL VENTILATION. *Prerequisite: Mech. Eng. 108 (8). (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.

237 (40). FACTORY MANAGEMENT—FIELD WORK. *Prerequisite: Mech. Eng. 135 (35) and 136 (36).* I and II. *(3).*

The principles of production developed in Mech. Eng. 135 (35) and 136 (36) are in this course applied to specific problems in factory management. Consists of inspection trips to manufacturing plants, with problems and discussions based on these trips.

238 (42). FACTORY MANAGEMENT—PURCHASING. *Prerequisite: Mech. Eng. 135 (35).* I. *(3).*

Inventory management, selection of sources, price analysis, standards and specifications, organization of a purchasing department, government regulations, buying policies. Lectures, recitations, and semester report.

240. SEMINAR IN INDUSTRIAL ENGINEERING. *Prerequisite: Mech. Eng. 237 (40) or permission of instructor.* I. *(2).*

Current topics in industrial engineering. Reading, research, and preparation of papers.

251 (41). AUTOMOBILE ENGINEERING SEMINAR. *(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 (134). ADVANCED AUTOMOBILE DESIGN AND RESEARCH. *Prerequisite: Mech. Eng. 151 (30) and 153 (31). (To be arranged).*

Special problems in the design of some automobile or truck unit. Drawing.

255 (133). ADVANCED AUTOMOBILE TESTING AND RESEARCH. *Prerequisite: Mech. Eng. 155 (32).* I and may be elected for II. *(3).*

An opportunity for advanced experimental and research work. Laboratory, reports.

280 (180). BALANCING, CRITICAL SPEEDS, AND GYROSCOPIC ACTION. *Prerequisite: Eng. Mech. 3. (2).*

Fundamental equations of dynamics, static and dynamic balance. Balancing of rotating and reciprocating masses; balancing machines; vibrations and damping; critical speeds; gyroscopic torque and application of gyroscopic action. Lectures, recitations, and laboratory demonstrations.

[282. SUPERPRESSURE PROCESS EQUIPMENT AND TECHNIQUE. *Prerequisite: Mech. Eng. 82 (2), and Mech. Eng. 106 or Ch. and Met. 111 (11). (3).* Not offered in 1949–50.]

72. NAVAL ARCHITECTURE AND MARINE ENGINEERING

Professor Baier; Associate Professor Adams; Assistant Professors Spooner and Benford.

The work in this department has for its object the training of men in the design and construction of ships, their propelling machinery, and auxiliaries. The curriculum is ultimately directed to the following two divisions:

Naval architecture, which 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, and

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

In addition to the above two fields of employment in the shipbuilding industry, graduates of this department frequently become connected with the operating divisions of transportation companies. Others have entered the Coast Guard Service or other governmental maritime agencies. Some prefer the small-boat field and specialize in the design, construction, and brokerage of both power and sail yachts. The courses offered in the department are therefore designed to give a student a thorough training in the fundamental problems relating to the marine field, 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.

The department of naval architecture and marine engineering in planning its course of study has had in mind the fact that the basic work is similar to that in mechanical engineering, with the slight differentiation largely in the fourth year. As a ship represents a floating power plant, fundamental courses in civil, electrical, and chemical engineering also are included. While recognizing the fact that, in the shipbuilding and shipping industry, men are eventually segregated into the above groups, 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 and enter the Graduate School. 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, so as to aid its graduates in obtaining positions in the various lines mentioned above.

Naval tank. The experimental model basin is situated on the first floor of the east wing of the West Engineering Building. The tank is three hundred and sixty feet long and twenty-two feet wide, with a depth of water of ten feet. At the south end is a model room and workshop for the purpose of making models of vessels.

The models used in the tank for testing purposes are eight to twelve feet long and are made of wood. The tank is spanned by a traveling tow car, which is driven by an electric motor and can be run at any required speed. Upon this car are mounted the dynamometers for measuring the resistance of the models of various forms over a range of speeds. A wooden false bottom, 140 feet in length, is hung on threaded bronze rods, allowing adjustment to any desired depth below the water surface, in order to simulate shallow-water conditions for testing purposes.

Equipment is available for studies relating to ship resistance, shallow-water effects, streamline flow, wave profiles, wake, and rolling.

ADVICE TO STUDENTS of other colleges and universities, with regard to planning their courses before coming to the University, is given in section 14.

MILITARY AND NAVAL SCIENCE. The attention of prospective students in naval architecture and marine engineering is called to the Reserve Officers' Training Corps. Those who consider taking military science or naval science are urged to enroll at the beginning of their course. For further details see sections 59 and 62.

CURRICULUM IN NAVAL ARCHITECTURE AND MARINE ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Naval Architecture and Marine Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 36.

a)	*Preparatory Courses*	*Hours*
	English 11 (1), 21 (2), 12 (3), and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Nontechnical electives	6
	Mathematics 13, 14, 53, 54	16
	Physics 45, 46	10
	Chemistry 5E	5
	Drawing 1, 2, 3	8
	Metal Proc. 1 and Ch. and Met. Eng. 1	5
	Economics 53, 54	6
	Total	66
b)	*Secondary and Technical Courses*	
	Civil Eng. 4 (Surv. 4), Use of Instruments	2
	Eng. Mech. 1, Statics	3
	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. 127 (15), Theory of Structures in Ship Design	3
	Mech. Eng. 80 (1*a*), Mechanism	2
	Mech. Eng. 82 (2), Elements of Machine Design	3
	Mech. Eng. 105, Thermodynamics I	3
	Mech. Eng. 17 (7), Mechanical Engineering Laboratory	2
	Elec. Eng. 5 (2*a*), D.C. and A.C. Apparatus and Circuits	4
	Civil Eng. 21 (2), Theory of Structures	3
	Nav. Arch. 11, Introduction to Practice	2

	Hours
Nav. Arch. 12, Form Calculations I	3
Nav. Arch. 141 (41), Marine Machinery	4
Nav. Arch. 151 (51), Resistance; Power; Propellers	3
Total	48

c) *Group Options*

Option A—Naval Architecture

(For those principally interested in ship design and hull construction)

Nav. Arch. 13, Form Calculations II	3
Nav. Arch. 21, Structural Design I	3
Nav. Arch. 22, Structural Design II	2
Nav. Arch. 131 (31), Ship Design I	3
Nav. Arch. 132 (32), Ship Design II	3
Nav. Arch. 33, Contracts and Specifications	1
Nav. Arch. 34, Cost Estimating	1
Nav. Arch. 152 (52), Naval Tank	2
Free electives	8
Total	26

Option B—Marine Engineering

(For those who wish to specialize in the design of propelling and other ship machinery)

	Hours
Mech. Eng. 104 (4), Hydraulic Machinery	3
Mech. Eng. 106, Thermodynamics II	3
Mech. Eng. 108 (8), Mechanical Engineering Laboratory	3
Mech. Eng. 113 (13), Steam Turbines	3
Mech. Eng. 115 (15), Internal-Combustion Engines	3
Nav. Arch 142 (42), Marine Steam Generators, Drawing and Design, or Nav. Arch. 143 (43), Marine Propulsion Machinery, Drawing and Design, or Nav. Arch. 144, Heat Balance	3
Free electives	8
Total	26

Summary:

Preparatory courses	66
Secondary and technical courses	48
Group options	26
Total	140

PROGRAM

For uniform first-year program see section 47.

SECOND YEAR

FIRST SEMESTER	Hours	SECOND SEMESTER	Hours
Math. 53 (Calculus I)	4	Math. 54 (Calculus II)	4
Physics 45	5	Physics 46	5
Eng. Mech. 1	3	Eng. Mech. 2	4
Drawing 3	2	Eng. Mech. 2a	1
Nav. Arch. 11 or Civ. Eng. 4 (Surv. 4)	2	Civ. Eng. 4 (Surv. 4) or Nav. Arch. 11	2
Mil. or Nav. Science	(1)	Mil. or Nav. Science	(1)
	16 or (17)		16 or (17)

SUMMER SESSION

	Hours
Mech. Eng. 105	3
Mech. Eng. 80 (1a)	2
Eng. Mech. 3	3
	8

THIRD YEAR

FIRST SEMESTER	Hours Option A	Hours Option B	SECOND SEMESTER	Hours Option A	Hours Option B
Nav. Arch. 12	3	3	Civ. Eng. 21 (2)	3	3
Nav. Arch. 13	3		Nav. Arch. 21	3	
Mech. Eng. 106 (5)		3	Nav. Arch. 22	2	
Mech. Eng. 17 (7)	2	2	Nav. Arch. 141	4	4
Mech. Eng. 82 (2)	3	3	Mech. Eng. 113 (13) or 115 (15)		3
Eng. Mech. 127 (15)	3	3	Mech. Eng. 104 (4)		3
Eng. Mech. 4	3	3	*Elective	6	5
	17	17		18	18

FOURTH YEAR

FIRST SEMESTER	Hours Option A	Hours Option B	SECOND SEMESTER	Hours Option A	Hours Option B
Econ. 53	3	3	Econ. 54	3	3
Elec. Eng. 5 (2a)	4	4			

* See footnote on p. 156.

		Hours			
Mech. Eng. 115 (15) or 113 (13)		3	Nav. Arch. 132 (32)	3	
Nav. Arch. 152 (52)	2		Nav. Arch. 151 (51)	3	3
English (Group III)	2	2	Nav. Arch. 33	1	
Mech. Eng. 108 (8)		3	Nav. Arch. 34	1	
Nav. Arch. 131 (3)	3		†Design		3
*Elective	3	2	*Electives	5	7
	17	17		16	16

COURSES IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

11. Introduction to Practice. *Prerequisite: sophomore standing and Draw. 1 and 2.* I and II. (*2*).

An introductory course describing types of ships, nomenclature, methods and materials of construction, shipyard practice, and drawing-room details. The lines of a small vessel are faired, and drawings prepared for simple ship structures. Details of shell expansion and other mold loft work are discussed. Lectures, recitations, and drawing room.

12. Form Calculations I. *Prerequisite: Nav. Arch. 11, Math. 54, 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; 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, launching, and flooding curves. Drawing room.

21. Structural Design I. *Prerequisite: Eng. Mech. 2 and Nav. Arch. 12, preceded or accompanied by Nav. Arch. 13, Eng. Mech. 127 (15), and Civ. Eng. 21 (2).* I and II. (*3*).

Discussion and practice in the design of the ship's principal structure and fastenings to meet the general and local strength requirements. A thorough study is made of the application of the classification societies' rules to framing, connections, shell, decks, bulkheads, welding, riveting, and testing. Lectures, recitations.

22. Structural Design II. *Prerequisite: preceded or accompanied by Nav. Arch. 21.* I and II. (2).

The student develops the "Midship Section" and "Structural Profile and Decks" for an assigned vessel according to the Rules of the Classification Society. Attention is paid to the most economical distribution of structural material.

* Total electives, fourteen hours, are to be made up of six hours nontechnical and the balance in free electives except for those students taking military or naval science, in which case not to exceed four hours of military or naval science may be considered as a nontechnical subject.

† Elect Nav. Arch. 142(42), 143(43), or 144(44) as the design course in Option B.

123. ADVANCED STRUCTURAL DESIGN. *(To be arranged).*

131 (31). SHIP DESIGN I. *Prerequisite: Nav. Arch. 13 and preceded or accompanied by Nav. Arch. 21.* I. *(3)*.

Includes a review of statical stability and continues with the dynamical stability of ships. Discussions of rolling, pitching, and seagoing qualities of ships; rudders, turning and maneuvering; freeboard; tonnage; grounding and deflections. The latter part of the course is devoted to estimates and calculations involved in the preliminary design of ships. Lectures and recitations.

132 (32). SHIP DESIGN II. *Prerequisite: Nav. Arch. 22 and preceded or accompanied by Nav. Arch. 131 (31).* I and II. *(3).*

The student is given the owner's general requirements and prepares a complete design of a suitable ship, including form, power, and strength calculations; midship section, lines, profiles, and arrangement plans. Drawing room.

33. CONTRACTS AND SPECIFICATIONS. First half of II. *(1).*

A discussion of the principal features of ship specifications and contracts. Lectures and recitations.

34. COST ESTIMATING. Second half of II. *(1)*.

Methods and practice of estimating cost of repair work and new construction. Lectures and recitations.

135 (35). ADVANCED SHIP DRAWING AND DESIGN. I and II. *(To be arranged).*

36. SMALL BOAT DESIGN. *Prerequisite: Nav. Arch. 22 and 131.* I. *(2).*

Designs of motor and sailing yachts and small fishing and work boats are investigated and developed. Recitations and problems.

141 (41). MARINE MACHINERY. *Prerequisite: Mech. Eng. 105 and Eng. Mech. 1.* II. *(4).*

Familiarizes the student with the different types of machinery used for propelling vessels. A study is made of the principles of heat transfer with attention to the steam consumption of reciprocating engines and turbines, and of the capacity of different types of boilers to supply steam for their needs. The use of coal, pulverized coal, and fuel oil in connection with boilers is studied, and also the use of oil in internal-combustion engines. A brief study is made also of condensers and air pumps. Lectures, recitations.

142 (42). MARINE STEAM GENERATORS. *Prerequisite: Nav. Arch. 141.* I and II. *(3).*

Heat transfer calculations, design, and layout drawings are prepared for a modern type of marine steam generator. Drawing room.

143 (43). MARINE PROPULSION MACHINERY. *Prerequisite: Nav. Arch. 141.* I and II. *(3).*

Design calculations and principal drawings are prepared for either a triple expansion steam engine or a main propulsion turbine. Drawing room.

144 (44). HEAT BALANCE. *Prerequisite: Nav. Arch. 141.* I and II. *(3).*

Detailed design calculations and engine and fireroom layouts are prepared for a large steam- or motorship. Drawing room.

145 (45). ADVANCED READING AND SEMINAR IN MARINE ENGINEERING. I and II. *(To be arranged).*

151 (51). 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., are discussed. Lectures and recitations.

152 (52). NAVAL TANK. *Prerequisite: Eng. Mech. 4; preceded or accompanied by Nav. Arch. 131 (31) or Nav. Arch. 141.* I and II. (2).

The theory of model testing, with particular attention to surface vessels, is discussed, and the student familiarized with the methods of estimating speed, power, and revolutions. A model is towed in the tank, and resistance, trim, wake, and other data worked up. Lectures, drawing room, and laboratory.

153 (53). RESEARCH IN NAVAL TANK. I and II. *(To be arranged).*

154 (54). ADVANCED READING AND SEMINAR IN NAVAL ARCHITECTURE. I and II. *(To be arranged).*

55. PILOTING AND CELONAVIGATION. *(3).*
Nontechnical elective.

73. PHYSICS

Professors Barker, Colby, Sawyer, Dennison, Lindsay, Cork, Uhlenbeck, Crane, and Laporte; Associate Professors Meyer, Sleator, Wolfe, and Williams; Assistant Professors Wiedenbeck, Hazen, McCormick, Katz, Parkinson, and Nierenberg; Dr. Lennox, Dr. Peters, and Dr. Jastram.

The Department of Physics offers instruction in general physics and also in a number of special fields. It is well equipped with apparatus for lecture demonstrations, for laboratory experiments, and for a great variety of research investigations. The classes in general physics are held in the West Physics Building, which contains classrooms, laboratories, two lecture rooms, and the instrument shop. Advanced work and research are carried on in the Harrison M. Randall Laboratory of Physics, which also houses the departmental library and offices. Several research laboratories in this building are devoted to investigations of industrial problems directed by members of the staff in collaboration with the Engineering Research Institute.

The introductory courses (45 and 46), consisting of three recitations, two demonstration lectures, and a two-hour laboratory period each week for two semesters, provide a thorough training in the fundamental principles of mechanics, heat, sound, light, and electricity. They are required of all engineering students. Physics 45 is a prerequisite for all other courses in the department, and Physics 46 for all subsequent courses.

CURRICULUM IN PHYSICS

The inclusion of a degree in physics, among other degrees offered by this college, has its justification in the rapid introduction of the findings of physics and the methods of physical research into industry. The demand for physicists far exceeds the supply.

The schedule of courses leading to the degree of Bachelor of Science in Engineering (Physics) is given below. The department will be glad to consult with any interested student, as to both the possibilities of this profession and the particular work best suited to the individual.

Since this curriculum leads to fields other than engineering it is not listed for accrediting with the Engineer's Council for Professional Development.

Candidates for the degree of Bachelor of Science in Engineering (Physics) are required to complete the following curriculum. For the definition of an hour of credit see section 36.

	Hours
a) *Preparatory Courses*	
English 11 (1), 21 (2), 12 (3), Group II, Group III	10
Modern language (preferably German or French)	8
Mathematics 13, 14, 53, 54, 57	18
Physics 45, 46, 147, 165, 196	20
Chemistry 5E, 21E, 188	13
Drawing 1	3
Ch. and Met. Eng. 1 and Metal Proc. 1	5
Total	77
b) *Secondary and Technical Courses*	
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Elec. Eng. 2, Direct-Current Apparatus and Circuits	4
Elec. Eng. 3, Alternating-Current Circuits	4
Total	15
c) *Options and Electives*	
Options in physics	13
Options in chemistry	3
Options in mathematics	3
Options in engineering	10
Electives from economics, geography, history, philosophy, political science, sociology	6
Free electives	13
Total	48
Summary:	
Preparatory courses	77
Secondary and technical courses	15
Options and electives	48
Total	140

COURSES IN PHYSICS

45. MECHANICS, SOUND, AND HEAT. *Prerequisite: one year of high-school physics or college chemistry; trigonometry is essential, and calculus should be elected simultaneously with physics.* I and II. (*5*).

Two lectures, three recitations, and one two-hour laboratory period each week.

46. ELECTRICITY AND LIGHT. *Prerequisite: Phys. 45.* I and II. (*5*).

Two lectures, three recitations, and one two-hour laboratory period a week.

85. MODERN PHYSICS. *Prerequisite: Phys. 46.* I. (*2*).

A discussion of fundamental experiments on the nature of light, electricity, and matter.

147. ELECTRICAL MEASUREMENTS. *Prerequisite: Elec. Eng. 3.* I. (*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. II. (*3*).

The characteristics of electron tubes and their functions as detectors, amplifiers, and generators.

166. HIGH-FREQUENCY ELECTRONICS. *Prerequisite: Phys. 165.* I. (*3*).

The characteristics of high-frequency circuits and their radiations. Two lectures, one laboratory period a week.

171. MECHANICS OF SOLIDS. *Prerequisite: Phys. 46 and Math. 54.* I. (*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.

[175. SOUND. I. (*2*). Omitted in 1949–50.]

[176. LABORATORY WORK IN SOUND. (*2*). Omitted in 1949–50.]

177. APPLICATIONS OF PHYSICAL MEASUREMENTS TO BIOLOGY. *Prerequisite: Phys. 46 and eight hours of biological science.* I. (*3*).

181. HEAT. *Prerequisite: Phys. 46 and Math. 54.* I. (*2*).

Thermal expansion, specific heats, change of state, and van der Waals' equation; elementary kinetic theory and the absolute scale of temperature.

183. LABORATORY WORK IN HEAT. I. (*2*).

To follow or accompany Physics 181. Use of modern methods and instruments for the measurement of thermal quantities.

186. LIGHT. *Prerequisite: Phys. 46 and Math. 54.* II. (*3*).

Theory of interference, diffraction, polarization.

187. OPTICS AND OPTICAL INSTRUMENTS. *Prerequisite: Phys. 46 and Math. 54.* I. (*4*).

Principles of geometrical optics and of optical instruments.

188. LABORATORY WORK IN LIGHT. II. (*2*).

To accompany or follow Physics 186. Experiments on interference, diffraction, polarization, double refraction, and the fundamental properties in light.

189. ELECTRON OPTICS AND THE ELECTRON MICROSCOPE. *Prerequisite: Phys. 187.* II. (*3*).

190. X Rays. *Prerequisite: Phys. 46 and Math. 54.* II. (*3*).

The emission, absorption, refraction, and diffraction of X rays, with special emphasis on the interpretation of spectroscopic results.

191, 192. Introduction to Theoretical Physics. *Prerequisite: Phys. 171 and Math. 150 or 154.* 191, I; 192, II. (*2 each*).

A survey of the procedures employed in the mathematical formulation and solution of problems in theoretical physics. Recommended as a preparation for the courses numbered 205 and above.

196. Atomic and Molecular Structure. *Prerequisite: Math. 57 and five hours of intermediate physics or physical chemistry.* II. (*3*).

A review of recent developments, based on fundamental experiments. This includes the determination and description of characteristic energy levels, and the classification of electrons.

197. Nuclear Physics. *Prerequisite: Phys. 85 or 196.* II. (*2*).

Natural radioactivity; nuclear physics; apparatus and methods of nuclear physics. Artificial transmutations and cosmic rays.

[199. Nuclear Physics Laboratory. (*1*). Omitted in 1949–50.]

205, 206. Electricity and Magnetism. *Prerequisite: Phys. 147 and Math. 151.* 205, I; 206, II. (*3 each*).

A fundamental treatment of electromagnetic theory. Maxwell's equations and the radiation from a Hertzian oscillator. The 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*).

The 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. The phase rule of Gibbs. Theory of binary mixtures.

210. The Kinetic Theory of Matter. *Prerequisite: Phys. 209.* I. (*3*).

The kinetic and statistical methods of Boltzmann, and the explanation of the second law. Extension to the quantum theory. Nonideal gases and the theory of the solid body. The 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.

[213, 214. Methods of Theoretical Physics. (*3*). Omitted in 1949–50.]

215, 216. Special Problems. 215, I; 216, 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. The Physics of Continuous Media. II. (*3*).

219, 220. Physics of the Solid State. 219, I; 220, II. (*3 each*).

PART IV

SUMMARY OF STUDENTS

1947–48

Both Semesters and 1947 Summer Session

	1st Year	2nd Year	3rd Year	4th Year	Special	Total
Civil	...	134	84	116	13	347
Mechanical	...	268	237	265	24	794
Electrical	...	315	217	207	28	767
Chemical	...	171	150	177	12	510
Naval Architecture and Marine	...	49	27	37	1	114
Aeronautical	...	112	116	138	11	377
Mathematics	...	6	11	33	...	50
Physics	...	27	33	37	2	99
Engineering Mechanics	...	1	4	5	...	10
Mechanical and Industrial	...	117	126	169	7	419
Engineering—Law	...	...	...	1	...	1
Engineering—Business Administration	...	1	...	2	...	3
Transportation	...	...	4	3	...	7
Metallurgical	...	21	20	38	1	80
Unclassified, first year	618	...	...	...	38	656
Grand total	618	1,222	1,029	1,228	137	4,234
Counted twice	...	4	13	39	...	56
Net total in Engineering	618	1,218	1,016	1,189	137	4,178

Undergraduates, College of Engineering	4,178
Students in Engineering enrolled Summer Session 1947, only	192
Students in Engineering enrolled in the Graduate School	886
Students enrolled in Engineering Extension Courses*	133

* 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.

INDEX

UNIVERSITY OF MICHIGAN OFFICIAL PUBLICATION

The University of Michigan Official Publication is the title given to the series of administrative bulletins published by the University. This series includes the following:

BULLETINS FOR PROSPECTIVE STUDENTS

The prospective student should have, in addition to a copy of the bulletin of General Information, a copy of one or more of the announcements. These will be sent, without charge, on request to the University of Michigan.

Bulletin of General Information

Announcements:
- College of Architecture and Design
- College of Engineering
- College of Literature, Science, and the Arts
- College of Pharmacy
- Horace H. Rackham School of Graduate Studies
- Institute of Public Administration
- Institute of Social Work
- Law School
- Medical School
- School of Business Administration
- School of Dentistry
- School of Education
- School of Forestry and Conservation
- School of Music
- School of Nursing
- School of Public Health
- Summer Session
- W. K. Kellogg Foundation Institute: Graduate Dentistry
- W. K. Kellogg Foundation Institute: Postgraduate Dentistry

Educational Opportunities for Veterans

Bulletins describing the work of various departments and curriculums.

OTHER BULLETINS

The President's Report

Reports and communications of University officers

For bulletin of General Information, announcements, and other information concerning the University, address University of Michigan, Ann Arbor, Michigan.