

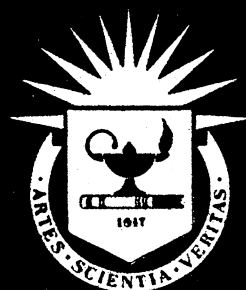
**UNIVERSITY OF MICHIGAN
OFFICIAL PUBLICATION**

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COLLEGE OF ENGINEERING

ANNOUNCEMENT

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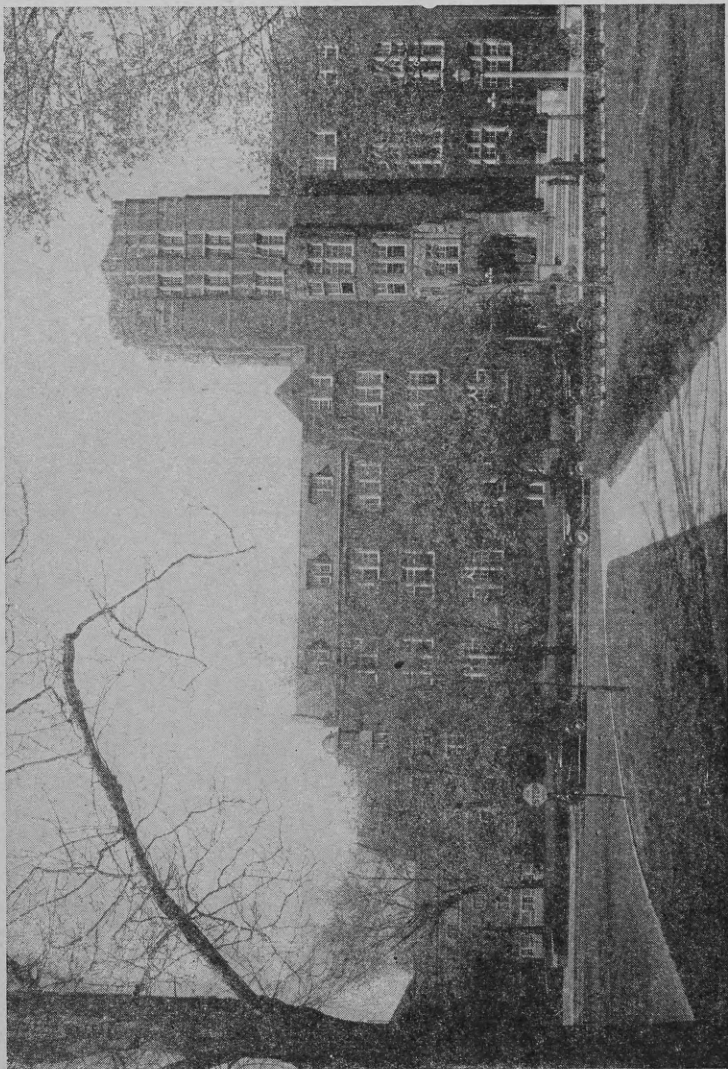
COLLEGE OF ENGINEERING

Announcement

1946-1947



**ANN ARBOR, MICHIGAN
PUBLISHED BY THE UNIVERSITY**



THE MICHIGAN UNION

CONTENTS

UNIVERSITY CALENDAR	4
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PART I

OFFICERS AND FACULTY	5
GENERAL INFORMATION	7
History	7
Extracurricular Opportunities	7
Veterans Service Bureau	8
Programs of Study	8
Combined Programs with Other Institutions	9
Orientation Period	9
Room and Employment Service	10
Foreign Students	10
Admission	11
Fees and Expenses	16
University Health Service	21
Facilities for Physical Education	21
Assembly, Mentor, and Placement System	24
Honor System	25
Rules Governing Election of Studies	25
Requirements for Graduation	30
Relation of Students to the Civil Authorities	31
Michigan Union and Michigan League	32
The International Center	33
Societies	33
Fellowships	35
Scholarships, Prizes, and Student Aids	36
Loan Funds	37
Bequests and Other Gifts	38

PART II

NONPROFESSIONAL DEPARTMENTS: Studies of the First Year; De- partments of Instruction; Engineering Research	41
---	----

PART III

PROFESSIONAL DEPARTMENTS	69
--------------------------------	----

PART IV

SUMMARY OF STUDENTS	167
INDEX	169

UNIVERSITY CALENDAR, 1946-47

Spring Term, 1945-46

1946

February 27-March 2, Wednesday-SaturdayOrientation Period
February 28-March 2, Thursday-Saturday Registration for spring term
March 4, MondaySpring term begins
May 30, ThursdayMemorial Day, holiday
June 3-7, Monday-FridayEntrance examinations
June 22, SaturdaySpring term ends. Commencement Day.

Summer Session, 1946*

June 24, MondaySummer session begins in Law School
July 1, MondaySummer session begins in other units
July 4, ThursdayIndependence Day, a holiday
August 10, SaturdaySix-week courses end in summer session
August 19-23, Monday-FridayEntrance examinations
August 23, FridayEight-week courses end in summer session
September 7, SaturdaySummer session ends in Law School

First Semester, 1946-47

September 16-21, Monday-SaturdayOrientation Period
September 19-21, Thursday-SaturdayRegistration
September 23, MondayFirst semester begins
November 28, ThursdayThanksgiving, a holiday
December 20, Friday (evening)Christmas recess begins

1947

January 6, Monday (morning)Classes resume
January 13-17, Monday-FridayEntrance examinations
January 25-February 4, Saturday-TuesdayExamination period
February 6-8, Thursday-Saturday (morning)Registration for
second semester
February 8, SaturdayFirst semester closes

Second Semester, 1946-47

February 10, MondaySecond semester begins
February 22, SaturdayWashington's Birthday, a holiday
April 4, Friday (evening)Spring recess begins
April 14, Monday (morning)Classes resume
May 30, FridayMemorial Day, a holiday
May 31-June 10, Saturday-TuesdayExamination period
June 2-6, Monday-FridayEntrance examinations
June 14, SaturdayCommencement

* Courses in summer camps and special courses for veterans to be announced.

Part I

OFFICERS AND FACULTY

ADMINISTRATIVE OFFICERS

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

JAMES PICKWELL ADAMS, A.M., 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 Engineering Research*

FACULTY

Members of the faculty are listed at the head of the particular field of study in which they serve. A complete list may be obtained from the University's publication *Register of Staff and Graduates*.

EXECUTIVE COMMITTEE

Dean I. C. CRAWFORD, Chairman ex officio

Professor G. G. BROWN, term 1942-46

Professor R. A. DODGE, term 1943-47

Professor W. E. LAY, term, 1944-48

Professor L. A. BAIER, term, 1945-49

STANDING COMMITTEE

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

COMMITTEES OF THE COLLEGE OF ENGINEERING

Committee on Classification:

Associate Professor C. F. KESSLER, Professors C. E. LOVE, 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, R. SCHNEIDEWIND, and L. N. HOLLAND, Associate Professor I. H. WALTON, and Assistant Professor A. L. CLARK, JR.

Committee on Discipline:

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

Committee on Scholarships:

Professors H. W. MILLER, F. N. MENESEE, 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.

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 comprises 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 Post-graduate 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 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; the Counselor in Religious Education and the pastors have been chosen because of their effective work with young people.

The University Musical Society provides unusual musical advantages, including several series of concerts, either at moderate prices

or without charge, in which leading artists of the country and from abroad and local musicians take part. The University has in its galleries a small art collection of great merit, and the Ann Arbor Art Association gives 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 SERVICE BUREAU

3. A Veterans Service Bureau has been established by the University to assist in special ways the men and women who return from war service and desire by means of a period of study to fit themselves to fill positions in normal civil life. This bureau is not intended to supersede the arrangements for counsel and guidance that already exist in the several schools and colleges and that, presumably, will be used by the majority of returning veterans. It will, however, be available to all to provide general information about the opportunities for study at the University, to help the individual select his program, to put him in touch with the school or college in which he will enroll, and to assist him in any matter relating to the records of previous experience or to the rehabilitation services available through state and federal agencies. Veterans are cordially invited to call at, or correspond with, the bureau at Room 1510, Rackham Building and to avail themselves of the many forms of assistance which it offers them.

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 (including transportation), 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 astronomy, 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 may indicate. For example, under

Chemical Engineering will be found metallurgical, industrial, and general chemical engineering; under Civil Engineering will be found geodesy and surveying, structural, hydraulic, transportation, sanitary, and municipal engineering; under Electrical Engineering will be found power, communication, and illumination engineering and electrical design; under Mechanical Engineering will be found steam power, internal combustion, hydromechanical, heating, ventilating and refrigerating, automobile and industrial engineering, and machine design.

The Electrical and Mechanical Engineering departments offer a five-year co-operative program with industry, conforming substantially to the following principles: 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 periods of an entire term or of an entire summer session. For details see sections 69 and 72.

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 there 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.

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 others will plan to take part in the entire program of activities.

Students admitted to 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 the Dean of Students, Room 2, University Hall. His secretaries are actively interested in assisting newcomers to find rooms and boarding places, and his office also 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 term, however, every foreign student is considered as on trial. If at the end of the term 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 term 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 42, 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 must include four sequences, two major sequences from Groups A and C and two minor sequences from Groups B and 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. Foreign-Language Group	
A minor sequence of two units of a single language, Greek, Latin, French, German, or Spanish is required	2
C. 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
(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.)	
D. 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
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. It is recommended that one unit of history, or one-half unit of American government and one-half unit of American history, be included in this group. (Such half units are acceptable only if taken in the eleventh or twelfth grade)	5
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. These deficiencies must be made up during the first year of residence, without credit toward graduation, but if elected in college 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 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.

NOTES ON THESE REQUIREMENTS

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

c) **Foreign Language.**—No less than two units of any language will be accepted for admission. Foreign languages other than those listed are sometimes accepted in the case of students whose native language is other than English. These cases will be considered individually.

d) **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 3 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 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 individual 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

* 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.

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. However, college credit may be given for languages presented in excess of the fifteen units required for admission, if the courses 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 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—given 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 examinations. Entrance examinations are held each year in August, Registrar at least one month in advance of the dates set for the

February, and June. The applicant may divide the examinations, taking some either a year or a term 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 TO 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. After all entrance requirements are fulfilled the Assistant Dean, with the advice of the various teaching departments concerned, evaluates tentatively, in terms of our own equivalent courses, the advanced credit to be allowed the student. Credit will not be given in general for courses passed with a D, or low-pass grade.

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 25.

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 Courses 1, 2, and 3 in drawing. 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 Literature, Science, and the Arts 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 CREDITS

16. Advanced credit for studies taken elsewhere is given only for work equivalent to courses offered in the University of Michigan and is adjusted in terms of semester hours completed without any scholastic grade being assigned to this credit. The student's scholastic average is determined by grades earned while he is enrolled in this College. At the end of the first semester after transfer the student's performance is reviewed by the Assistant Dean. If the average grade for the semester is 2.0 honor points (C full pass) or better, the tentative advanced credits are validated. If the average grade is below 2.0, the tentative credits are reviewed for readjustment in consultation with the professional department concerned.

Applicants for advanced credit should apply at the time of entrance at Room 255, 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 are not candidates for a degree, are designated special students.

Persons over twenty-one years of age who wish to pursue particular studies in engineering, and who show by examination or by the presentation of satisfactory certificates that they are prepared to do good work in the selected courses, may be admitted as special students on the recommendation of the chairmen 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 has to pay a semester fee. For Michigan students, the semester fee in the College of Engineering is \$70 for each semester, for non-Michigan students, \$130 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.—Six hours or fewer in the Graduate School or the Law School or eight hours or fewer in any other school or college are considered a reduced program. Those electing such a program shall pay each term 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.

Fees

GROUP	DESCRIPTION	MICHIGAN	
		STUDENTS	NONRESIDENTS
1.	Registration for work on doctoral dissertations or library privileges, work <i>in absentia</i> , or election of two hours	\$18	\$28
2.	Three or four hours	35	55
3.	Five or six hours	50	75
4.	Seven or eight hours	60	90

Students in Groups 1 and 2 may obtain privileges of the Health Service upon an additional payment of \$7.50 per semester *at the time of registration*. Election of Health Service privileges is entirely optional to these two groups; however, those not electing such privileges are required to sign a waiver at the time they register.

All students in Groups 3 and 4 are entitled to Health Service privileges without further payment.

At the time of registration all students in the four 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 physical education upon payment of the annual fee of \$7.50 plus federal tax at the office of the Director of Physical Education and Athletics.

Regulations Governing Residence.—Residence in Michigan for the purpose of registration in the University shall be determined according to the state constitutional provision governing the residence of electors.

No one shall be 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 the state while a student in the University excepting changes in status effected under the two following paragraphs.

The residence of a minor shall follow that of the parents or the legal guardian.

The residence of a wife shall follow that of the husband.

Minor students coming to the University from other states or countries shall not 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 individual case.

Aliens who have taken out their first citizenship papers, and the wives or minor children of such aliens, who have otherwise met these requirements for residence, shall be regarded as eligible for registration as residents of Michigan. Any student who registers improperly under this rule is, when discovered, required to pay not only the proper nonresident fees, but is assessed, as an addition to the fee for that term, the sum of \$10.

Discretion to adjust individual cases within the spirit of these rules shall be lodged with the Secretary of the University with the right of appeal to the Regents.

Late Registration.—Registration (i.e., enrollment, payment of fees, and classification) must be entirely completed before the first day of the semester. Students failing to complete their registration before the first day of any semester shall pay a late registration fee of \$1.00 a day with a maximum of \$3.00 for registration three days after the last regular day. In addition a fee of \$1.00 will be assessed students who do not complete their classification before the first day of the semester.

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 materials actually consumed by them 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 shall pay all accounts due the University not later than the last day of classes of each semester or summer session. Student loans which fall due during any semester or summer session and which are not paid or renewed are subject to this regulation; however, student loans not yet due are exempt. Any unpaid accounts at the close of business on the last day of classes will be reported to the Cashier of the University and:

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

b) No students owing such accounts will be allowed to register

in any subsequent semester or summer session until payment has been made.

c) University authorities may request the withdrawal of any student who through oversight has been allowed to register contrary to this regulation regarding University fees or contrary to actions of faculty disciplinary committees.

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 characteristics. For the eighteen week semester the cost of a room is estimated at \$90 and that of board at \$190. Some students, men in particular, can and do secure room and board for less than these amounts.

The following items are necessary for an engineering student during the first year.

Set of drawing instruments, board, T square, triangles, scales	\$40
Slide rule, notebook, paper	15
Textbooks, \$25 each semester	50

REFUND OF FEES

21. a) No student will be entitled to a refund in accordance with scale below except upon (1) presentation to the Cashier of the University of a certificate of withdrawal from the proper official 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 or book or 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 one year after withdrawal.

c) When a student transfers from full program to reduced program status or vice versa or changes his status under a reduced program, and both the refund and the new fee involve incidental

fees, the refund shall be so calculated that the combined amount paid for any incidental fee shall not exceed the total amount of such fee.

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

e) 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.

f) 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.

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

h) A student who transfers from full program to reduced program status will receive a refund in accordance with regulations (*d*), (*e*), and (*f*) above and will be required to pay the appropriate reduced program semester fee.

i) A student who transfers from reduced program to full program status will receive a full refund of the reduced program semester fee and will be required to pay the entire full program semester fee.

j) A student on a reduced program who increases the number of hours elected will receive a full refund of the original fee paid and will be required to pay the appropriate fee for the new program elected.

k) A student on a reduced program who decreases the number of hours elected will receive a refund in accordance with regulations (*d*), (*e*), and (*f*), above, and will be required to pay the appropriate fee for the new program elected.

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

FELLOWSHIPS AND SCHOLARSHIPS

22. There are a number of fellowships and scholarships in the College of Engineering. For details see sections 44 and 45.

There are also appointed annually a few assistants at salaries ranging from \$100 to \$200. For the most part, these assistants are graduate students and seniors who have shown themselves proficient in certain lines.

HEALTH SERVICE APPROVAL

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

a) Students who enroll for the first time in either the first or

second semester on full program status must obtain Health Service approval. The same requirement shall apply to all applicants on reduced program status who have not waived Health Service privileges. 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 shall be in conformity with the rules and regulations of the Health Service.

UNIVERSITY HEALTH SERVICE

24. 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 develop after term 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 near the central campus 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

25. a) Facilities.—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 located southwest of Ferry Field. In addition to the playing field there are a football stadium seating 82,000, 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 around.

b). Physical Education Requirement for Men.*—During the present war emergency, the University of Michigan has taken the position that the physical fitness of its students is of paramount importance. Upon the recommendation of the War Board, the Board of Regents adopted the following program for the period of the emergency:

A physical conditioning, noncredit course conforming to Army and Navy requirements, especially designed to fit students for services in the armed forces. This physical conditioning course consists of three one-and-one-half-hour periods each week and is supplemented by corrective exercises where necessary.

As a condition to continued attendance at the University the above physical training course is required of all students. Students may be excused from taking this course by the Health Service because of physical defects. Each term the executive committee of any school or college may excuse individual students for other reasons.

All courses for men in the Department of Physical Education and Athletics are integrated into this general program of physical conditioning.

Program. Each period of one and one-half hours is divided into two forty-five minute sections (1) for mass activities and (2) for individual activities. These sections are further divided as follows:

- 1) *The Mass Program*
 - a) Calisthenics
 - b) Mass activities
 - (1) Games, (2) relays, (3) obstacle racing, (4) individual and mass combative activities.
- 2) *The Individual Program*
 - a) Boxing
 - b) Gymnastics
 - c) Wrestling
 - d) Track and field
 - e) Games

Students participate in each of these activities in a course of twelve lessons.

* By Regents' action of December 29, 1944, all veterans of World War II are excused from P.E.M., and from the regular requirements of physical education if they have had army basic training or the equivalent.

Swimming Requirement. All students are required to pass the standard Navy 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 conditioning. In general, however, varsity athletics will take place in the Yost Field House and Ferry Field, the physical conditioning course at either the Intramural Sports Building, Field House, or Waterman Gymnasium, and remedial physical education at Waterman Gymnasium.

Lockers. Each student is to rent a locker and towel at a cost of \$2.00 per term. There is a refund of fifty cents at the end of the term when the last towel is returned. The locker and towel fee is paid at the Sports Building and Waterman Gymnasium on the first day of classes.

Uniform. Each participant is to provide himself with a regulation uniform consisting of navy blue shorts, white "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, and (3) attitude.

Absences. All unexcused absences must be made up. Health Service statements will be accepted only for illnesses of more than 24 hours. All excuses for absences must be presented to the Intramural Sports Building Office or the Waterman Gymnasium Office for approval.

Exemptions. Any exemptions from this program must come through the following channels:

- 1) Health Service for cases of physical or medical disabilities.
- 2) The dean of the school or college.
- 3) The Director of Physical Education and Athletics.

Detailed announcement of sections will appear in a fall supplementary announcement.

Freshman Hygiene Lectures. Six hygiene lectures are required of all freshmen. Detailed schedules will appear in the fall supplementary bulletin.

Physical Education for Men (P.E.M.) This is a physical conditioning course required of all men students registered in the University.

Competitive Athletics. Intercollegiate competition is offered in football, basketball, baseball, track and field, wrestling, golf, swimming, hockey, and tennis. Students of superior ability may try out for these teams. Members of these teams may substitute this participation for P.E.M. during the season of competition.

Remedial Physical Education. All students who are physically or medically disabled or who are unable to take part in P.E.M. for any other reason will be assigned to a section in remedial physical education. Individual instruction and training in a wide range of recreational and individual sports will be given.

c) **Physical Education Requirement for Women.** All freshman women must complete satisfactorily a minimum requirement in physical education extending through the two terms 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 standings from other colleges will, in general, have fulfilled the freshman physical education requirement. The Office of the Director of Admissions on Advanced Standing will determine the status of each individual's physical education requirement.

ASSEMBLY, MENTOR, AND PLACEMENT SYSTEM

26. a) Each engineering class has its separate assembly. The freshman class is brought together once a week, other classes about four times a year. Attendance at freshman assembly is required; unexcused absences subject the absentee to discipline. In freshman assemblies, faculty members and visiting engineers address the students, and the regular business of the class is assured of attention by the class as a whole.

b) Closely connected with these assemblies is the Mentor System. When Orientation Period ends, the Mentor System begins; the faculty adviser continues with his group as mentor for the group. Both socially and in an advisory capacity the mentor is the personal representative of the Dean, so that each student may feel free to call on his mentor at any time with reference to any subject relating to his college life.

The 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, and about four weeks before the final examinations; he is therefore able to give the men in his group not merely general advice but definite information as to how they are getting along in their college work.

c) 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

27. 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

28. *a)* No student shall be permitted to elect fewer than twelve hours, and no student whose grade average for the preceding semester is less than three shall be permitted to elect more than eighteen hours a semester (exclusive of military science), except by permission of the classifier.

b) 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.

c) 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.

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

e) 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.

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

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

h) 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.

i) 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

29. An applicant who fails, or is deficient, in some part of the admission requirements may, at the discretion of the Assistant Dean, be admitted, provided he passes in fifteen units; but the removal of entrance deficiencies shall take precedence of 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

30. 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 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 is required for graduation, the difference between this requirement and six hours may be considered as nontechnical.

Students in aeronautical engineering are advised to elect German; and students in astronomy, 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.

EXAMINATIONS

31. 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

32. 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 partially 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

33. a) The average semester grade and the general average grade is computed for each student at the end of each semester and becomes 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 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 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 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 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 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).

n) 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.

o) 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.

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

EXCUSES FOR ABSENCES

34. 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

35. 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,

* For the definition of upperclassmen, see section 35.

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.

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

36. 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

37. 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 or above. See section 33.

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 are entitled to receive degrees in June are expected to be present at the Commencement exercises.

DEGREES CONFERRED IN THE COLLEGE OF ENGINEERING

38. 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

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

40. 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

41. 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 amount of \$5.00 per 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 per 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.

THE INTERNATIONAL CENTER

42. 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

43. **The 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, Aero, and Transportation 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.

The 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 in 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.—This section is 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 professionals in the field, and who derive valuable experience in self-expression, as well as in technical knowledge from the discussions which they must make for themselves. Each member of the branch receives *Electrical Engineering*, which is issued once each month.

Chemical Engineering Section.—This section is a *student branch of the American Institute of Chemical Engineers*. The student branch holds meetings where subjects of professional interest are discussed. It has been assigned a clubroom in the East Engineering Building.

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.

The 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 are 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.

The **Transportation Club** is an organization formed by students with a mutual interest in the general subject of transportation. It forms a common meeting ground for students of railroads, highway engineering and transport, aeronautics, marine engineering, business administration, and economics. Because of its universal nature, it has developed a general appeal to the student body, and the monthly meetings are addressed by prominent engineers.

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.

The **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.

The **Stump Speakers' Society of Sigma Rho Tau**.—This is 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.

FELLOWSHIPS

44. 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 a special bulletin on *Scholarships, Fellowships, Prizes, and Loan Funds*, which will be sent by the University upon request.

SCHOLARSHIPS, PRIZES, AND STUDENT AIDS

45. 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 Engineering before April 1. The awards are published in May and are paid in the amounts of one-half of the award when the recipients have enrolled for the first semester and one-half when they have enrolled for the second semester of the following year.

Robert Campbell Gemmell Memorial Scholarships.—This scholarship fund in memory of her brother, Robert Campbell Gemmell, B.S.(C.E.), '84, C.E., '95, M.Eng.(hon.), '13, 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 3.0. Applications must be filed in the office of the Assistant Dean of En-

gineering before April 1. The awards are published in May and are paid in full in September after the recipients have enrolled for the first semester of their sophomore year.

Harriet Eveleen Hunt Scholarships.—This trust fund was established in 1937 by Mr. 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 fifteen semester hours of work at the University of Michigan with a minimum average of 2.5. Application must be filed in the office of the Assistant Dean of Engineering before April 1. The awards will be paid the same as for the Donovan Scholarship.

Simon Mandelbaum Scholarships.—These scholarships were established in 1929 by the late Mary S. Mandelbaum (Mary S. Mandelle) of Detroit, Michigan, in memory of her father, Simon Mandelbaum. 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 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 school year.

Frank Sheehan Scholarship in Aeronautics.—This scholarship was 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.—This fund is 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

46. 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 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, *Scholarships, Fellowships, Prizes, and Loan Funds*, which is available on request. Applications should be made to the Dean of Students, Room 2, University Hall.

BEQUESTS AND OTHER GIFTS

47. 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 contemplating 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 due 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.



EAST ENGINEERING BUILDING

Part II

NONPROFESSIONAL DEPARTMENTS

STUDIES OF THE FIRST YEAR

48. 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 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		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 13 (Alg. and Anal. Geom.)	4	Math. 14 (Pl. and Sol. Anal. Geom.)	4
*English 11 (1)	3	*English 12 (3)	2
*English 21 (2)	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Cr. and Met. Eng. 1 and Metal Proc. 2	5	†Ch. and Met. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. or Nav. Science	0 to 1	‡Physical Ed. or Mil. or Nav. Science	0 to 1
16 or 17		16 or 17	

Physical education three times a week throughout the year (without credit in hours) is required of all first-year students, unless military or naval science (one hour's credit each semester) is elected as a substitute. Enrollment in military or naval 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

* If modern language is elected, it may be classified here and the English postponed. See section 30.

† See note, section 52.

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

trigonometry and chemistry as described in section 10a. 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 3, first semester, followed by Chemistry 4, second semester, in place of Chemistry 5E. The student entering without solid geometry will take Mathematics 6 without credit.

In case the admission requirements have been fully met on entrance, the trigonometry described in section 10a and Chemistry 3 taken in college will give credit toward graduation as nontechnical subjects. See section 30.

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 for their removal. See section 29.

NONPROFESSIONAL COURSES

49. 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 thought to be inadequate.

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

50. BACTERIOLOGY AND WATER ANALYSIS

Professor SOULE and Assistant Professor EMERSON.

51. **General Bacteriology.** A study of 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. The techniques of pure culture study are developed and extended to include certain considerations of the yeasts and molds. Deposit, \$5.00. *Prerequisite: Chemistry 4.* Four hours credit. First semester.

105. **Water Analysis.** Open to students of sanitary engineering and to others who are qualified. Tu and Th afternoons. 1552

East Medical Building. Two hours credit. First half of the first semester.

105a. **Special Problems on Water Analysis.** Hours and credit to be arranged. Each semester.

110. **General Bacteriology.** Lectures and recitations are given during the second semester. Qualified students from all schools and colleges may elect this course as it is the only lecture course offered by the department. *Prerequisite: Chemistry 53.* Four hours credit. Second semester.

111A. **Practical Bacteriology.** A laboratory course open to students other than those of the Medical School. *Prerequisite: Chemistry 53.* Three hours credit. Second half of the first semester.

[111E. **Practical Bacteriology.** Open only to students of sanitary engineering. Three afternoons each week. 2552 East Medical Building. Two hours credit. Second half of the first semester, beginning in November. Omitted in 1945-46.]

152. **Physiology of Bacteria.** The development of methods used in the study of bacterial metabolism, particularly quantitative procedures, and the use of bacteria, yeasts, and molds in industrial processes. Deposit, \$5.00. *Prerequisites: Bacteriology 51 or 111A and Chemistry 53.* Three hours credit. Second semester.

51. BUSINESS ADMINISTRATION

Professors STEVENSON, GRIFFIN, PATON, RODKEY, JAMISON, BLACKETT, ELLIOTT, GAULT, RIEGEL, WATERMAN, and WOLAVER; Associate Professor 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:

22. Statistical Method. 3 hours.

61. Banking and Finance. 3 hours.

- 62. Financial Principles. 3 hours.
- 105. Business Law: Contracts. 3 hours.
- 106. Business Law: Organizations and Securities. 3 hours.
- 111. Industrial Cost Accounting. 3 hours.
- 142. Industrial Relations. 3 hours.
- 151. Marketing I. 3 hours.

52.

CHEMISTRY

Professors SCHOEPFLE, WILLARD, BARTELL, FAJANS, BACHMANN, FERGUSON, ANDERSON, HALFORD, and BROCKWAY; Associate Professors McALPINE and SOULE; Assistant Professors CARNEY, MELOCHE, HODGES, WEATHERILL, CASE, and KELLER.

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 engineering.

The Chemistry Building provides excellent facilities for the work of all the schools and colleges of the University. Lecture and classrooms, laboratories for class instruction and individual research, a fully equipped stock room, and the chemical library are all located in the one building. The library contains about 13,000 volumes and is especially rich in complete sets of journals; 115 journals are currently received.

COURSES IN CHEMISTRY

3, 4. **General and Inorganic Chemistry.*** The chemistry of the nonmetallic elements (Chem. 3) and of the metallic elements (Chem. 4), with special emphasis upon the interpretation of chemical phenomena from the viewpoint of modern theory. Two lectures, two recitations, and two two-hour laboratory periods. *Chem. 3 is a prerequisite for Chem. 4.* Four hours credit each. Each semester.

5E. **General and Inorganic Chemistry.** 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 two three-hour laboratory periods. *Open to students who have presented a unit of chemistry for entrance and have passed the placement examination given during the Orientation Period.* All other students should elect Chem. 3, credit for which will be counted as a nontechnical elective. Five hours credit. Each semester.

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

21E. General and Analytical Chemistry. 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. *Prerequisite: Chem. 5E or 4, or equivalent.* Four hours credit. Each semester.

41. Quantitative Analysis. 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. *Prerequisite: Chem. 21E.* Four hours credit required. May be taken for five hours. Each semester.

53. Organic Chemistry. Intended for students who desire a more elementary course than Chem. 67E and 169E. Four lectures or recitations. *Prerequisite: Chem. 5E or 4, or equivalent.* Four hours credit. Each semester.

67E. Organic Chemistry. An elementary course covering only aliphatic and alicyclic compounds. Should be followed by Chem. 169E. Lectures and recitations. *Prerequisite: Chem. 21E.* Three hours credit. Each semester.

85E. Elementary Theoretical and Physical Chemistry. The fundamentals of physical chemistry with particular emphasis on the solution of problems. The subjects treated include the gaseous, liquid, and solid states, solutions and thermochemistry. Two lectures and two recitations. *Prerequisite: Chem. 21E or equivalent, Phys. 46, and a knowledge of calculus.* Three hours credit. Each semester.

87E. Elementary Theoretical and Physical Chemistry. A continuation of Chem. 85E. Special emphasis will be placed on the subjects of chemical equilibrium and chemical kinetics. Two lectures and two recitations. *Prerequisite: Chem. 85E or its equivalent.* Three hours credit. Each semester.

141. Advanced Quantitative Analysis. This 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. *Prerequisites: Chem. 41 and Phys. 36.* Four or five hours credit. First and second semester.

169E. Organic Chemistry. A continuation of Chem. 67E, covering aromatic compounds. Lectures, recitation, and laboratory. *Prerequisite: Chem. 67E.* Five hours credit. Each semester.

171. Electrochemistry. An elementary treatment of the fundamentals of the subject. Two lectures. *Prerequisite: Chem. 87E.* Two hours credit. First semester.

185, 186. **Physicochemical Measurements.** Methods for the determination of molecular weight, viscosity, surface tension, reaction rate, solubility, etc., optical measurements with polarimeter, refractometer, spectrometer. Laboratory work. *Must be preceded or accompanied by Chem. 41 and 85E.* Two hours credit each. Each semester.

188. **Physical Chemistry.** A course in the fundamentals of physical chemistry particularly for students enrolled in the Curriculum in Physics, others by special permission. Four lectures. *Prerequisites: Chem. 4 or 5E, 21E, and calculus.* Four hours credit. Second semester.

234. **Physicochemical Methods in Quantitative Analysis.** Lectures and laboratory work. *Prerequisites: Chem. 87E and 141.* Two hours credit. Second semester.

255. **Advanced Organic Chemistry.** The commercial preparation of intermediates and dyes, and certain topics in the theory of organic chemistry. Two lectures and reading. *Prerequisite: Chem. 169E.* Two hours credit. First semester.

256. **Advanced Organic Chemistry.** The industrial application of some catalytic processes, and the synthesis of plastics, rubber, fibers, etc. Two lectures and reading. *Prerequisite: Chem. 169E.* Two hours credit. Second semester.

285. **Physicochemical Measurements.** A continuation of Chem. 185, 186. The work 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. One to four hours credit. Each semester.

291. **Colloid Chemistry.** The fundamental principles. Two lectures. *Open only to those obtaining permission of the instructor.* Two hours credit. First semester.

294. **Colloid Chemistry Laboratory.** An application in the laboratory of the principles of colloid chemistry. Laboratory work. *Must be preceded or accompanied by Chem. 291.* Two hours credit. Second semester.

ECONOMICS

Professors SHARFMAN, PATON, REMER, DICKINSON, ELLIOTT, WATKINS, HABER, PETERSON, and ADAMS; Associate Professors FORD, HOOVER, and SMITHIES*; Assistant Professors SIMMONS* and PALMER; Dr. BOND, Mr. ANDERSON, Dr. WIXON, Mr. LEVINSON, Mr. MORRISON, and Mr. TOMLINSON.

Economics 53 and 54 are introductory courses designed especially for students in the College of Engineering and are prerequisites

* On leave, 1945-46.

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.

COURSES IN ECONOMICS

53, 54. General Economics. For students of the College of Engineering and of Architecture and Design and other professional schools and colleges. These courses offer 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. *Economics 53 is a prerequisite to Economics 54. Not open to freshmen.* Three hours credit each. First and second semesters.

71, 72. Accounting. Deals with the concepts and procedures of accounting from the standpoint of investors and business management. *Economics 71 is a prerequisite to Economics 72. Not open to freshmen.* Three hours credit each. First and second semesters.

101, 102. Money and Credit. A general course dealing with the nature and functions of money and banking and giving attention to war and postwar monetary problems. *Prerequisites: Economics 53 and 54. Economics 101 is a prerequisite to Economics 102.* Three hours credit. Economics 101, first and second semester; 102, second semester.

121. Labor I. A general course dealing with background and development of the American labor movement. Considers problems of workers and labor unrest, including insecurity, wages, collective bargaining. Appraises possible remedies by employers, unions, and the government. *Prerequisites: Economics 53 and 54.* Three hours credit each. First and second semesters.

122. Labor II. Considers employers, unions, and the government as possible agents to deal with problems raised in the preceding course, with emphasis on trade union history, organization, and policies, and on labor legislation. *Prerequisite: Economics 121.* Three hours credit. Second semester.

123. Social Security. The application of the principles of social insurance to the problems of economic insecurity. Considers American experience, federal and state legislation, and recent proposals; also foreign experience and proposals, including the Bev-

eridge report. *Prerequisites: Economics 121 or permission of instructor.* Three hours credit. First semester.

124. **Manpower Resources and Their Utilization.** Manpower as a national resource; wartime organization of the labor market and utilization of the labor force; employment prospects in the transition and postwar period; the work of the United States Employment Service. *Prerequisites: Economics 53 and 54 or permission of instructor.* Three hours credit. Second semester.

125. **Labor Disputes.** Deals with the nature of labor disputes and the methods of adjusting them. *Prerequisite: Economics 121 or permission of instructor.* Two hours credit. First semester.

131. **Corporations.** 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. *Prerequisites: Economics 53 and 54.* Three hours credit. First semester.

133. **Transportation.** Deals with the nature and problems of the transportation industry from the standpoint of government regulation. *Prerequisites: Economics 53 and 54.* Three hours credit. First semester.

134. **Public Utilities.** Deals with the nature and problems of the public utility industries from the standpoint of government regulation. *Prerequisites: Economics 53 and 54.* Three hours credit. Second semester.

153. **Modern Economic Society.** A brief survey of economic principles and their applications to questions of public policy. *For seniors and graduates who have had no course in economics and who desire one term of work in the subject. Does not admit to advanced courses.* Three hours credit. First and second semesters.

173. **Fundamentals of Accounting.** A survey course which emphasizes cost determination and financial statements. *Not open to students who have had Economics 71.* Three hours credit. First and second semester.

175. **Elementary Economic Statistics.** An introduction to the principal methods of statistical analysis as applied to economic problems. *Prerequisites: Economics 53 and 54. Juniors and seniors may elect this course concurrently with Economics 53 or 54.* Three hours credit. Second semester.

181. **Public Finance.** A study of the principles and problems of governmental finance—federal, state, and local. *Prerequisites: Economics 53 and 54.* Three hours credit. First semester.

ENGLISH

Professors BRANDT, THORNTON, and BURKLUND; Associate Professors BRACKETT, WALTON, and EGLY; Mr. MACK, Mr. SENSEMAN, Dr. BRITTON, and Mr. MCEWEN.

The work in English aims to prepare the student to speak and write effectively and to give 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 to this 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 shall be reported to the office of the Assistant Dean. The Assistant Dean shall refer the case to the Department of English for study and recommendation. The report of the department shall be 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 located in the Chemical Engineering Library on the third floor of the East Engineering Building.

COURSES IN ENGLISH

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

12 (3). **Expository Writing.** A continuation of English 11 with special emphasis on the longer composition. *Prerequisites: English 11 and 21.* Two hours credit. Each semester.

21 (2). **Oral Exposition.** 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. One hour credit. Each semester.

GROUP II

One of these courses must be elected to complete the freshman requirement; the others give credit as nontechnical electives. Except for English 41 (4) and 46 (5), in which the work is of a specialized nature, three to five papers, besides impromptu, are required. *Prerequisites: English 11 and 21.*

31 (8). **Advanced Composition.** A course for students who desire special practice in the various forms of composition. Two hours credit.

41 (4). **Public Speaking for Engineers.** A study of the problems of organization, illustration, and effective presentation in public address, affording frequent opportunity for practice and class criticism. Two hours credit.

46 (5). **The Scientific and Technical Lecture.** The preparation and delivery of lectures on scientific subjects intended for scientific societies or for popular assemblies; presentation of technical reports and demonstration methods. Two hours credit.

51 (20). **Contemporary Literature.** Readings in contemporary prose fiction, drama, and poetry. Two hours credit.

56 (23). **The Short Story.** Reading and analysis of short stories from the nineteenth and twentieth centuries. Two hours credit.

63 (21). **Contemporary Drama.** A study of representative dramas from Ibsen to the present day. Two hours credit.

65 (22). **Contemporary Novel.** Reading and discussion of outstanding European and American novels from about 1890 to the present. Two hours credit.

75 (19). **Contemporary Poetry.** A survey of the principal British and American poets of the twentieth century. Readings, lectures, and discussions. Two hours credit.

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. *Prerequisites: English 11 (1), 12 (3), 21 (2), and one course in Group II.*

136 (6). **The Technical Report.** 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.* Two hours credit.

141 (7). **Argumentation and Debate.** Study of problems most commonly met by engineers in furthering their projects; emphasis on clear, logical thinking and convincing argument; frequent opportunity for extemporaneous presentation of material. Two hours credit.

156 (24). **The Professional Student and His Reading.** Studies in literature in relation to philosophy and the social sciences. Two hours credit.

158 (27). **The Literature of Science.** Review of the writings of eminent scientists—ancient, modern, and contemporary. Two hours credit.

161 (30). **Shakespeare.** A study of eight of the principal plays. Two hours credit.

162 (25). **The Drama.** An appreciative study of significant dramas in classical and western civilizations. Two hours credit.

167 (26). **The Novel.** Reading and discussion of major works in the prose fiction of the eighteenth and nineteenth centuries. Two hours credit.

175 (28). **American Literature.** Readings in the works of representative leaders in American thought. Two hours credit.

181 (29). **Literary Masterpieces.** Studies in the works of exceptional merit in the various literary forms. Two hours credit.

55. FORESTRY AND CONSERVATION

Professors DANA, MATTHEWS, ALLEN, GRAHAM, RAMSDELL, YOUNG, KYNOCH, BAXTER, and CHASE; Associate Professors R. CRAIG and O'ROKE; Forest Manager MURRAY; Mr. PATRONSKY.

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

COURSES IN FORESTRY

31. **Introduction to Forestry.** Economic and social importance of forestry; character, distribution, management, and utilization of our timber resources; forest influences; relation between forestry and wood technology. Three hours credit. Second semester.

101. **Tree Identification and Distribution.** Classification, identification, characteristics, and distribution of the more important forest trees of the United States. *Prerequisite: Botany 1.* Three hours credit. First semester.

128. **Pathology of Wood.** Recognition and control of the important agents which cause decay and stain in wood and wood products. *Prerequisites: Botany 1 and Forestry 162.* Three hours credit. Second semester.

130. **Forest Entomology.** Characteristics, life histories, types of injury, and control of insects attacking forest trees and forest products. Three hours credit. First semester.

154. **Logging and Milling.** Methods and costs of logging and of lumber manufacture. Three hours credit. Second semester.

159. **Wood-Using Industries.** Requirements, processes, and products of the major wood-using industries of the United States. Three hours credit. First semester.

160. **Tools of the Wood-Using Industries I.** Character and use of the principal tools, both hand and machine, employed in the wood-using industries. Two hours credit. First semester.

160a. **Tools of the Wood-Using Industries II.** Continuation of Forestry 160. *Prerequisite: Forestry 160.* Three hours credit. First semester.

161. **Machinability of Wood.** Action of cutting edges on wood in the process of machining and power required for their efficient use. *Prerequisite: Forestry 160.* Two hours credit. First semester.

162. **Structure and Identification of Woods I.** Structure, identification, properties, and uses of North American woods. Three hours credit. First semester.

163. **Structure and Identification of Woods II.** Structure, identification, properties, and uses of tropical woods, with special reference to the microscopic structure of woods. *Prerequisite: Forestry 162.* Two hours credit. Second semester.

164. **Physical and Mechanical Properties of Woods I.** Study of the physical and mechanical properties of woods, and of the relation of these properties to their industrial utilization. *Prerequisite: Forestry 162.* Three hours credit. First semester.

165. **Physical and Mechanical Properties of Woods II.** Continuation of Forestry 164. *Prerequisite: Forestry 164.* Three hours credit. Second semester.

166. **Seasoning and Kiln Drying of Woods.** Air drying, kiln drying, and chemical seasoning of woods by various methods. *Prerequisite: Forestry 162.* Three hours credit. First semester.

167. **Design of Woodworking Machinery.** 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. *Prerequisites: Forestry 160 and 162.* Three hours credit. Second semester.

169. **Protection of Wood from Destructive Agencies.** Protection of wood from destruction or deterioration, particularly by decay, fire, and insects. *Prerequisite: Forestry 162.* Three hours credit. Second semester.

170. **Lumber Grading and Specifications.** American lumber standards and their application, including actual practice in lumber grading and identification, and in the drafting of bills of materials and specifications. *Prerequisite: Forestry 162.* Three hours credit. Second semester.

172. **Plywood and Laminated Construction.** Manufacture, properties, and utilization of plywood, including the choice and use of adhesives. *Prerequisite: Forestry 162.* Four hours credit. Second semester.

174. **Design and Construction of Containers.** Kinds, characteristics, and handling of materials used in containers; principles of container design and construction. *Prerequisite: Forestry 162.* Two hours credit. Second semester.

175. **Furniture Construction, Assembly, and Finishing I.** Comprehensive study of the principles and processes involved in the construction and finishing of different kinds of furniture from their various parts. *Prerequisite: Forestry 172.* Three hours credit. First semester.

175a. **Furniture Construction, Assembly, and Finishing II.** Continuation of Forestry 175. *Prerequisite: Forestry 175.* Three hours credit. Second semester.

176. **Forest Economics.** Economic principles and problems involved in the handling of forest lands and in the utilization and distribution of forest products. *Prerequisites: Economics 51, 53, or 153.* Three hours credit. Second semester.

182. **Foundations of Forest Management.** Preparation and

revision of forest working plans. *Prerequisites: Forestry 115 and 118.* Three hours credit. First semester.

183. **Forest Valuation.** Methods of appraising the value of forest properties; appraisal of damages; forest taxation and insurance; determination of the right use of land. *Prerequisite: Forestry 182.* Three hours credit. First semester.

185. **Forest Industry Economy.** 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. Three hours credit. First semester.

191. **Forest and Land Policy.** Development of federal, state, and private forest policies; forest resources and products, and their place in the economic and social life of the nation. Three hours credit. First semester.

194. **Conservation of Natural Resources.** Natural resources of the United States in soil, forests, minerals, and water; their contribution to the economic and social development of the country. Three hours credit. First semester.

56.

GEOLOGY

Professors LANDES, SCOTT, LOVERING,* EHLERS, HUSSEY, and EARDLEY;
Associate Professors KELLUM, BELKNAP, STANLEY, and SENSTIUS;
Dr. WILSON, Dr. GREGORY,* and others.

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

COURSES IN GEOLOGY

11. **Introductory Geology.** A general course leading to an understanding of the principles of physical and structural geology, required of students of civil engineering and geodesy and surveying, and open to others as an elective. Lectures, recitations, laboratory, and excursions. Four hours credit. Each semester.

For other courses in geology to which students of engineering are eligible, see the *Announcement* of the College of Literature, Science, and the Arts. It is suggested that Geology 12 (Historical Geology), 131 (Soil Geology), and 40 and 43 (Economic Geology) are especially useful courses for engineering students.

Summer Session

Geology 11 is also given at Camp Davis, Wyoming. This course runs for four weeks and follows immediately after the close of the

* On leave, 1945-46.

courses in geodesy and surveying given by the Department of Civil Engineering. Also given at Camp Davis are Geology 73 and other courses in field geology.

57. MECHANISM AND ENGINEERING DRAWING

Professors MILLER, FINCH, and PALMER; Associate Professors HOBART and COLE; Assistant Professors POTTS, CLARK, EICHELBERGER, ORBECK, SMITH, SCHRUBEN, LAKE, and HEPPINSTALL.

The subjects of Engineering Drawing 1, 2, and 3 comprise the total course in engineering drawing in the four-year curriculum. Content of these three subjects has been arranged to include elementary engineering drawing and descriptive geometry. The emphasis is on the language of drawing because there is not sufficient time available in the four-year curriculum to master both the language and the art. Furthermore, the art of drawing has become subordinated to the language in modern production methods and procedures in design. It is a thorough mastery of the language of drawing which the engineering student requires for his courses in design, laboratory demonstrations, and later professional service.

COURSES IN ENGINEERING DRAWING

1. **Elementary Engineering Drawing.** 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 constructions; 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. Three hours credit. Each semester.

2. **Descriptive Geometry.** Has been outlined and the problems chosen to accomplish the principal purpose of developing working facility in solving the five principal and basic geometrical problems of engineering. These are determination of any and all problems of distances, all problems of angles, all problems of intersection of any line with any surface, all problems of intersection of surfaces, and all problems of plane dimensions, areas, and patterns of developable surfaces. Since no other subject in the engineering curriculum gives instruction on the methods of solving these vital problems of all engineering design it has been felt wise to shape the subject of this course to the purpose. The subject covers at the same time, however, the principles of engineering descriptions of engineering projects. Three two-hour drafting-room periods, three hours homework a week. *Prerequisites: solid geometry and Eng. Draw. 1.* Three hours credit. Each semester.

3. **Advanced Engineering Drawing.** Instruction includes engineering sketching of models in orthographic, isometric, and oblique

projection; practice in the 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. *Prerequisites: Eng. Draw. 1 and 2.* Two hours credit. Each semester.

11. **Engineering Drawing.** 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. One hour credit. Second semester.

12. **Graphical Presentation and Computation.** 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. *Prerequisites: Eng. Draw. 1, 2, and 3.* Two hours credit. Each semester.

58.

METAL PROCESSING

Professor BOSTON; Associate Professor GILBERT; Assistant Professors COLWELL and SPINDLER; Mr. GAUTHIER, Mr. TRUCKENMILLER,* Mr. GERHARD, Mr. TELFER, Mr. GRENNAN, and Mr. MCKEE.

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 south 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, smithing coal, coke, iron and steel scrap, and pig iron are stored in bins under the court of the building.

The Machine Tool Laboratory, 60 by 130 feet, is on the first floor and has been carefully arranged to demonstrate the two types of machine-shop methods, toolroom and production. One part of the laboratory contains one or more of each of the principal types of machine tools used in toolrooms. In another part of the laboratory the machines are arranged to give the student a perspective of the machines, tools, and methods used in the manufacture of articles in production.

* On leave, 1945-46.

The **Machinability Laboratory**, on the second floor, contains drill presses, 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.

The **Design Room** on the second floor will accommodate twenty students majoring in tool design, jig and fixture design, die design, machine tool design, and other phases of tool engineering.

The **University Instrument Shop**, on the second floor at the east end, is equipped for fine instrument work. Research 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.

The **Metal Working, Treating, Welding, and Physical Testing Laboratory**, 60 by 100 feet, on the third floor, is equipped with a wide variety of machines and equipment used in forging, welding, brazing, heat-treating, and testing steel.

The **Foundry Laboratory**, 60 by 130 feet, on the fourth floor, contains equipment for bench, floor and machine molding, coremaking, melting, cleaning, and mechanical testing. Molding sand and core-testing equipment, as well as facilities for chemical analysis and metallographic studies, are available for instruction and research.

The **Gaging and Measuring Laboratory**, 36 by 24 feet, is situated in Room 2311 on the second floor, south 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.

COURSES IN METAL PROCESSING

2. **The Working, Treating, and Welding of Steel** is an introductory study of the principles and practice relating to the processing, properties, and application of wrought-steel products. Melting practice in relation to the classification and specifications for steel is considered. The effects of mechanical working, heat-treating, and welding on the microstructure and physical properties of carbon and alloy constructional and tool steels are studied in the classroom and evaluated in the laboratory. One recitation and one three-hour laboratory period a week. *Must be preceded or accompanied by Chem. and Met. Eng. 1.* Two hours credit.

3. **Foundry.** 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. *Prerequisite: Metal Proc. 2.* Four hours credit.

4. **Machine Shop.** Planned to give a 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. *Prerequisites: Metal Proc. 2 and Eng. Mech. 2.* Four hours credit.

9. **Foundry.** 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. One recitation and one three-hour laboratory period a week. Two hours credit.

102 (12). **Advanced Working, Treating, and Welding of Steel.** Further work on these subjects may be elected by making arrangements with the instructor. *Prerequisite: Metal Proc. 2 and Chem. and Met. Eng. 107 (7).* Work in the field of welding should also be preceded by Metal Proc. 105.

103 (13). **Advanced Foundry.** 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 (14). **Advanced Machine Shop.** For correlating design and production, students may, working separately or in groups, prepare complete manufacturing drawings of a device, carefully select the type and form of material for each part, and then actually construct it. Arrangements are to be made with the instructor. *Prerequisite: Metal Proc. 4.* Two or more hours credit.

105 (5). **Welding.** Arc welding; welding costs; shrinkage stresses and distortion; weldability of steel; oxygen cutting; and the application of these and other processes in welding procedures. Laboratory assignments include arc and other welding processes, and testing of welds. One lecture and one three-hour laboratory period a week. *Prerequisite: permission of the instructor.* Two hours credit.

106 (8). **Foundry Costs and Organization.** A study of foundry costs methods, foundry records, and standard instructions for foundry operations. Lectures and assignments. *Prerequisite: Metal Proc. 3.* Two hours credit.

107. **Metal Stamping, Die Casting, and Plastic Molding.** The characteristics and properties of products manufactured by metal-stamping, die-casting, and plastic-molding processes are studied. These processes constitute an important supplement to the machining processes for large-quantity production of mechanical goods. Emphasis is placed on the processing, comparison of materials, the design of the product as affected by the characteristics of the process, and relative costs. Two lectures and one two-hour design period per week. *Prerequisite: Metal Proc. 4 and Mech. Eng. 86 (6).* Two hours credit.

108. **Jigs, Fixtures, and Machining Tools.** 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 per week. *Prerequisites: Metal Proc. 3 and 4; Metal Proc. 111 is desirable.* Two hours credit.

109. **Machinability.** Advanced studies are made of metal cutting from theoretical and practical viewpoints. Reference reading and laboratory experiments are carried out. Experimental data are compiled into charts, slide rules, and mathematical equations so as to be of value in practice. *Prerequisite: Metal Proc. 4.* Two or more hours credit.

110. **Materials for Aircraft Construction (Aero. Eng. 140 [17]).** 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. *Prerequisites: Metal Proc. 4 and Aero. Eng. 101 (5).* Two hours credit.

111.(10). **Measuring and Gaging.** 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. *Prerequisite: Metal Proc. 4.* Two hours credit.

112. **Parts Processing.** A complete routing is made of each of several selected parts which are to be manufactured in accordance with a given schedule. This 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. *Prerequisite: Metal Proc. 4 and further qualifications approved by the instructor*, as this course is based on the subject matter of all previous metal processing courses. Three hours credit.

MILITARY SCIENCE AND TACTICS

CONSULTATION HOURS.—During registration period, 8 A.M. to 12 noon and 1 to 4 P.M., at the department office. Consultation hours with individual members of the faculty by appointment.

Courses in military science and tactics are offered to all physically fit male students who are citizens of the United States. The courses are designed to give a thorough groundwork in the military subjects considered necessary as a part of the education of a commissioned officer in the Officers' Reserve Corps of the military forces of the United States. The successful completion of eight semesters' work will lead to the recommendation for a commission in the Officers' Reserve Corps.

The course in military science and tactics as offered is composed of two groups, a basic group and an advanced group.

A deposit of \$20 is required of each basic course student to cover property responsibility.

R.O.T.C. Basic

Theoretical and practical work which will enable the student to understand and make proper use of infantry weapons, to handle small infantry units according to modern tactical principles, and to understand the co-ordination and co-operation with associated arms.

Open to all physically qualified male students. Appropriate credit given for previous military training or active duty in armed forces.

Program

	<i>First Semester</i>	<i>Second Semester</i>
First Year	Mil. Sci. 1	Mil. Sci. 2
Second Year	Mil. Sci. 63	Mil. Sci. 64

Students will enroll in the appropriate course taught in the semester in which they enroll.

INFANTRY DRILL.—Two hours of drill each week are required with each basic course in military science and tactics. Drill is used as a vehicle for laboratory practice in command and leadership; every responsibility is placed on the student.

1. **Military Fundamentals.** Elementary principles of military courtesy and discipline; customs of the service; organization of the Army; military sanitation and first aid; interior guard duty; personal and sex hygiene; military censorship; infantry drill, formations, and ceremonies. One hour credit. First semester.

2. **Military Fundamentals.** Elementary principles of combat organizations and formation; map and aerial photograph reading; practical rifle marksmanship; infantry drill, formations, and ceremonies. One hour credit. Second semester.

63. **Military Fundamentals.** Principles of cover and concealment; scouting and patrolling; scouts, observers, and messengers; practical training in marches and bivouacs, including tent pitching; infantry drill, formations, and ceremonies. One hour credit. First semester.

64. **Military Fundamentals.** Administration (general); map and photograph reading; safeguarding military information; training management; infantry drill, formations, and ceremonies. One hour credit. Second semester.

R.O.T.C. Advanced

Open to all physically qualified males who are not less than nineteen nor more than twenty-six years of age at time of admission and who have either successfully completed two years Basic Course R.O.T.C. or have served not less than one year in the armed forces. Enrollment in the University will be accepted as satisfactory educational requirements. The applicant must have at least two academic years before graduation or before completion of all work for an advanced degree.

Attendance at an advanced camp is a prerequisite to a commission.

All members of the Advanced Course R.O.T.C. will receive the following emoluments:

1. A sum equivalent to the Army garrison ration at the current value paid monthly during the periods of enrollment. This sum is in addition to any benefits received under the G. I. Bill of Rights.
2. An officer type uniform complete, with field overcoat.
3. Transportation, uniforms, equipment, quarters, rations, medical attention, and the pay of an enlisted man seventh grade while in attendance at the advanced camp.

The Advanced Course R.O.T.C. comprises five-hour class attendance weekly, consisting of two hours conference, two hours laboratory, and one hour drill. Two hours academic credit toward graduation is allowed each semester.

More detailed information regarding the Advanced Course R.O.T.C. will be issued at a later date in a supplemental announcement.

MINERALOGY AND PETROGRAPHY

Professors HUNT and RAMSDELL; Associate Professor SLAWSON.

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. The department is equipped with a platinum-resistance quenching furnace for the investigation of silicate melts. 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 special attention can be given to graduate work and special investigations in mineralogy, crystallography, and petrography.

COURSES IN MINERALOGY

31. Elements of Mineralogy. Includes the elements of crystallography, and the physical and chemical properties, occurrence, uses, and determination of the more common minerals. Three lectures and two hours of laboratory a week. *Prerequisite: a knowledge of elementary inorganic chemistry.* Three hours credit. First and second semesters.

94. Useful Minerals, Building and Decorative Stones. Designed primarily for students of architecture and engineering. The first half of the course treats of the properties and uses of the common minerals and ores; the second half is devoted to a discussion of rocks. Three lectures and two hours of laboratory work a week. *Prerequisite: a knowledge of elementary inorganic chemistry.* Three hours credit. Second semester.

99. Elements of Crystallography. Covers crystallography, crystal projections, and the underlying principles of crystal structure. Designed primarily for students in metallurgical engineering. Lecture and laboratory work. One hour credit. First semester.

151. Optical Crystallography. 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. *Prerequisite: permission of the instructor.* Three hours credit. First semester.

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

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 astronomy, 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.** Pronunciation. Understanding of grammatical constructions. Easy reading. Daily oral practice. Composition work is deferred. Four hours credit. Each semester.

2. **Elementary French, Continued.** Continued oral practice. Reading. Grammar accompanied by exercises and easy composition. Conducted partly in French. *Prerequisite: French 1 or equivalent.* Four hours credit. Each semester.

3. **Second-Year French.** 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. *Prerequisite: French 2 or a two-year course in high school.* Four hours credit. Each semester.

32. Second-Year French, Continued. French 32 may be followed by any or all of the courses, French 91 (four hours credit), 93 (three hours credit), 161 (two hours credit), or 83 (two hours credit). *Prerequisite: French 31 or a three-year course in high school.* Four hours credit. Each semester.

51 (11). First Special Reading Course. The main aim of this course is the acquisition of the ability to read French. An outline survey of the grammar precedes study of several simple reading texts. *French 51 is designed for upperclassmen who do not intend to continue more than two or three terms. Underclassmen may elect this course only by special permission of the department. Graduate students wishing to do the work of this course should enroll early through the College, as the sections are limited in size.* Four hours credit. First semester.

52 (12). Second Special Reading Course. Careful reading and study of a series of graded texts constitute the work of this course, which presupposes such linguistic skill as may be attained in French 51 or its equivalent. *French 52 is for upperclassmen. Underclassmen may elect it only by special permission. Graduate students wishing to do the work of this course should enroll early through the College, as the sections are limited in size.* French 52 may be followed by French 53. Four hours credit. Second semester.

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

GERMAN

1. Elementary German. A study of the essentials of the grammar, with practice in reading and writing German. Four hours credit. Each semester.

2. Elementary German. 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. Four hours credit. Each semester.

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

11. First Special Elementary Course. A brief study of the essentials of grammar followed by the reading of suitable graded texts. *This course is specifically designed for and open only to seniors who are primarily interested in acquiring a rapid reading knowledge of German. Graduate students wishing to attend the course should enroll early through the College, for this section will be limited in size.* Three hours credit. First semester.

12. **Second Special Elementary Course.** Careful reading and study of a series of texts best suited to the specific needs of the class. *Prerequisite: German 11 or its equivalent.* Three hours credit. Second semester.

31. **Second-Year German.** German prose and poetry. Selected readings from representative modern prose writers. Reviews of grammar with practice in speaking and writing German. *Prerequisites: German 1 and 2 in the University or two years of German in high school.* Four hours credit. Each semester.

32. **Second-Year German.** Continuation of German 31. Selected readings from modern writers and the classic poets. Reviews of grammar with practice in speaking and writing German. *Prerequisites: German 1, 2, and 31 or three years of German in high school.* Four hours credit. Each semester.

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.** Grammar, oral work, and reading. Four hours credit. Each semester.

2. **Elementary Spanish.** Continuation of Spanish 1. *Prerequisite: Spanish 1 or equivalent.* Four hours credit. Each semester.

31. **Second-Year Spanish.** Reading of modern texts, grammar review, and conversation. *Prerequisite: Spanish 2 or two years of high-school Spanish.* Four hours credit. Each semester.

32. **Second-Year Spanish.** Continuation of Spanish 31. *Prerequisite: Spanish 31 or three years of high-school Spanish.* Four hours credit. Each semester.

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.

NAVAL SCIENCE AND TACTICS

Professor MICHAUX; Associate Professors GILLETTE, FITCH, and ATHERTON; Assistant Professors REH, IZZO, HALE, JENNINGS, RICE, WYANT, THRONSON, McMILLAN, NEAL, O'LOUGHLIN, SCHOONBECK, BOWMAN, and JACKSON.

The object of the courses in naval science is to provide systematic training and instruction in essential naval subjects for a group of physically qualified and selected students, concurrently with their preparation for a civilian profession, in order that they may be qualified to serve as officers, thus assisting in meeting the demands

for increased commissioned personnel of the United States Navy in event of national emergency, forwarding the plans for national defense, and training young men in the ideals of citizenship. The course is technical to the extent that it makes available to the student a knowledge of seamanship, ordnance, gunnery, engineering, electricity, communications, naval tactics (surface, subsurface, and aerial), military law, and navigation. Eight terms of academic studies at a leading university plus his studies combined with naval experience, tradition, customs, and leadership acquired through drills, cruises, and practical work should qualify him on graduation, if he possesses aptitude, to receive a commission from the President of the United States, to perform the duties of an officer in the United States Navy, Naval Reserve, Marine Corps, or in the United States Marine Corps Reserve.

The curriculum of courses which will be offered in Naval R.O.T.C. for the next semester is not available at present. It is expected that this listing of courses of study will be announced in the near future and should be found in the *Supplementary Announcement*.

The election of the courses in naval science and tactics by a student of engineering entails some readjustment of the type programs shown under the several professional departments given in this *Announcement*. These special programs will be arranged by the classifiers in the several departments.

Naval R.O.T.C. practice cruises on battleships, cruisers, or destroyers are held annually during the summer, when possible. Attendance on a cruise following the junior year is a prerequisite to receiving a commission and must be considered in connection with any work planned to be taken during the University summer sessions.

Uniforms and textbooks are furnished by the Government without charge. All students attending a summer cruise are provided transportation and subsistence. Students enrolled in the advanced course are paid commutation of subsistence during the period of their enrollment.

The naval unit is organized as a battalion of infantry with military drills held in the fall and spring of the year. Other drills include radio, signaling, small-bore rifle target practice and competition, pistol practice, seamanship, tactics, navigation, and service of the naval gun in preparation for firing at sea.

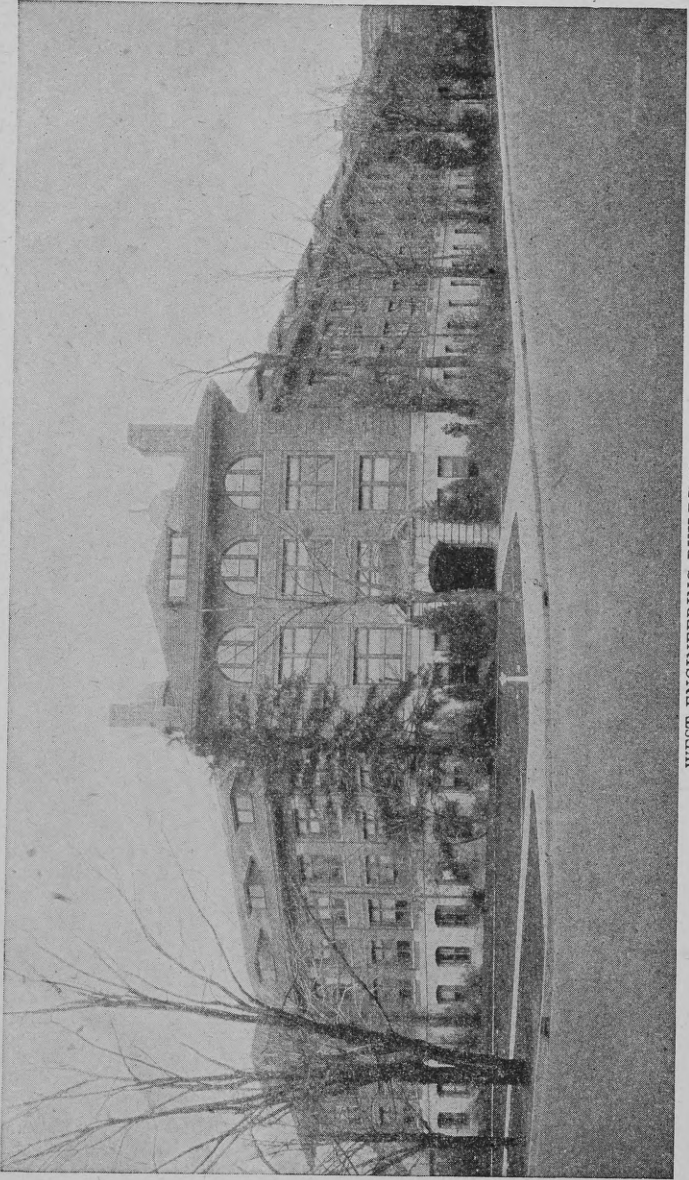
63.

ENGINEERING RESEARCH

Professor A. E. WHITE, Director; Professor GOOD, Assistant Director; Mr. QUINSEY and Mr. SMALL, Assistants to the Director; Research Engineers BADGER, BEEBE, FREEMAN, NIESET, and WALKER; Research Physicists BLACK, BOGLE, BOYD, ENNS, FOWLER, GEIGER, GOLDBERG, PARSONS, PLYLER, and WOLFE; Research Associates DOANE, EWALD, FAIRBANKS, FREDERICK, FREUND, GOLDENBERG, GRATIAN, HADLEY, HANAU, HEATH, KESSLER, KIANG, KOHLER, LOWRY, REYNOLDS, TORIBARA, and WAGNER; Research Assistants EDICT, GAULT, HOWELL, MCKEE, PIDD, SHIGEKAWA, and VOGT.

The Department of Engineering Research was established in October, 1920. It affords an official channel through which the research facilities of the University in engineering and related fields of work are made available to the civic and industrial interests of the state and elsewhere. No course work is offered but many of the research projects which come to the department afford an opportunity for students to work as assistants.

The function of the department is largely administrative. The technical direction of researches sponsored through it is generally 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.



WEST ENGINEERING BUILDING

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, Metallurgical, and Transportation 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.

Information regarding the several professional departments of the College of Engineering, facilities for instruction, requirements for graduation, schedules of study, etc., will be found in the following pages.

65. AERONAUTICAL ENGINEERING

Professors CONLON, KUETHE, and PAWLOWSKI*; Assistant Professors STEINBACHER, LESHER, and SCHETZER; Mr. CURRY.

The work in this department has been arranged to cover all problems entering into the design and construction of machines that utilize the air as their means of support and transportation. This includes a study of general aerodynamics, the determination of stresses, and the general design of structures for all parts of an aircraft, and the design of propellers and propelling machinery.

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

* On retirement furlough, 1945-46.

Each student has the choice of one of two groups of study; either Group A, Airplane Structure and Design, or Group B, Aircraft Power Plants.

Preparatory courses in mathematics, theory of structures, hydro-mechanics, 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 Aeronautical Engineering Department has two laboratories, one devoted to aerodynamics and the other to structures.

The Aerodynamic Laboratory consists of two wind tunnels. The larger one is an open-throat, double-return type. The throat has an octagonal cross section which may be varied from five feet to eight feet. With the large diameter the maximum wind velocity is eighty miles per hour. This tunnel is equipped with a six-component wire balance, a dynamic stability balance, and a balance incorporating the rigid model support particularly suited to experimentation with boundary-layer control. Facilities for testing model propellers are also provided.

The smaller wind tunnel is the closed-throat, single-return type. The throat is twenty inches by thirty inches, and the tunnel has a maximum velocity of sixty miles per hour.

The Structures Laboratory is designed for testing both stressed-skin and truss-type structures. The equipment includes a drop-test apparatus for the investigation of landing-gear shock struts, optical-strain gages capable of measuring elongations of .000002 of an inch, electric strain gage equipment, and other special equipment.

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 66 and 71.

**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 37.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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, 150	20
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Ch. and Met. Eng. 1	5
Total	70
<i>b) Secondary Courses</i>	
Metal Proc. 4, Machine Shop	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, 2a, Strength and Elasticity	5
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil 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. 105 (5), Thermodynamics	3
Mech. Eng. 17 (7), Laboratory	2
Mech. Eng. 160 (60), Aircraft Power Plants	3
Elec. Eng. 5 (2a), Electric Apparatus and Circuits	4
Aero. Eng. 1, General Aeronautics	3
Aero. Eng. 110 (2), Theory of Aviation	3
Aero. Eng. 111 (3), Theory and Design of Propellers	2
Aero. Eng. 130 (4), Basic Airplane Structures	3
Aero. Eng. 112 (6), Experimental Aerodynamics	1
Total	52
<i>Summary:</i>	<i>Hours</i>
Preparatory courses	70
Secondary and technical courses	52
Group options and electives	18
Total	140

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

<i>Group A. Airplane Structure and Design</i>		<i>Hours</i>
Aero. Eng. 101 (5), Airplane Design		2
Aero. Eng. 131 (23), Airplane Structures		3
Aero. Eng. 113 (25), Advanced Airplane Performance		2
Aero. Eng. 114 (27), Applied Aerodynamics		3
Free electives		8
		18
<i>Group B. Aircraft Power Plants</i>		
Mech. Eng. 115 (15), Internal Combustion Engines		3
Mech. Eng. 161 (61), Experimental Tests		3
Mech. Eng. 162 (62), Design of Aircraft Engines		2
Mech. Eng. 163 (63), Design of Aircraft Engines		2
Free electives		8
		18

PROGRAM

For uniform first-year program see section 48.

SECOND YEAR

COURSES	COURSES	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. 2a	1
Econ. 53	3 Econ. 54	3
Mil. or Nav. Science	(1) Mil. or Nav. Science	(1)
	(18) or 17	(18) or 17

SUMMER SESSION

COURSES	<i>Hours</i>
Metal Proc. 4	4
Elec. Eng. 5 (2a),	4

THIRD YEAR

Math. 150	4 Mech. Eng. 82 (2)	3
Eng. Mech. 3	3 Mech. Eng. 105 (5)	3
Eng. Mech. 4	3 Civil Eng. 21 (2)	3
Mech. Eng. 13 (3)	4 Aero. Eng. 110 (2)	3
Mech. Eng. 17 (7)	2 Aero. Eng. 111 (3)	2
Aero. Eng. 1	3 Mech. Eng. 160 (60)	3
	19	17

FOURTH YEAR

Group A

English (Group III)	2	Aero. Eng. 101 (5)	2
Aero. Eng. 130 (4)	3	Aero. Eng. 112 (6)	1
Aero. Eng. 113 (25)	2	Aero. Eng. 131 (23)	3
Electives	8	Aero. Eng. 114 (27)	3
		— Electives, free or	
	15	nontechnical	6
			<hr/>
			15

Group B

Aero. Eng. 130 (4)	3	English (Group III)	2
Mech. Eng. 115 (15)	3	Aero. Eng. 112 (6)	1
Mech. Eng. 161 (61)	3	Mech. Eng. 163 (63)	2
Mech. Eng. 162 (62)	2	Electives, free or	
Electives, free or		nontechnical	10
nontechnical	4		<hr/>
			15
	<hr/>		
	15		

COURSES IN AERONAUTICAL ENGINEERING

1. **General Aeronautics.** An introductory course giving briefly the essentials of aeronautics as applied to the airplane, airship, and other modern means of flight. Lectures and recitations. *Open to all students except freshmen.* Three hours credit. Each semester.

101 (5). **Airplane Design.** Design procedure including layouts and preliminary structural design; stress analysis and detail design. Lectures and drawing. *Prerequisites: Aero. Eng. 110 (2) and 130 (4), accompanied by Aero. Eng. 131 (23).* Two hours credit. Each semester.

102 (13). **Advanced Design.** Continuation of Aero. Eng. 101 (5), taking up some of the more complex or special problems. *Open primarily to graduates.* Credits to be arranged. Each semester.

103 (32). **Airplane Design Practice II.** 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. *Prerequisite: Aero. Eng. 113 (25).* Two hours credit.

104 (31). **Elementary Vibration and Flutter.** Study of the fundamental equations of motion; Lagrangian equations; theory of static and dynamic balance; introduction to flutter theory. *Prerequisites: Aero. Eng. 110 (2) and Math. 150.* Two hours credit.

105, 105a. (11, 11a). **Dynamics of the Airplane.** An advanced study of the dynamics of the airplane and its parts. The mathematical theory of the stability of the airplane as a rigid body is given, and the subjects of spinning and the vibration and flutter of certain parts of the airplane are also discussed. Lectures and recitations. *Prerequisites: Aero. Eng. 110 (2) and Math. 150. Aero. Eng. 105 (11) is a prerequisite for 105a (11a).* Two hours credit for each course.

110. (2). **Theory of Aviation.** Presents a development of the fundamentals of aerodynamics which form the basis for the study of modern aircraft. Lectures and recitations. *Must be preceded or accompanied by Math. 150.* Three hours credit. Each semester.

111 (3). **Theory and Design of Propellers.** Deals with the aerodynamic theories of the propeller and with its strength. The selection of propellers for specific conditions is discussed. Lectures and recitations. *Must be preceded by Eng. Mech. 2, and preceded or accompanied by Aero. Eng. 1.* Two hours credit. Each semester.

112 (6). **Experimental Aerodynamics.** Modern methods for obtaining experimental aerodynamic data are discussed and illustrated. Lectures and laboratory. *Prerequisite: Aero. Eng. 110 (2). Open only to seniors and graduates.* One hour credit. Each semester.

113 (25). **Advanced Airplane Performance.** The relationship of engine, propeller, and airplane is considered in this course. The effect of changes in these items on the performance of the airplane as a whole are treated in detail. *Prerequisites: Aero. Eng. 110 (2) and 111 (3).* Two hours credit. Each semester.

114 (27). **Applied Aerodynamics.** Applies theoretical aerodynamics and modifications based on experiment to the calculation of actual air loads on the airplane. *Prerequisites: Aero. Eng. 150 (2) and Math. 150.* Three hours credit. Each semester.

115 (15). **Theoretical Aerodynamics.** 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. *Prerequisites: Aero. Eng. 110 (2) and Math. 150.* Three hours credit.

116 (20). **Advanced Fluid Mechanics.** 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. *Prerequisites: Eng. Mech. 4 and Math. 150.* Three hours credit.

117 (21). **Advanced Theory of Propellers and Fans.** 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. *Prerequisites: Aero. Eng. 110 (2), 111 (3), and Mech. Eng. 105 (5).* Two hours credit.

118 (24). **Advanced Experimental Aerodynamics.** 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. *Prerequisites: Aero. Eng. 110 (2), Eng. Mech. 4, and Math. 150.* Two hours credit.

119 (29). **Mechanics of Fluid Resistance.** 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. *Prerequisite: Aero. Eng. 115 (15).* Two hours credit.

120. **Fans and Duct Systems.** 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. *Prerequisites: Eng. Mech. 4, Mech. Eng. 105 (5).* Two hours credit.

130 (4). **Basic Airplane Structures.** 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. *Must be preceded or accompanied by Aero. Eng. 1 and preceded by Civil Eng. 21 (2).* Three hours credit. Each semester.

131 (23). **Airplane Structures.** Deals with 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. *Prerequisite: Aero. Eng. 130 (4) or by special arrangement for students from other departments.* Three hours credit. Each semester.

132 (26). **Airplane Structures Laboratory.** The lectures and experiments include proof tests of control surfaces and control systems; stress distribution in a monocoque structure; the use of sensitive strain gages; drop tests of landing gears; and other special topics. *Prerequisites: Aero. Eng. 130 (4) and 131 (23).* One hour credit.

133 (30). **Advanced Airplane Structures.** Deals with special airplane stress analysis problems of 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. *Prerequisite: Aero. Eng. 131 (23)*. Three hours credit.

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)*. One hour credit.

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

161 (14). **Research.** Continuation of Aero. Eng. 112 (6) offering an opportunity for students to pursue experimental investigations. *Prerequisites: Aero. Eng. 112 (6)*. Credit to be arranged. Each semester.

162 (19). **Analytical Research.** A theoretical investigation of problems in aeronautical engineering which are particularly suited to treatment by analytical and mathematical methods. Hours and credits to be arranged.

201. **Dynamics of Viscous Fluids.** Deals with effects of viscosity in fluid flows. Laminar and turbulent boundary layers in theory and experiment; flow through tubes; flow separation; turbulence theories. *Prerequisites: Aero. Eng. 110 (2) and Math. 150*. Three hours credit.

202. **Dynamics of Compressible Fluids.** 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, transonic and supersonic airfoil theory. *Prerequisites: Aero. Eng. 110 (2) and Math. 150*. Three hours credit.

203. **Dynamics of Perfect Fluids.** A continuation of Aero. Eng. 115 (110), 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. *Prerequisites: Aero. Eng. 115 (110), Math. 110 and 176*. Three hours credit.

ASTRONOMY

Professors RUFUS,* McLAUGHLIN and McMATH*; Associate Professors ROSSITER† and MAXWELL; Assistant Professors LOSH, MOHLER‡, and GOLDBERG‡.

The University Observatory is situated at the corner of Ann and Observatory streets.

Its equipment includes a 37½-inch equatorial reflecting telescope which is used for stellar spectrographic work; a 12½-inch equatorial refractor; a six-inch meridian circle; mean and sidereal clocks and chronometers, chronograph, theodolites, sextants, seismographs, computing machines, and measuring engines.

The Observatory Library contains about 6,000 volumes, devoted mainly to technical astronomy. It includes the more important works on theoretical and practical astronomy, many star catalogues, files of the leading astronomical periodicals, and the publications of the more important observatories.

The Astronomical Laboratory is located on the fifth floor and the roof of Angell Hall. The present equipment of this laboratory includes a fifteen-inch reflector, a ten-inch refractor, a three-inch astronomical transit, a horizontal spectrohelioscope, 3 portable refractors, a planetarium, celestial globes, and other smaller instruments.

The Observatory maintains, through the generosity of Mr. Robert P. Lamont, '91 *e*, a branch observing station, called the Lamont-Hussey Observatory, in Bloemfontein, South Africa. The equipment includes a twenty-seven-inch refractor and a six-inch visual and photographic telescope. The observers at Bloemfontein are devoting their time to research in the field of visual double stars.

Another branch observatory is the McMath-Hulbert Observatory, located at Lake Angelus, Michigan, of which Professor Robert R. McMath, '14*e*, is director. This institution specializes in the recording, by the motion-picture method, of celestial phenomena showing motion or change. It contains a twenty-four-inch reflector, with much auxiliary apparatus, and a new solar tower, for studies of solar phenomena.

CURRICULUM IN ASTRONOMY

Since this curriculum leads to fields other than engineering it is not listed for accrediting with the Engineers' Council for Professional Development.

The first two years' work in any department of engineering constitutes good preparation for a curriculum looking toward the profession of astronomy.

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

* On retirement furlough, 1945-46.

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

‡ At the McMath-Hulbert Observatory of the University.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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, or 103	18
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2	2
Economics 53, 54	6
Total	65
 <i>b) Secondary and Technical Courses</i>	
Eng. Mech. 1, 3	6
Civil Eng. 102 (2)	3
Civil Eng. 1, 2 (Surv. 1, 2)	7
Civil Eng. 105 (Surv. 5) or Astronomy 154	2
Astronomy 51, 53 (or 31, 32, 33), 72, 101, 151, 152, 156	20 or 22
Mathematics 105, 106, and 141, 142 or 145, 146	8 or 10
Physics 181, 186, 188, 195	8
Total	56 or 58
 <i>Summary:</i>	
Preparatory courses	65
Secondary and technical courses	56 or 58
Electives, nontechnical, additional 6 hours; in astronomy, physics, or other sciences, 11 or 13 hours	19 or 17
Total	140

COURSES IN ASTRONOMY

Astronomy 31, 32, 33, 103, and 104 are recommended to those who wish to obtain a general knowledge of modern astronomy without entering far into its mathematical details. Engineers are recommended to take Astronomy 51, with its accompanying laboratory, Astronomy 53, in place of 31, 32, and 33. Astronomy 35, 72, 101, 154, and 156 are recommended to those who wish to obtain a knowledge of practical astronomy in its applications to engineering and geodesy.

Courses in addition to those mentioned below are listed in the *Announcement* of the College of Literature, Science, and the Arts. These include advanced work in theoretical astronomy, practical astronomy, and astrophysics. The larger instruments of the Observatory are intended primarily for research and are available to that end to those students who have assigned problems requiring their use.

31. **Descriptive Astronomy. The Solar System.** Includes the fundamental principles of astronomy, and a presentation of the leading facts concerning the sun, moon, planets, and comets. Three lectures or recitations, and one observatory exercise. Three hours credit.

32. **Descriptive Astronomy, Stars and Nebulae.** Devoted mainly to stars and nebulae, including the study of the sun as a typical star. Three lectures or recitations, and one observatory exercise. Three hours credit.

33. **Observational Astronomy.** Constellation studies and telescopic examinations of the heavenly bodies. Selected problems with the celestial globe and equatorial telescope. Laboratory period of three hours. *Open to those who have had or are taking Astronomy 31, 32, or 35.* One hour credit.

35. **Practical Astronomy.** The elements of spherical and geometrical astronomy, with practical applications. Theory of the determination of time, latitude, longitude, and azimuth. This course is intended primarily for students in engineering. Recitations and problems. *Open to those who have had trigonometry and analytical geometry.* Two hours credit.

36. **Nautical Astronomy.** The celestial sphere and co-ordinate systems. Use of the sextant. Designed to prepare students for a course in navigation. Two hours credit. Each semester.

51. **General Astronomy.** Designed for students interested in the physical sciences. A treatment of methods of measurement and of the results of modern astrophysics. *Prerequisites: high-school algebra and geometry, and Astronomy 31 or 32,* but the astronomy prerequisite is waived for students who have had high-school physics and trigonometry. Four hours credit.

53. **Intermediate Laboratory Astronomy.** Experiments in the methods of observational astronomy, with emphasis on the principles and use of astronomical instruments. *Prerequisites: same as for Astronomy 51.* One hour credit.

72. **Navigation.** The principles of pilotage, dead reckoning, and nautical astronomy. Lectures based on Bowditch's *American Practical Navigator*, supplemented by practical problems. *Open to those who have had plane trigonometry.* Three hours credit.

101. **Practical Astronomy.** Studies in spherical astronomy. Theory of the meridian circle and equatorial and their use in observational work. This course includes observational work with instruments and the reduction of measurements. Recitations, practical problems. *Open to those who have had trigonometry and analytical geometry.* Three hours credit.

103. History of Astronomy. A history of astronomy from the dawn of science, treating especially of its modern development. *Prerequisites: Astronomy 31 and 32 or equivalent.* Two hours credit.

104. History of Astronomy in America. A study of the progress of astronomy in the United States. *Prerequisite: Astronomy 103.* Two hours credit.

105. Variable Stars. Lectures, collateral reading, and observations of variables. *Prerequisites: Astronomy 31 and 32.* Three hours credit.

151. Solar Physics. Studies of methods and results of modern solar research. Lectures and collateral reading. *Open to those who possess a general knowledge of astronomy and physics.* Two hours credit.

152. Astrophysics. Studies of methods and results in physical astronomy and especially in stellar spectroscopy. Three recitations and one laboratory period each week. *Open to those who have had calculus and college physics and who possess a general knowledge of astronomy.* Four hours credit.

154. Method of Least Squares. Theory of the error curve and of the combination of observational data according to the method of least squares. Recitations, problems. *Prerequisite: calculus.* Two hours credit.

156. Advanced Practical Astronomy. Studies in continuation of Course 101. *Prerequisite: Astronomy 101 and calculus.* Three hours credit.

CHEMICAL AND METALLURGICAL ENGINEERING

Professors G. G. BROWN, A. E. WHITE, BRIER, UPTHEGROVE, WOOD, KATZ, SCHNEIDEWIND, and CARRICK; Associate Professors THOMASSEN, MCCREADY, and SIEBERT; Assistant Professors FOUST, TOWNSEND, MONROE, and R. R. WHITE; Mr. YORK, Mr. BROWNELL, Mr. BANCHERO, Mr. VAN WINKLE, and Mr. SINNOTT.

"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 to an equal degree to the metallurgical engineer, although the metallurgical engineer is more concerned with metals than with other 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 doctor's degree to one with a bachelor's degree on the grounds that the man with postgraduate training advances faster

and further 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 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. All students desiring 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.

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 Department of Engineering Research.

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 Course 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. It is the most complete equipment of its kind in the country and is a gift of the Swenson Evaporator Company of Harvey, Illinois.

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. Of particular mention is an automatic gas-fired diphenyl boiler for the purpose of supplying high-temperature vapor for heat transfer determination at temperatures up to about 700°F.

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 con-

struct columns of different plate spacings and of different internal design. 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 located 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 the single crystal methods.

In addition to the laboratories including facilities for general instruction in chemical and metallurgical engineering, there are 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 Course 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 neighboring cities within easy reach of Ann Arbor allows a varied 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 club-rooms 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 in residence, provided they take one summer in a military camp. See sections 59 and 62 for further details. Students considering taking military or naval service 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 37.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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
Mech. Eng. 13(3), Heat Engines	4
Met. Proc. 2 and Ch. and Met. Eng. 1	5
Ch. and Met. Eng. 2, Engineering Calculations	3
Total	85

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

Chem. 41, Analytical Chemistry	4
Chem. 67E, 169E, Organic Chemistry	8
Chem. 85E, 87E, Physical Chemistry	6
Elec. 5(2a), Electrical Apparatus and Circuits	4
Ch. and Met. 16, Measurements	2
Ch. and Met. 111(11), Thermodynamics	3

	<i>Hours</i>
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. 129(29), Engineering Lab. and Design	4
Ch. and Met. 130 (34), Process Design	3
Electives	8
Total	55

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. 85E, 87E, Physical Chemistry	6
Elec. 5 (2a), Electrical Apparatus and Circuits	4
Metal Proc. 9, Foundry	2
Ch. and Met. 16, Measurements	2
Ch. and Met. 111 (11), Thermodynamics	3
Ch. and Met. 113 (13), 119, Operations	8
Ch. and Met. 118, Structure of Solids	3
Ch. and Met. 124 (44), X Rays	2
Ch. and Met. 127, 128 (27, 28), Physical Metallurgy	5
Ch. and Met. 129 (29), Engineering Lab. and Design	4
Electives	8
Total	55

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.

Chem. 41, Analytical Chemistry	4
Chem. 67E, 169E, Organic Chemistry	8
Chem. 85E, 87E, Physical Chemistry	6
Elec. 5 (2a), Electrical Apparatus and Circuits	4
Metal Proc. 9, Foundry	2
Ch. and Met. 16, Measurements	2
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. 124 (44), X Rays	2
Ch. and Met. 127 (27), 128 (28), Physical Metallurgy ...	5
Ch. and Met. 129 (29), Engineering Lab. and Design	4
Ch. and Met. 130 (34), Process Design	3
Electives	10
Total	67

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 or metallurgical curriculum, substitute three hours of advanced mathematics for Economics 173.

CURRICULUMS IN CHEMICAL AND INDUSTRIAL ENGINEERING AND IN METALLURGICAL AND INDUSTRIAL ENGINEERING

Combined curriculums in chemical or metallurgical engineering and business administration lead to the degree of Bachelor of Science in Engineering (Chemical Engineering or Metallurgical Engineering) at the completion of 141 hours, and to the degree of Master of Science (Industrial Engineering) at the completion of an approved program in the Graduate School. The undergraduate programs contain the full program in chemical engineering or in metallurgical engineering. Students will then enroll in the Graduate School, and at the completion of an approved program will receive the Master of Science degree in industrial engineering. At least two semesters' work in the Graduate School will be necessary.

PROGRAMS IN CHEMICAL ENGINEERING AND IN METALLURGICAL ENGINEERING

FIRST YEAR

See section 48 for program common to first-year engineering students. If the student earns an average grade of B, 3.0 points or better, in the first term he may substitute Chem. 21E, 4 hours, for English Group II in the second term and take English Group II later, making it possible to complete the requirements in eight terms without a summer session by advancing subsequent courses marked x to an earlier semester.

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSE	HOURS	COURSE	HOURS
Math. 53, Calculus I	4	Math. 54, Calculus II	4
Draw. 3, Adv. Eng.		Mech. 13 (3) Heat Engines	4
Drawing	2	Physics 46, Electricity and	
Physics 45, Mech. Sound		Light	5
and Heat	5	xChem. 41, Quan. Analysis	4
xChem. 21E, Genl. and			
Anal. Chem.	4		17
Electives	2		
	<hr/>		

SUMMER SESSION

xCh. and Met. 2, Eng. Cal.	3
Eng. Mech. 6, Statics	4
xElectives	2
	<hr/>
	9

FIFTH SEMESTER

CHEMICAL ENGINEERING		METALLURGICAL ENGINEERING	
COURSE	HOURS	COURSE	HOURS
xChem. 67E	3	xChem. 53	4
Chem. 85E	3	Chem. 85E	3
Ch. and Met. 111 (11)	3	Ch. and Met. 111 (11)	3
Ch. and Met. 113 (13)	4	Metal Proc. 9	2
Mechanics 2	4	Mechanics 2	4
	<hr/>		<hr/>
	17		16

SIXTH SEMESTER

xChem. 169E	5	Ch. and Met. 113 (13)	4
Chem. 87E	3	Chem. 87E	3
Ch. and Met. 16	2	Ch. and Met. 16	2
Ch. and Met. 115 (15)	3	Ch. and Met. 118	3
Econ. 173	3	Ch. and Met. 127 (27)	2
	<hr/>	Econ. 173	3
	16		<hr/>
			17

SEVENTH SEMESTER

Ch. and Met. 117 (17)	3	Ch. and Met. 128 (28)	3
Ch. and Met. 118	3	Ch. and Met. 119 (19)	4
Elec. 5 (2a)	4	Elec. 5 (2a)	4
Econ. 153	3	Econ. 153	3
Electives	3 or 4	Electives	2 or 3
	<hr/>		<hr/>
	16 or 17		16 or 17

EIGHTH SEMESTER

Ch. and Met. 129 (29)	4	Ch. and Met. 129 (29)	4
Ch. and Met. 130 (34)	3	Ch. and Met. 124 (44)	2
Engl. Group III	2	Engl. Group III	2
Electives	5 or 6	Electives	6 or 7
	<hr/>		<hr/>
	14 or 15		14 or 15

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 are suggestive of the way in which special fields may be covered by advanced students.

SUGGESTIVE 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. 126, Quality Control
 Metal Proc. 111, Gauging
 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. 235 (155), 251 (151), 254, or 258
 Ch. and Met. 315 (215) Azeotropic Distillation
 Chem. 255 or 256, Organic Chemistry
 Chem. 291, Colloid and Surface Chemistry
 Mech. Eng. 182, Design of Process Equipment
 Mech. Eng. 282, Design of Superpressure Equipment
 Math. 109, Graphical Methods
 Math. 126, Status and Quality Control
 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 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, Colloids—Surface 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. 126, Statistics and Quality Control

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. 126, Statistics and Quality
 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. 355 (254), Petroleum Production Engineering
 Chem. 276, Heterogeneous Equilibrium
 Chem. 291, Colloid and Surface 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 and Surface Chemistry
- Chem. 292, Adv. Colloid and Surface Chemistry
- Chem. 294, Colloid and Surface Chemistry Lab.
- Physics 186, Light
- Physics 188, Light Laboratory
- Math. 109, Graphical Methods
- Math. 126, Statistics and Quality Control

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 and Surface 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. 126, Statistics and Quality Control

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. 126, Statistics and Quality Control

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 and Surface 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. Metals, alloys, cement, clay products, protective coatings, fuels, and water. An introductory course. Two lectures, two recitations. Required for all engineering students. *Prerequisite: an acceptable high-school course in chemistry or Chem. 3, and preceded or accompanied by Metal Proc. 2.* Three hours credit.

2. Engineering Calculations. Material and energy balances and their application to chemical and metallurgical problems. Lectures and recitations. *Prerequisites: general chemistry and Physics 45.* Three hours credit.

10. Fuels. Laboratory testing of fuels, gases, oils, and water, and interpretation of results. Is scheduled with Mech. Eng. 17 (7). One hour credit.

16. Measurements Laboratory. Physical-chemical measurements and determination of properties. Laboratory, computations, and reports. *Must be preceded or accompanied by Chem. 85E.* Two hours credit.

100 (20). Plant Work. 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. One hour credit.

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.

107 (7). Metals and Alloys. 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. Lectures and recitations. *May not be elected by chemical or metallurgical engineers. Prerequisite: Ch. and Met. Eng. 1.* Two hours credit.

108. Properties of Aircraft Materials (Aero. Eng. 141). Structure and properties of materials used in aircraft. Light alloys,

heat treatment, plywood, plastics, etc. Lectures and recitation. *Prerequisite: Ch. and Met. Eng. 1.* Three hours credit.

111 (11). **Thermodynamics.** The laws of energy applied to continuous or flow processes, chemical equilibria, properties of materials and solutions, and the concept of availability. Lectures and recitations. *Prerequisites: Ch. and Met. Eng. 2 and Math. 54.* Three hours credit.

113 (13). **Unit Operations.** Equipment and theory of unit operations and their application. Lectures and recitations. *Must be preceded or accompanied by Ch. and Met. Eng. 111 (11).* Four hours credit.

115 (15). **Unit Operations Design.** The theories of heat and mass transfer operations and their application in calculations for equipment design. Lectures and recitations. *Prerequisites: Ch. and Met. Eng. 113 (13).* Three hours credit.

117 (17). **Metals and Alloys.** The structures of metals as affected by composition and thermal and mechanical treatment; their resultant physical properties and behavior in service. Lectures, recitations, and laboratory. *Must be preceded or accompanied by Ch. and Met. Eng. 118.* Three hours credit.

118. **Structure of Solids.** Atomic structure, radioactivity, and artificial nuclear reactions. The course treats 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. *Must be preceded or accompanied by Chem. 87E.* Three hours credit.

119 (19). **Metallurgical Process Design.** The 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. *Prerequisite: Ch. and Met. Eng. 113 (13).* Four hours credit.

124 (44). **X-Ray Studies of Engineering Material.** The principal methods. Lectures, recitations, and laboratory. *Prerequisite: Ch. and Met. Eng. 117 (17) or 127 (27).* Two hours credit.

125 (25). **Colloidal and Amorphous Materials.** Chemistry and properties of organic and amorphous materials and applications. Lectures, recitations, and laboratory. *Must be preceded or accompanied by Chem. 169E.* Three hours credit.

127 (27). **Physical Metallurgy I.** Structures and properties of metals as related to composition and thermal and mechanical

treatment. Lectures, recitations, and laboratory. *Prerequisite: Ch. and Met. Eng. 2 and preceded or accompanied by Ch. and Met. Eng. 118.* Two hours credit.

128 (28). **Physical Metallurgy II.** Thermal and mechanical properties of metals as related to macro- and microstructure. Lectures, recitations, and laboratory. *Prerequisite: Ch. and Met. Eng. 127 (27).* Three hours credit.

129 (29). **Engineering Laboratory and Design.** Laboratory determination of actual operating data of equipment and design of equipment for chemical and metallurgical operations. Laboratory, conferences, reports and design. *Prerequisite: Ch. and Met. Eng. 115 (15) or 119 (19).* Four hours credit.

130 (34). **Chemical Process Design.** Application of chemistry and the unit operations to the design of chemical processes. Lectures and recitations. *Prerequisites: Ch. and Met. Eng. 115 (15) and 117 (17).* Three hours credit.

209 (109). **Research Seminar.** Required of all applicants and candidates for the doctorate. One hour credit.

210 (110). **Special Research and Design Problems.** Laboratory and conferences. Hours and credit to be arranged.

- a) Heat transfer and evaporation.
- b) Distillation and gas absorption.
- c) Extraction and leaching.
- d) Filtration and sedimentation.
- e) Transportation and handling of fluids.
- f) Food processing.
- g) Gas. Manufacture, properties and uses of coal gas, water gas, oil gas, and producer gas.
- h) Hydraulic cements as influenced by chemical composition and temperature of burning.
- i) Electrodeposition and electrochemical processes.
- j) Paint, varnish, and pyroxylin lacquers.
- k) Pulp and paper manufacture.
- l) Plastics.
- m) Ferrous metallurgy. Structures and properties of iron and steel.
- n) Nonferrous metallurgy. Structures and properties of nonferrous metals.
- o) High-temperature metallurgical problems.
- p) Petroleum, natural gas, and motor fuels.
- x) Application of X rays to the structure and properties of materials.

211 (105). **Engineering Thermodynamics.** A study of the principles of the three fundamental laws of energy as applied to chemical and metallurgical engineering problems. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 111 (11).* Three hours credit.

213 (113). **Advanced Unit Operations.** Fluid flow, heat transfer, evaporation, filtration, and sedimentation. Lectures and recitations. *Prerequisites: Ch. and Met. Eng. 115 (15).* Four hours credit.

215 (115). **The Mass Transfer Operations.** An advanced study of distillation, absorption, extraction, leaching, and allied operations. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 115 (15).* Four hours credit.

216 (152). **Pyrometry and Furnace Control.** The theory, construction, calibration, and use of commercial pyrometers; the methods of thermal analysis and the means of temperature control in furnaces. Recitation and laboratory. *Prerequisite: Ch. and Met. Eng. 16.* Three hours credit.

217. **Corrosion and High-Temperature Resistance of Metals.** Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 117 (17) or 127 (27).* Three hours credit.

219. **Metallurgical Operations.** Rolling, forging, extrusion, piercing, drawing, and straightening. *Prerequisites: Ch. and Met. Eng. 119 (19) and 127 (27).* Three hours credit.

220. **Operation and Management of Chemical Plants.** Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 130 (34) or special permission of the instructor.* Three hours credit.

221 (121). **Design of Chemical Engineering Equipment.** 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. *Prerequisites: Ch. and Met. Eng. 115 (15), 117 (17), and 129 (29).* Three hours credit.

224 (144). **X-Ray Studies of Engineering Materials II.** Conference and laboratory. *Prerequisites: Ch. and Met. Eng. 124 (44).* Three hours credit.

228 (143). **Metallography of the Nonferrous Metals.** The microscopic structure of the common nonferrous metals and alloys and of the effect on their structure and properties of heat treatment, mechanical work, and composition. Lectures, recitation, and laboratory. *Prerequisite: Ch. and Met. Eng. 128 (28).* Three hours credit.

229. **Engineering Laboratory.** Laboratory, conferences, and reports. *Prerequisite: Ch. and Met. Eng. 129 (29).* Four hours credit.

231 (171). **Explosives.** The manufacture of commercial and military explosives and pyrotechnic material; their properties and uses. Lectures and recitations. *Prerequisites: Chemistry 169E and Ch. and Met. Eng. 130 (34).* Four hours credit.

232 (172). **The Cellulose Industries.** The manufacture of pulp and paper, cellulose fibers, and plastics; their properties and uses. Lectures and recitations. *Prerequisites: Chem. 87E and Ch. and Met. Eng. 125 (25).* Three hours credit.

233 (125). **Plastics and High Molecular Weight Polymers.** Their manufacture, properties, and uses. Lectures, recitations, and laboratory. *Prerequisite: Ch. and Met. Eng. 125 (25).* Three hours credit.

235 (155). **Petroleum Refining.** The design of process and plant used in the manufacture of petroleum products and natural gasoline. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 115 (15).* Four hours credit.

236 (136). **Paints, Varnishes, and Lacquers.** Their manufacture, properties, and uses. Lectures and recitations. *Prerequisite: Chem. 53 or 169E.* Four hours credit.

239. **Food Processing.** The design and operation of plant for the commercial processing of food. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 129 (29).* Three hours credit.

240 (141). **Manufacture of Iron and Steel.** The design and operation of the blast furnace and steel-making processes. *Prerequisite: Ch. and Met. Eng. 119 (19).* Three hours credit.

241 (149). **Cast Iron and Steel.** The solidification, structures, and properties of cast ferrous metals. Lectures and recitation. *Prerequisites: Ch. and Met. Eng. 117 (17) or 127 (27) and Metal Proc. 9; or Ch. and Met. Eng. 107 (7) and Metal Proc. 3.* Three hours credit.

242 (150). **Alloy Steels.** The theory and practice of alloy additions to steel and the effect of alloying elements on properties of steel. Lecture and recitations. *Prerequisite: Ch. and Met. Eng. 128 (28).* Three hours credit.

251 (151). **Furnace Design and Construction.** Including a study of furnace atmospheres, refractory materials, and their application. Lectures and recitation. Three hours credit.

254. **Heavy Chemicals.** The design of process and plant for the manufacture of heavy chemicals. Lectures and recitations. *Prerequisites: Ch. and Met. Eng. 129 (29) and 130 (34).* Three hours credit.

258. **Electrochemical Operations.** The design and operation of plants for cleaning, anodizing, electrorefining, electrowinning, and electroplating. Lectures, recitations, and laboratory. *Prerequisite: Chem. 87E or a course in electrochemistry.* Three hours credit.

[265 (55). **Petroleum Laboratory.** Determination of properties of fuels, oils, gases, and special methods used in the petroleum industry. *Must be preceded by Ch. and Met. Eng. 16.* One or two hours credit. Omitted in 1945-46.]

266. **Paint, Varnish, and Lacquer Laboratory.** Their analysis, physical testing, and manufacture. Conferences and laboratory. *Prerequisite: preceded or accompanied by Ch. and Met. Eng. 236 (136).* Five hours credit.

311 (205). **Applied Thermodynamics.** An advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics. Conferences and recitation. *Prerequisite: Ch. and Met. Eng. 211 (105).* Three hours credit.

315 (215). **Azeotropic and Extractive Distillation.** The design of processes used in operations involving nonideal solutions. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 215 (115).* Three hours credit.

321 (221). **Plant Location and Layout,** and the design and selection of processes and auxiliary equipment. Three hours credit.

328 (241). **Physical Metallurgy Seminar.** *Prerequisite: Ch. and Met. Eng. 228 (143).* Two hours credit.

335 (255). **Petroleum Refinery Engineering.** Conferences and recitations. *Prerequisite: Ch. and Met. Eng. 235 (155).* Four hours credit.

336. **Paint, Varnish, and Lacquer Formulation.** A study of their economic formulation, manufacture, and uses. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 236 (136).* Five hours credit.

340 (245). **Metallurgical Reactions.** *Prerequisites: Ch. and Met. Eng. 211 (105) and 240 (141).* Two hours credit.

355 (254). **Petroleum Production Engineering.** Petroleum gases and liquids under high pressure, the production of natural gases and crude oil, and process design of separation plants. Lectures and recitations. *Prerequisite: Ch. and Met. Eng. 235 (155).* Four hours credit.

68.

CIVIL ENGINEERING

Professors GRAM,* WORLEY,* CISSEL, MORRISON, WISLER, SHERLOCK, BOUCHARD, SADLER, BOYCE, and CRAWFORD; Associate Professors EMMONS, HOUSEL, ALT, and MAUGH; Assistant Professors McFARLAN, YOUNG, BLEEKMAN, and BRATER; Mr. DAVIES and Mr. BOYD.

* On retirement furlough, 1945-46.

The Department of Civil Engineering is organized into the several administrative divisions described below, corresponding to the specialized practice in which civil engineers are engaged. Each of these divisions under the direction of an experienced engineer and teacher contributes to the program of courses required of all students, but there is opportunity for only a few advanced courses in any division within the limits of the four-year schedule.

Geodesy and Surveying have to do with the making, recording, and reduction of observations for determining the relative positions of points on or near the earth's surface. Geodetic theory is applied when the work is of such extent as to be influenced by the size and shape of the earth. The practice of plane surveying is confined to relatively small areas, is essential for determining land boundaries, for the planning of construction, for directing construction according to design, and for the making of maps and systematic records for general purposes.

Structural Engineering deals with the theory, design, and construction of structures, such as bridges, buildings, dams, retaining walls, etc., involving the use of steel, reinforced concrete, and timber.

Hydraulic Engineering takes up the control and use of water, including irrigation, drainage, water power, and navigable rivers and harbors, and deals with the measurement of water and the design and construction of dams, locks, wharves, irrigation works, and all other forms of hydraulic structures.

Transportation Engineering deals with railroads, highways, waterways, and other forms of transportation; location, design and construction, maintenance, operation, and also the history and economics of transportation systems.

Sanitary Engineering has to do with 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; with the improvement and regulation of natural waters for purposes of sanitation; with air sanitation; and with the principles and standards for the ventilation of buildings and for working under compressed air.

Municipal Engineering deals with the design, construction, maintenance, and management of the streets, pavements, sewers, systems of transportation, utilities, and other public improvements which, taken together, constitute the physical structure of the modern city, with comprehensive planning for cities and metropolitan areas, with the management of public utilities, and in general with the creation and maintenance of safe and wholesome physical conditions within the city.

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 Work leading to advanced degrees is offered to graduates whose records indicate that they can pursue it profitably. 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 44.

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 located 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 6,000 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.

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 37.

a) <i>Preparatory Courses</i>	<i>Hours</i>
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	4
Ch. and Met. Eng. 1 and Metal Proc. 2	5
Economics 53, 54	6
Total	68
b) <i>Secondary and Technical Courses</i>	<i>Hours</i>
Civil Eng. 1, 2 (Surveying 1, 2)	7
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2a, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Elec. Eng. 5 (2a), Electrical Apparatus and Circuits	4
Mech. Eng. 13 (3), Heat Engines	4
Civil Eng. 20 (1), Structural Drafting	2
Civil Eng. 22 (2c), Theory of Structures	3
Civil Eng. 121 (3), Reinforced Concrete	3
Civil Eng. 23 (5a), Elementary Design of Structure	3
Civil Eng. 140 (10), Hydrology	3
Civil Eng. 142 (12), Water Power Engineering	2
Civil Eng. 180 (26), Specifications and Contracts	2
Civil Eng. 50 (30), Fundamentals of Sanitary Engineering	2
Civil Eng. 151 (32), Water Supply and Sewerage	3
Civil Eng. 60 (40), Highway Engineering	2
Civil Eng. 120 (42c), Concrete Mixtures	1
Civil Eng. 70 (50), Railroad Engineering	2
Total	57

<i>c) Electives</i>	<i>Hours</i>
Major and free	15
<i>Summary:</i>	
Preparatory courses	68
Secondary and technical courses	57
Electives	15
	—
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.

Geodesy and Surveying

- Civil Eng. 3 (Surv. 3), Summer camp in surveying.. 8
- Choice of any—
- Civil Eng. design and accompanying theory courses.. 5

Structural Engineering

- Civil Eng. 123 (5*b*), Design of Structures 3
- Civil Eng. 122 (4), Advanced Theory of Structures .. 2
- Choice of either—
- Civil Eng. 125 (6), Applied Soil Mechanics 3
- Civil Eng. 124 (7*h*), Rigid Frame Structures 3

Hydraulic Engineering

- Civil Eng. 146 (16), Hydraulic Engineering Design .. 3
- Civil Eng. 141 (11), Hydraulics 2
- Civil Eng. 144 (14), Hydraulic Structures 3

Municipal and Sanitary Engineering

- Civil Eng. 154 (35), Sanitary Engineering Design ... 3
- Civil Eng. 152 (31), Water Supply Engineering 2
- Civil Eng. 153 (33), Sewerage and Sewage Disposal.. 3
- Bacteriology 51 4

Highway Engineering

- Civil Eng. 170 (54), Railway and Highway Location Design 3
- Civil Eng. 167 (46), Highway and Railway Economics 2
- Civil Eng. 165 (45), Highway Traffic Control 2

Railroad Engineering

- Civil Eng. 170 (54), Railway and Highway Location Design 3
- Civil Eng. 176 (51), Economics of Railroad Construction and Operation 2
- Civil Eng. 172 (52), Railroad Maintenance 2

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 requirements 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 48.

NOTE.—See section 33 for ruling on freshmen repeating subjects graded D.

SECOND YEAR

COURSES	HOURS	COURSES	HOURS
Math. 53	4	Math. 54	4
Physics 45	5	Eng. Mech. 2	4
Civil Eng. 1 (Surv. 1)	3	Eng. Mech. 2a	1
Eng. Mech. 1	3	Civil Eng. 2 (Surv. 2) ...	4
Civil Eng. 20 (1)	2	Civil Eng. 60 (40)	2
	—	Elective	2
	17		—
			17

SUMMER SESSION (at Camp Davis)

Electives

8

THIRD YEAR

Electives	2	Civil Eng. 23 (5a)	3
Physics 46	5	Civil Eng. 121 (3)	3
Civil Eng. 22 (2c)	3	Econ. 54	3
Econ. 53	3	Eng. Mech. 3	3
Civil Eng. 120 (42c)	1	Civil Eng. 50 (30)	2
Eng. Mech. 4	3	Civil Eng. 70 (50)	2
	—		—
	17		16

FOURTH YEAR

Geology 11	4	English 136 (6)	2
Civil Eng. 142 (12)	2	Mech. Eng. 13 (3)	4
Civil Eng. 140 (10)	3	Elec. Eng. 5 (2a)	4
Civil Eng. 151	3	Civil Eng. 180 (26)	2
Electives	5	Electives	4
	—		—
	17		16

**CURRICULUM IN TRANSPORTATION AND REQUIREMENTS
FOR GRADUATION**

Candidates for the degree of Bachelor of Science in Engineering (Transportation Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 37.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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
Chemistry 5E	5
Drawing 1, 2	6
Ch. and Met. Eng. 1 and Metal Proc. 2	5
Econ. 53, 54, 173	9
Total	67
<i>b) Secondary and Technical Courses</i>	
Civil Eng. (Surv. 1)	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2a, Laboratory on Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil Eng. 20 (1), Structural Drafting	2
Civil Eng. 22 (2c), Theory of Structures	3
Civil Eng. 121 (3), Reinforced Concrete	3
Civil Eng. 23 (5a), Elementary Design of Structures	3
Civil Eng. 180 (26), Specifications and Contracts	2
Civil Eng. 183 (27), Public Utility Problems	2
Civil Eng. 60 (40), Highway Engineering	2
Civil Eng. 120 (42c), Concrete Mixtures	1
Civil Eng. 70 (50), Railroad Engineering	2
Civil Eng. 173 (53), Terminal Design	3
Civil Eng. 178 (58), Transportation	2
Mech. Eng. 13 (3), Heat Engines	4
Elec. Eng. 5 (2a), Electrical Apparatus and Circuits	4
Total	50

c) *Group Options—one of the six groups listed below*

COURSES	HOURS	COURSES	HOURS
<i>Railroad</i>		<i>Highway</i>	
Civil Eng. 167 (46)	3	Civil Eng. 125 (6)	3
Civil Eng. 168 (52a)	2	Civil Eng. 161 (42a)	2
Civil Eng. 170 (54)	3	Civil Eng. 164 (44)	2
Elec. Eng. 158 (8)	2	Civil Eng. 165 (45)	2
Electives	13	Civil Eng. 167 (46)	3
	—	Mech. Eng. 150 (29)	3
	23	Electives	8
			—
			23
<i>Traffic</i>		<i>Marine</i>	
Civil Eng. 164 (44)	2	Naval Arch. 11	2
Civil Eng. 165 (45)	2	Naval Arch. 151 (51)	3
Civil Eng. 166 (47)	2	Naval Arch. 12	3
Mech. Eng. 150 (29)	3	Naval Arch 141 (41)	3
Land. Arch. 102	2	Electives	12
Electives	12		—
	—		23
	23		
<i>Aeronautical</i>		<i>Automotive</i>	
Aero. Eng. 1	3	Mech. Eng. 82 (2)	3
Aero. Eng. 111 (3)	2	Mech. Eng. 86 (6)	4
Aero. Eng. 130 (4)	3	Mech. Eng. 150 (29)	3
Math. 103	3	Mech. Eng. 155 (32)	3
Electives	12	Electives	12
	—		—
	23		23
<i>Summary:</i>			
Preparatory courses			67
Secondary and technical courses			50 (47)
Group options			23 (26)
			—
Total			140

PROGRAM

The first three semesters of the curriculum in Transportation are the same as in Civil Engineering (see page 102). In the fourth semester Physics 46 replaces Civil Eng. 60 (40) and electives in the latter curriculum, making a total of sixteen hours instead of seventeen.

• SUMMER SESSION (following second year)

Electives 8 hrs.

THIRD YEAR

FIRST SEMESTER			SECOND SEMESTER		
COURSES	HOURS		COURSES	HOURS	
Civil Eng. 22 (2c)	3		Civil Eng. 121 (3)	3	
Civil Eng. 120 (42c)	1		Civil Eng. 23 (5a)	3	
Eng. Mech. 4	3		Civil Eng. 180 (26)	2	
Civil Eng. 70 (50)	2		Eng. Mech. 3	3	
Mech. Eng. 13 (3)	4		Economics 54	3	
Economics 53	3		Civil Eng. 178 (58)	2	
	16			16	

FOURTH YEAR

FIRST SEMESTER			SECOND SEMESTER		
<i>Highway</i>			<i>Railroad</i>		
Civil Eng. 125 (6)	3		Civil Eng. 183 (27)	2	
Civil Eng. 183 (27)	2		Civil Eng. 168 (52a)	2	
Civil Eng. 173 (53)	3		Civil Eng. 173 (53)	3	
Civil Eng. 161 (42a)	2		Elec. Eng. 5 (2a)	4	
Civil Eng. 164 (44)	2		Economics 173	3	
Economics 173	3		Electives	3	
Electives	2				
	17			17	

SECOND SEMESTER			SECOND SEMESTER		
<i>Highway</i>			<i>Railroad</i>		
Civil Eng. 165 (45)	2		Civil Eng. 167 (46)	3	
Civil Eng. 167 (46)	3		Civil Eng. 170 (54)	3	
Elec. Eng. (2a)	4		Elec. Eng. 158 (8)	2	
Mech. Eng. 150 (29)	3		English 136 (6)	2	
English 136 (6)	2		Electives	7	
Electives	3				
	17			17	

NOTE.—For students electing the aeronautical, automotive, marine, or traffic group options the classifier will arrange a program for the semesters subsequent to the fourth.

PROGRAM IN MUNICIPAL ENGINEERING LEADING TO A BACHELOR'S DEGREE IN CIVIL ENGINEERING AND A MASTER'S DEGREE IN ENGINEERING AND PUBLIC ADMINISTRATION

The College of Engineering and the Institute of Public Administration offer a combined program to meet the needs of students who plan to work in the administrative-technical positions which are to be found in many phases of governmental service.

The field of activity for which this combination of training will

be most useful is that of city management. It is especially necessary in the smaller cities for a manager to be a competent engineer and in addition to be acquainted with the latest technique of public personnel and fiscal administration. There are also a number of other fields, however, such as public personnel administration, highway department administration, waterworks management, and other phases of public works administration, in which this combination training should be very useful.

Students who desire to follow this program must confer with the committee in charge before diverging in any manner from the regular civil engineering curriculum. Inasmuch as the demands made upon practitioners in this field of professional work are usually exacting in certain respects, some discretion will be exercised by the committee in approving candidates for the combined program.

After being accepted for this combined program, the student is registered in the College of Engineering until the completion of his undergraduate curriculum, and then in the Horace H. Rackham School of Graduate Studies for at least a fifth year of formal course work, six months of supervised field work, and a satisfactory thesis. The curriculum in the Engineering College leads to a bachelor's degree in Civil Engineering. The satisfactory completion of the continuation program in the Graduate School leads to a master's degree in Engineering and Public Administration.

Engineering College Program.—The curriculum in the Engineering College comprises the following list of courses:

<i>a) Preparatory Courses</i>	<i>Hours</i>
English 11 (1), 21 (2), 12 (3), 136 (6), and a course from Group II	10
Nontechnical electives, see section 49	6
Mathematics 13, 14, 53, 54	16
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2	6
Geology 11	4
Ch. and Met. Eng. 1 and Metal Proc. 2	5
Econ. 53, 54	6
Total	68
<i>b) Secondary and Technical Courses</i>	<i>Hours</i>
Civil Eng. 1, 2 (Surv. 1, 2)	7
Eng. Mech. 1, 2, 2a, 4	11
Mech. Eng. 13 (3)	4
Elec. Eng. 5 (2a)	4
Civil Eng. 20 (1), 22 (2c), 121 (3), 23 (5a), 140 (10), 180 (26), 50 (30), 151 (32), 60 (40), 120 (42c)	24
Total	50

c) *Courses in Special Field*

Civil Eng. 154 (35), Sanitary Engineering Design	3
Civil Eng. 153 (33), Sewerage and Sewage Disposal; or	
Civil Eng. 155 (34), Municipal and Industrial Sanitation	3
Civil Eng. 165 (45), Highway Traffic Control	2
Land. Arch. 102, City Planning	2
Econ. 71, 72, Accounting	6
Pol. Sci. 107, American Government	3
Pol. Sci. 142, Municipal Government	3
Total	22
Grand Total	140

Graduate School Program.—The continuation program in the Graduate School includes at least thirty hours of course work, six months of supervised internship in some public service department, and a thesis, all under the supervision of the committee in charge. The course work should ordinarily be chosen from the following list:

	<i>Hours</i>
Pol. Sci. 271, 272, Advanced Public Administration	6
Econ. 174, Government Accounting	6
Econ. 121, 122, Labor	6
Econ. 181, 182, Public Finance. Taxation	6
Econ. 175, Economic Statistics	3
Civil Eng. 183 (27), Public Utility Problems	2
Civil Eng. 152 (31), Water Supply Engineering	2
Civil Eng. 153 (33), Sewerage and Sewage Disposal; or	
Civil Eng. 155 (34), Municipal and Industrial Sanitation	3
Civil Eng. 162 (42 <i>b</i>), Bituminous Materials	2
Civil Eng. 167 (46), Highway Administration	2
Mech. Eng. 104 (4), Hydraulic Machinery	3
Mech. Eng. 109 (9), Power Plants	3
Mech. Eng. 142 (17), Pumping Machinery	3
Mech. Eng. 125 (25), Heating and Ventilation	2
Elec. Eng. 171 (7 <i>a</i>), Building Illumination	1
Elec. Eng. 140 (11), Power Plants and Transmission Systems	5
Law, Municipal Corporations	2
Hygiene 203, Applied Hygiene and Public Health	2

Committee in Charge.—During his fourth year in the College of Engineering and his period of registration in the Graduate School the student will be under the general supervision of a committee made up of members from the College of Engineering and the Institute of Public Administration, for counsel and advice and for aid in carrying forward his program. Requests for minor changes and modifications in either the undergraduate curriculum or the graduate program will be considered by this committee.

COURSES IN CIVIL ENGINEERING

1. **Surveying.** Fundamental theory and practice. Lectures, text, field exercises. *Prerequisite: Math. 14.* Three hours credit.

2. **Surveying.** Lectures, text, field exercises. Topographic field work; stadia; plane table. *Prerequisite: Civil Eng. 1 (Surv. 1).* Four hours credit.

3. **Surveying.** Field problems, five and one-half days a week, for 8 weeks. *Prerequisites: Civil Eng. 1 and 2, or 12 and 13 (Surv. 1 and 2, or 12 and 13).* Eight hours credit. Summer Camp.

4. **Surveying.** Elementary theory and practice; use of instruments. Lectures, text, assignments, recitation, and field exercises. *Prerequisite: Math. 14.* Two hours credit.

12. **Surveying.** Similar to Civil Eng. 1 (Surv. 1) with drawing work added. Designed for forestry students. Lectures, text, recitations, field. *Prerequisite: Math. 13.* Four hours credit.

13. **Surveying.** Similar to Civil Eng. 2 (Surv. 2). Designed for forestry students. Lectures, text, two recitations, and two four-hour field or drawing periods. *Prerequisite: Civil Eng. 12 (Surv. 12).* Four hours credit.

20 (1). **Structural Drafting.** Graphical methods of presenting and recording civil engineering data. Lectures, text, and laboratory. *Prerequisite: Draw. 2.* Two hours credit.

21 (2). **Theory of Structures.** 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. Prerequisite: Eng. Mech. 2.* Three hours credit.

22 (2c). **Theory of Structures.** 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. *Prerequisite: Eng. Mech. 2.* Three hours credit.

23 (5a). **Elementary Design of Structures.** Theory of beams and plate girders, and elements of design of simple structures. Computations, drawing work. *Must be preceded by Civil Eng. 20 (1) and preceded or accompanied by Civil Eng. 22 (2c).* Three hours credit.

50. **Fundamentals of Sanitary Engineering.** A presentation of the environmental factors affecting public health that may be con-

trolled 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. Not restricted to engineering students.* Two hours credit.

60 (40). **Highway Engineering.** Historical development; economics; preliminary investigations; design of road and street systems and the individual highway; military roads; construction and maintenance of roads and pavements. *Not restricted to engineering students.* Two hours credit.

70 (50). **Railroad Engineering.** Civil and military railways; design, construction, and maintenance. Lectures, text, problems. *Open to juniors and seniors, but not restricted to engineering students.* Two hours credit.

FOR UNDERGRADUATES AND GRADUATES

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

102 (2). **Geodesy.** Methods employed and field covered by the United States Coast and Geodetic Survey. Lectures, reference work. *Prerequisite: Civil Eng. 101 (Geod. 1).* Two hours credit.

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

106 (6). **Advanced Surveying.** Special advanced work can be provided for those who have received credit in Civil Eng. 3 (Surv. 3). Given only at Camp Davis. Credit, two to eight hours, depending upon the character of the work.

107 (7). **Municipal Surveying.** Surveys for streets, grades, paving, sewers, property lines, subdivisions. Lectures, text, drawing, field period. *Prerequisite: Civil Eng. 3 (Surv. 3).* Two hours credit.

109 (9). **Railway Surveying.** Text, field, track problems. One recitation and one four-hour field period. *Prerequisite: Civil Eng. 3 (Surv. 3), except for students in transportation.* Two hours credit.

111 (21). **Photography. Basic Course.** Fundamental theory and practice. Lectures, reference work, and laboratory period. *Prerequisites: elementary chemistry and physics.* Three hours credit.

112 (22). **Advanced Photography.** Continuation of Civil Eng. 111 (Surv. 21). Lectures, reference work, laboratory period. *Prerequisite: Civil Eng. 111 (Surv. 21).* Two hours credit.

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

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

115 (35). **Boundary Surveys.** Problems relating to the establishment of boundaries. Lectures, reference work. *Prerequisite: Civil Eng. 3 (Surv. 3).* Three hours credit.

120 (42c). **Concrete Mixtures.** Theory and design of concrete mixtures; analysis of aggregate grading; bulking due to moisture; strength, permeability, durability, yield, and economy. Discussions, problems, laboratory. One hour credit.

121 (3). **Reinforced Concrete.** Properties of materials; analysis of stresses in plain and reinforced concrete structures. *Must be preceded or accompanied by Civil Eng. 22 (2c).* Three hours credit.

122 (4). **Advanced Theory of Structures.** A continuation of Civil Eng. 22 (2c). Analysis of stresses in advanced types of trusses; statically indeterminate structures; arches. Lectures, texts, problems. *Prerequisite: Civil Eng. 22 (2c).* Two hours credit.

123 (5b). **Design of Structures.** Design of reinforced concrete and steel structures. Computations, drawing work. *Prerequisites: Civil Eng. 121 and 23 (3 and 5a).* Three hours credit.

124 (7h). **Rigid-Frame Structures.** Analysis of rigid frames by methods of successive approximations and slope deflections; special problems in the design of continuous frames. Lectures, references, problems. *Must be preceded or accompanied by Civil Eng. 123 (5b).* Three hours credit.

125 (6). **Applied Soil Mechanics.** A study of 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. *Prerequisite: Civil Eng. 121 (3). Should be accompanied by Civil Eng. 126 (42d).* Three hours credit.

126 (42d). **Soil-Mechanics Laboratory.** Laboratory soil tests; demonstrations and analysis of field tests; soil surveys; soil classification. *Must be preceded or accompanied by Civil Eng. 125 (6).* One hour credit.

127 (7d). **Timber Construction.** Physical characteristics of structural woods; grading rules; design of timber structures. *Pre-*

requisite: Civil Eng. 23 (5a). One hour credit. Summer session and first semester.

128 (5c). **Design of Arc-Welded Steel Structures.** 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. *Prerequisite: Civil Eng. 23.* One hour credit.

130 (8). **Construction Methods and Equipment.** Contractors' organizations; laws of management; plant selection and layout; methods of construction. Lectures, class discussion. *Open to seniors and graduates.* Two hours credit.

131 (9). **Cost Analysis and Estimating.** Elements of cost in construction; determination of unit costs; analysis of cost records; estimates of cost; quantity surveys. Lectures, references, problems. *Open to seniors and graduates.* Two hours credit.

140 (10). **Hydrology.** A study of the relationship between rainfall and runoff. Two recitations and one three-hour laboratory period. Three hours credit.

141 (11). **Hydraulics.** Principles of uniform and nonuniform flow in open channels; critical depth; hydraulic jump; waves; etc. Lectures, problems. *Prerequisite: Eng. Mech. 4.* Two hours credit.

142 (12). **Water-Power Engineering.** Hydraulics of turbines and fundamental principles of water-power development. Lectures, recitations, problems. *Must be preceded or accompanied by Civil Eng. 140 (10).* *Open only to seniors and graduates.* Two hours credit.

144 (14). **Hydraulic Structures.** Dams, head gates, canals, flumes, pipes, breakwaters, and other structures; principles of irrigation, drainage, and harbor design. *Prerequisite: Civil Eng. 140 (10).* Three hours credit.

145 (15). **Hydraulic Models.** A study of the use of hydraulic models; principles of dimensional analysis and hydraulic similitude and applications to hydraulic problems. *Open to advanced seniors and graduate students.* Two hours credit.

146 (16). **Hydraulic Engineering Design.** Design of hydraulic structures; dams; regulating works, etc. Lectures, computations, design. *Must be preceded by Civil Eng. 121 (3), and preceded or accompanied by Civil Eng. 141 (11).* Three hours credit.

151. **Water Supply and Sewerage.** 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 a municipal sewerage system. Funda-

mentals of design of sewage treatment plants. Lectures, problems. *Prerequisites: Eng. Mech. 4 and Civil Eng. 50 (30a)*. Open to seniors and graduates. Three hours credit.

152 (31). **Water Supply Engineering.** Relates to 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. *Prerequisite: Civil Eng. 50 (30)*. Open to seniors and graduates. Two hours credit.

153 (33). **Sewerage and Sewage Disposal.** 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. *Prerequisite: Civil Eng. 151 (32)*. Open to seniors and graduates. Three hours credit.

154 (35). **Sanitary Engineering Design.** 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. *Must be preceded by Civil Eng. 121 (3), and accompanied or preceded by either Civil Eng. 152, 153, or 155 (31, 33, or 34)*. Three hours credit.

155 (34). **Municipal and Industrial Sanitation.** 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. Three hours credit. Summer session and first semester.

160 (41). **Advanced Highway Engineering.** A seminar course dealing with special phases in which the individual student may be particularly interested. Assigned reading, reports, consultation at stated intervals. Two hours credit.

161 (42a). **Highway Materials Laboratory.** Sources, production, and testing of highway materials; specifications; minor research problems. Lectures, text, laboratory. *Must be preceded or accompanied by Civil Eng. 60 (40)*. Two hours credit.

162 (42b). **Bituminous Materials Laboratory.** Sources, production, and testing of bituminous materials; theory of bituminous pavements; design of mixtures. Lectures, text, laboratory. *Prerequisite: Civil Eng. 60 (40)*. Two hours credit.

163 (43). **Soils in Highway Engineering.** 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. *Must be preceded or accompanied by Civil Eng. 125 (6) and Civil Eng. 126 (42d).* Two hours credit.

164 (44). **Highway Transport.** Fundamentals of transportation of passengers and commodities over highways; regulation of motor carriers; management of transportation companies. *Open to seniors and graduates.* Two hours credit.

165 (45). **Highway Traffic Control.** Causes of and remedies for street traffic congestion and accidents. *Open to seniors and graduates.* Two hours credit.

166 (47). **Highway Traffic Surveys.** Traffic studies for highway planning and for the facilitation and safeguarding of traffic flow. Assigned reading and field work. *It is desirable that this course be preceded or accompanied by Civil Eng. 165 (45).* *Open to seniors and graduates.* Two hours credit.

167 (46). **Highway and Railway Economics.** 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.* Three hours credit.

168 (52a). **Heavy Excavation and Tunnel Work.** Study of the methods and machinery applicable to all types of heavy excavation. Construction practices in the use of tunnel shields, lining, ventilation, drilling, and high explosives. Two hours credit.

170 (54). **Railway and Highway Location Design.** Field and office practice of location and construction. Text, field work, and drawing work. Three hours credit.

171 (56). **Advanced Railroad Location.**

172 (52). **Railroad Maintenance.**

173 (53). **Terminal Design.** Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities. Text, problems, drawing work. Three hours credit.

174 (53a). **Airport Design and Construction.** Location and size of airports; design of runways; materials, types of construction for paved areas. Lectures, assigned reading, problems. Two hours credit.

175 (55). **Advanced Terminal Design.**

176 (51). **Economics of Railroad Construction and Operation.**

177 (57). **Railroad Administration.**

178 (58). **Transportation.** History of transportation; relation of highway, waterway, railway, and airway transportation. Lectures, library research; seminar. Two hours credit.

180 (26). **Specifications, Contracts, and Professional Conduct.** Engineering relations; ethics; war and civil contracts, and specifications. Lectures, reading, discussion. Two hours credit.

181 (20). **Legal Aspects of Engineering.**

182 (21). **Patent Law for Engineers.**

183 (27). **Public Utility Problems.** Relation of public service corporations to the public; organization; ownership; valuation; depreciation; accounting; regulation; taxation; rates; problems of different utilities. Lectures, library reading. Two hours credit.

PRIMARILY FOR GRADUATES

221 (7b). **Structural Engineering Design.** Reinforced concrete building design; drafting-room practice in the general design and detailing of reinforced concrete. Lectures, drawing work. *Prerequisite: Civil Eng. 123 (5b).* Three hours credit.

225 (7j). **Foundations and Underground Construction.**

227 (7a). **Bridge Engineering.**

228 (7c). **Bridge Design.**

229 (7i). **Mechanical Methods of Stress Analysis.** The mechanical analysis of stresses in structures by means of models. *Must be preceded or accompanied by Civil Eng. 124 (7h).* One hour credit.

239 (65). **Structural Engineering Research.** 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.* Credit to be arranged.

240 (61). **Hydrological Research.** Assigned work on some special problem in the field of hydrology. An enormous amount of data is available for such studies. *Prerequisite: Civil Eng. 140 (10).* *Open only to graduates.* Credit to be arranged.

241 (64). **Hydraulic Engineering Research.** Assigned work in hydraulic research; a wide range of matter and method permissible. *Prerequisite: Civil Eng. 141 (11).* *Open only to graduates.* Credit to be arranged.

250 (60). **Sanitary Engineering Research.** 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.* Credit to be arranged.

251 (36). **Public Water Supply.** Deals with 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. Three hours credit.

252 (37). **State Health Department Engineering Practice.** A critical and analytical study of the jurisdictions, functions, standards, and activities of engineering divisions of state departments of health. Two hours credit.

260 (66). **Highway Engineering and Highway Transport Research.** 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.* Credit to be arranged.

270 (67). **Railroad Engineering Research.** 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.* Credit to be arranged.

280 (63). **Civil Engineering Research.** 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.* Credit to be arranged.

69.

ELECTRICAL ENGINEERING

Professors LOVELL, HIGBIE, CANNON, MOORE, ATTWOOD, STOUT, DOW, and HOLLAND; Associate Professors GAULT and BULL; Mr. CLINE, Mr. GOMBERG, and Mr. NEEDLE.

Electrical engineers practice in a field of such great breadth that complete classification of subject matter and functional duties is difficult. The main subdivision 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 indi-

vidual 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 a dynamo laboratory, communication laboratories, a photometric laboratory, an electronics laboratory, a heat-transfer laboratory, and an electrical standards laboratory.

The dynamo laboratory is fully equipped with direct- and alternating-current motors, generators, and control of various types, and includes the necessary complement of meters and oscillographs. The communication laboratories are well equipped with oscillators, vacuum-tube voltmeters, impedance bridges, cathode-ray oscillographs, 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 by models of the interior lighting of buildings. The electronics laboratory contains a 70,000-volt surge generator, a 60,000-volt cathode-ray oscillograph, microwave equipment needed to study electric-arc behavior, transient features of igniter rods and controlled rectifiers, etc. The electrical standards laboratory is provided with standards of resistance, inductance, and capacitance, standard cells, and other equipment needed to calibrate meters and instrument transformers. 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.

REQUIRED COURSES

The required courses offered by the department are designed to give every electrical 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 Elec-

trical 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 where 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 electrical 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 44 and 45.

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, as 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 GROUPS

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
- Civil 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 32, 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. 210 (25), 211 (25a), Electromagnetic Field Theory
- Elec. Eng. 212 (27), Electric and Magnetic Properties of Materials
- Elec. Eng. 250 (6), Advanced Theory of the Induction Motor
- Elec. Eng. 255 (34), Servomechanisms
- Elec. Eng. 260 (52), Heat Problems in Electrical Design
- Advanced courses in mathematics and physics

Communication

- Elec. Eng. 196 (16), Electrical Rectification
- Elec. Eng. 201 (26), Heaviside Operators
- Elec. Eng. 210 (25), 211 (25a), Electromagnetic Field Theory
- Elec. Eng. 220, Microwave Engineering
- Elec. Eng. 221, Radiation and Propagation
- Elec. Eng. 225 (22b), Television
- Elec. Eng. 285 (81), Theory of High-Vacuum Thermionic Tubes
- Elec. Eng. 286, Microwave Electron Tubes
- Physics 174, Sound
- Physics 176, Laboratory Work in Sound

General Theory and Measurement

- Elec. Eng. 101 (10), Advanced Theory of Electrical Circuits
- Elec. Eng. 102 (31), Symmetrical Components
- Elec. Eng. 131 (28), Technical Electrical Measurements
- Elec. Eng. 135, Methods of Instrumentation

- Elec. Eng. 201 (26), Heaviside Operators
- Elec. Eng. 210 (25), 211 (25a), 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 High-Vacuum Thermionic 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), Heaviside Operators
- Elec. Eng. 210 (25), 211, 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 High-Vacuum Thermionic 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 37.

Machinery-Power

<i>a) Preparatory Courses</i>	<i>Hours</i>
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
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Ch. and Met. Eng. 1	5
Economics 53, 54	6
Total	68
<i>b) Secondary and Technical Courses</i>	
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2a, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil 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 (3a), 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 (4a), Electrical Machinery	3
Elec. Eng. 160 (5), Design of Electrical Machinery	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

<i>a) Preparatory Courses</i>	<i>Hours</i>
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
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Ch. and Met. Eng. 1	5
Economics 53, 54	6
Total	68
<i>b) Secondary and Technical Courses</i>	
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2a, 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 (22a), Advanced Radio Communication	} 4
Elec. Eng. 126 (41), Telephone Communication	
Elec. Eng. 181 (83), Industrial Electronics	

Elec. Eng. 130 (Physics 147), Electrical Measurements	3
Elec. Eng. 141 (11a), 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
<hr/>	
Total	65

Summary:

Preparatory Courses	68
Secondary and Technical Courses	65
Electives	7
<hr/>	
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 28a.

For uniform first-year program see section 48.

NOTE.—See section 35 for ruling on freshmen repeating subjects graded D.

SECOND YEAR

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. Science(1)	
Mil. Science(1)		<hr/>	
			(17) or 16
	(18) or 17		

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. 2a	1	Elec. Eng. 130 (Physics 147)	3
Eng. Mech. 3	3	English (Group III)	2
Math. 57	2	<hr/>	
	18		17

Machinery-Power

SUMMER

Mech. Eng. 13 (3)	4
Eng. Mech. 4	3
Mech. Eng. 14 (3a)	1
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FOURTH YEAR

Elec. Eng. 151	3	Elec. Eng. 160 (5)	4
Elec. Eng. 140 (11)	5	Elec. Eng. 170 (7)	2
Mech. Eng. 82 (2)	3	Civil Eng. 21 (2)	3
Econ. 53	3	Econ. 54	3
Elective	3	Elective	3
	<hr/>		<hr/>
	17		15

Electronics-Communication

SUMMER

Mech. Eng. 13 (3)	4
Eng. Mech. 4	3
	<hr/>
	7

FOURTH YEAR

Elec. Eng. 101 (10)	3	Elec. Eng. 160 (5)	4
Elec. Eng. 120 (22)	4	Elec. Eng. 141 (11a)...	2
Mech. Eng. 82 (2)	3	Elec. Eng. 121 (22a) }	4
Econ. 53	3	126 (41) }	
Elective	3	181 (83) }	
	<hr/>	Econ. 54	3
	16	Elective	4
			<hr/>
			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 arrangements 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. Electric circuit theory, measuring instruments, and elementary treatment of motor and generator theory. Three lectures and one four-hour laboratory period. *Must be preceded or accompanied by Physics 46.* Four hours credit.

3. Alternating-Current Circuits. A study of 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. *Prerequisite: Elec. Eng. 2 or 5 (2a).* Four hours credit.

5 (2a). Direct- and Alternating-Current Apparatus and Circuits. Characteristic of direct- and alternating-current motors and generators; problem work on these and on electric circuits. A general course for nonelectrical students. Three lectures and one four-hour laboratory period. *Not open to electrical engineering students. Required of all other students in engineering. Prerequisites: Math. 54 and Physics 46.* Four hours credit.

10 (1). Principles of Electricity and Magnetism. Mathematical and physical treatment of force actions and energy relations in electrostatic and electromagnetic fields; capacitance and inductance of systems of conductors; development of systems of electric and magnetic units. Three lectures and one three-hour computing period. *Prerequisites: Math. 54 and Physics 46.* Four hours credit.

100 (17). Electromechanics. 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. *Prerequisite: Elec. Eng. 3.* Four hours credit.

102 (31). Circuit Analysis by Symmetrical Components. Representation of unbalanced polyphase currents and voltages by component symmetrical sets; solution of unbalanced circuit problems by the use of symmetrical components; faults on power systems. Lectures, recitations, and problems. *Must be preceded or accompanied by Elec. Eng. 100 (17).* Two hours credit.

120 (22). Radio Communication. Circuit theory with special emphasis on resonant circuits; audio-frequency and radio-frequency amplification; modulation and detection; transmitting and receiving circuits. Lectures and laboratory. *Prerequisites: Elec. Eng. 100 (17) and 180 (12) or Physics 165.* Four hours credit.

121 (22a). **Advanced Radio Communication.** Wide-band amplifiers; radio-frequency amplification; modulation and detection; transmitting and receiving circuits; radio-frequency transmission lines; antennas. Lectures and laboratory. *Prerequisite: Elec. Eng. 120 (22).* Four hours credit.

126 (41). **Telephone Communication.** Study of telephone circuits, networks, and apparatus. Lectures and laboratory. *Must be preceded or accompanied by Elec. Eng. 101 (10).* Four hours credit.

130 (Physics 147). **Electrical Measurements.** Methods of measuring current, resistance, electromotive force, capacitance, inductance, and hysteresis of iron, and the calibration of the instruments employed. *Must be preceded or accompanied by Elec. Eng. 100 (17).* Two lectures and one four-hour laboratory period. Three hours credit.

131 (28). **Technical Electrical Measurements.** Theory and practice in making measurements, particularly in alternating currents, to a precision and accuracy required by modern laboratories. Individual reports on various measurement problems. One afternoon of laboratory. *Prerequisite: Elec. Eng. 130.* Two hours credit.

135. **Methods of Instrumentation.** Application of electrical methods to the measuring and recording of physical quantities, such as displacement, stress, strain, pressure, velocity, and acceleration. A study is made of basic methods and their application to particular measurement problems. This course is open to students in various branches of engineering who have completed a course in alternating-current circuits. Two lectures and one four-hour laboratory period. *Prerequisite: Elec. Eng. 3 or 5 (2a).* Three hours credit.

140 (11). **Power Plants and Transmission Systems—Economics of Design.** 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. *Prerequisite: Elec. Eng. 3 or 5 (2a).* Five hours credit.

141 (11a). **Economic Applications in Electrical Engineering.** Study of corporate finance, cost of exchanges, economic decay, obsolescence, plant location, and conductor section. Problems with special application to the communication field. Lectures and recitations. *Prerequisite: Elec. Eng. 3.* Two hours credit.

150 (4). **Alternating Current Machinery.** Study of theory and operating characteristics of polyphase synchronous and induction machines; various types of single phase motors; selsyn devices. Lectures, computing period, and laboratory. *Prerequisite: Elec. Eng. 3.* Four hours credit.

151. Electrical Machinery. Further study of direct- and alternating-machine construction; design theory; control and applications. Lectures and laboratory. *Prerequisite: Elec. Eng. 150 (4).* Three hours credit.

155 (33). Industrial Electrical Engineering. Study of motors and control equipment suited to particular applications; amplidyne and similar control; electronic motor control. Lectures and laboratory. *Must be preceded by Elec. Eng. 5 (2a) or preceded or accompanied by Elec. Eng. 150 (4).* Three hours credit.

158 (8). Principles of Electric Traction. 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. *Prerequisite: Elec. Eng. 3 or 5 (2a).* Two hours credit.

160 (5). Fundamentals of Electrical Design. Design problems from various types of apparatus involving the electric and magnetic circuits; field mapping; heat-transfer and temperature-rise work. Two lectures and two four-hour computing periods. *Prerequisites: Elec. Eng. 3 and 10 (1).* Four hours credit.

170 (7). Illumination and Photometry. 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. *Must be preceded by Physics 46, and preceded or accompanied by Math. 54.* Two hours credit.

171 (7a). Building Illumination. A study of proper illumination for typical interiors such as schools, offices, and residences. This course is 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 term. *Not open to electrical engineering students.* One hour credit.

172 (7b). Electric Lighting and Distribution. Lectures and problems. For students of architecture particularly; students of electrical engineering cannot receive credit for this course. First semester only. Two hours credit.

173 (15). Advanced Lighting. 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. *Must be preceded by Elec. Eng. 3 and 170 (7).*

174 (70). **Electrical Distribution, Wiring and Control for Lighting.** Selection and application of equipment, design of circuits, study of methods of installation for electric-power supply to lamps. Lectures, problems, and surveys. *Prerequisites: Elec. Eng. 3 and 170 (7).* Two hours credit.

175 (74). **Lighting Equipment.** Analysis of design and performance of lamps, reflectors, refractors, diffusers, and other light-control media, and of complete luminaires. Lectures and problems. *Prerequisites: Elec. Eng. 3 and 170 (7).* Two hours credit.

180 (12). **Electronics and Electron Tubes.** Amplifier principles, gain, distortion, efficiency, coupling; oscillators; thermionic emission; grid control. Atom energy-level diagrams, ionization and excitation potentials. Three lectures and one three-hour laboratory period. *Must be preceded by Elec. Eng. 3 and preceded or accompanied by Elec. Eng. 10 (1).* Four hours credit.

181 (83). **Industrial Electronics.** An applicational study of electronic circuits, methods, and problems in the manufacturing and electric power industries. Three lectures and one four-hour laboratory period. *Prerequisite: Elec. Eng. 180 (12).* Four hours credit.

194 (73). **Photoelectric Cells and Their Applications.** Study of operating characteristics of photoelectric cells; amplifying circuits and relays; industrial applications; photoelectric photometers. Lectures and laboratory work. *Prerequisite: permission of instructor.* Two hours credit.

196 (16). **Electrical Rectification.** 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. *Must be preceded by Elec. Eng. 180 (12), and preceded or accompanied by Elec. Eng. 100 (17).* Two hours credit.

199 (9). **Directed Research Problems.** 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. *Prerequisite: Elec. Eng. 3.* Credit by arrangement.

201 (26). **Heaviside Operators.** Advanced theory of electrical circuits as developed by the application of Heaviside operators. Methods of circuit solutions for transients in circuits with lumped constants; circuits with distributed constants; long lines; cables. Lectures and discussions. *Prerequisite: Elec. Eng. 100 (17).* Two hours credit.

210 (25). **Electromagnetic Field Theory.** 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. *Prerequisites: Elec. Eng. 3 and 10 (1).* Three hours credit.

211 (25a). **Engineering Application of Electromagnetic Field Theory.** Lorentz' equations, retarded potentials, radiation from antennas. Skin effect. Mass as a function of velocity; energy and mass. Two-dimensional field studies, conformal transformations. *Prerequisite: Elec. Eng. 210 (25).* Three hours credit.

212 (27). **Electrical and Magnetic Properties of Materials.** Studies of the electric and magnetic properties of gaseous, liquid, and solid materials used in electrical engineering. Lectures and recitations. *Prerequisites: Elec. Eng. 180 (12) and 210 (25).*

220. **Microwave Engineering.** Theory and practice of microwave techniques. Microwave generation, detection, and measurement. Electromagnetic waves; wave guides and cavity resonance phenomena. Special circuits. Lectures and laboratory. *Prerequisite: Elec. Eng. 121 (22a).* Four hours credit.

221. **Radiation and Propagation.** Fundamental theory. Simple antennas; arrays and reflecting systems. Ionosphere; reflection and refraction; ground effects. Lectures. *Prerequisite: Elec. Eng. 121 (22a).* Three hours credit.

225 (22b). **Television.** Study of basic principles, cathode-ray scanning devices, and television receivers and transmitters. Lectures. *Prerequisite: Elec. Eng. 121 (22a).* Two hours credit.

240 (19). **Study of Design—Power Plants.** Study of 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. *Prerequisites: Elec. Eng. 140 (11) and 100 (17).* Two hours credit.

241 (20). **Study of Design—Electric Transmission and Distribution Systems.** 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. *Prerequisites: Elec. Eng. 140 (11) and 100 (17).* Two hours credit.

242 (36) **Electric Rates and Cost Analysis.** Capitalization; fair return on investment; analysis of costs and value of electrical energy; customer charge, demand charges, energy charges; in-

vestigations of practical systems used in charging for electrical energy. Lectures. *Prerequisite: Elec. Eng. 140 (11)*. One hour credit. Second semester.

255 (34). Servomechanisms. Study of automatic controller design and application, including mathematical theory. Two lectures and one three-hour laboratory period. *Prerequisites: Elec. Eng. 155 (33) and 201 (26)*. Three hours credit.

260 (52). Heat Problems in Electrical Design. Advanced work in the fundamentals of heat transfer by radiation, conduction, and natural and forced convection; application to specific situations. *Prerequisite: permission of the instructor*. Two hours credit.

271 (71). Interior Illumination, Study of Design. 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. *Prerequisite: Elec. Eng. 170 (7) or equivalent*. Two hours credit.

280 (82). Gaseous-Conducting Electronic Apparatus. 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. *Prerequisite: Elec. Eng. 180 (12)*. Three hours credit.

285 (81). Theory of High-Vacuum Electron Tubes. 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. *Prerequisite: Elec. Eng. 180 (12)*. Three hours credit.

286. Microwave Electron Tubes. Theory and operation of ultra-high-frequency electron tubes, including klystrons, magnetrons, triodes, and tetrodes. Two lectures and one four-hour laboratory period. *Prerequisite: Elec. Eng. 180 (12)*. Three hours credit.

287 (84). Electron Beam Tubes. 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. *Prerequisite: Elec. Eng. 180 (12)*. Three hours credit.

299 (18). Research Work in Electrical Engineering. 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. *Elected by permission of head of department*. Credit by arrangement.

70. ENGINEERING MECHANICS

Professors ERIKSEN, MENEFEE, VAN DEN BROEK, ORMONDROYD, and DODGE; Associate Professors SWINTON, OLMS TED, and HANSEN; Assistant Professors LIDDICOAT, EVERETT, and WOJTASZAK; Mr. HAGERTY.

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 the various phases of 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 with a demonstration room for illustrating principles of streamline flow, channel and weirs, pipe flow, orifices, etc.

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 50,000-pound, a 100,000-pound, and a 200,000-pound universal testing machine, a 72,000-pound universal hydraulic testing machine, a 230,000-inch-pound torsion machine with jaws for taking specimens $2\frac{7}{8}$ inches in diameter, an Olsen impact machine, an Upton Lewis endurance tester, an electrically driven bar bender for bars up to $2\frac{1}{2}$ inches in diameter, a Brinell hardness tester, a Rockwell hardness tester, a wire tester, a transverse bending machine for cast iron arbitration bars and other short demonstration beams, a nine-foot transverse bending machine and a power saw and grinder, an electric furnace, a polishing table and wheel with photographic equipment, and cement-testing equipment for all standard cement tests.

The special accessory equipment consists of one six-element tele-meter 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-Show 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.

	<i>Hours</i>
<i>a) Preparatory Courses</i>	
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
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Ch. and Met. Eng. 1	5
Economics 53 and 54	6
Total	68
<i>b) Secondary Courses</i>	
Civil Eng. 4 (Surveying 4)	2
Eng. Mech. 1, 2, 2a, 3, 4	14
Elec. Eng. 5 (2a)	4
Civil Eng. 21 (2)	3
Mech. Eng. 13 (3)	4
Total	27
<i>c) Advanced Courses</i>	
Technical group, in some specified technical engineering department, including an advanced design course; approximately	13
Eng. Mech. (advanced)	16
Mathematics group; approximately	10
Electives; approximately	6
Grand Total	140

The number of hours in the technical, mathematics, and elective groups are subject to variation on the advice of the Chairman of the Department.

COURSES IN ENGINEERING MECHANICS

1. Statics. Study of fundamental principles of mechanics and their application to the simpler problems of engineering. Forces, components, vectors, moments, couples, method of sections, cables, friction. Recitations, lectures, problems. *Must be preceded or accompanied by Math. 53 and Physics 45.* Three hours credit. Each semester.

2. Strength and Elasticity of Materials. A study of the application of mathematics and 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 by area moment method, and compounding of simple stresses. Recitations, lectures, and problems. *Must be preceded by Eng. Mech. 1 and preceded or accompanied by Math. 54.* Four hours credit. Each semester.

2a. Laboratory in Strength of Materials. Experiments with beams, struts, shafts, and engineering materials, supplementing text work. Attendance at laboratory once each week. *Must be preceded or accompanied by Eng. Mech. 2.* One hour credit. Each semester.

3. Dynamics. All motions of a particle, dynamics of moving bodies, Newton's laws, simple harmonic motion, elementary vibration problems, balancing, pendulums, impulse and momentum, gyroscope, and work and energy. Recitations, lectures, problems. *Prerequisites: Eng. Mech. 1 and Math. 54.* Three hours credit. Each semester.

3a. Experimental Dynamics. Experiments with acceleration, vibration, balancing, critical speeds, and gyroscopes. One hour laboratory period, with report, each week. *Must be preceded or accompanied by Eng. Mech. 3.* One hour credit.

4. Fluid Mechanics. Properties of fluids; statics of fluids, compressible and incompressible; flotation; accelerated liquids in relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; the flow of viscous fluids, thin films, discontinuity, Reynolds' number; viscometry; the flow of fluids in pipes, Reynolds' criterion; flow with free surface, channels, 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, cavitation, Bernoulli's theorem; dynamical similitude. Recitations, lectures, demonstrations. *Prerequisites: Eng. Mech. 1 and Math. 54.* Three hours credit. Each semester.

4a. Fluid Mechanics Laboratory. Visualizing flow of liquids; 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. *Must be preceded or accompanied by Eng. Mech. 4.* One hour credit.

5. Materials Testing. (Required only of architectural engineers.) History of rapid development of the science; correlation with mechanics; study of testing machines, calibration, and particular function. Written reports, special emphasis on technique of report writing, and graphic presentation and interpretation of data. Laboratory work devoted to tests on steel, iron, wood, brick, and structural materials, including standard cement tests, water-ratio theory, voids in sand and gravel, reinforced and unreinforced concrete beams, and granular metric analysis of sand. Lectures, laboratory, reports. *Prerequisite: Eng. Mech. 2.* Two hours credit. Each semester.

6. Statics and Dynamics. Study of fundamental principles of mechanics and their application to engineering problems. Forces, components, vectors, moments, couples, method of sections, friction, centroids, motions of a particle, dynamics of moving bodies, Newton's laws, simple harmonic motion, elementary vibration problems, balancing, impulse, and momentum gyroscopy, work and energy. Recitations, lectures, problems. *Prerequisites: Physics 45, preceded or accompanied by Math. 54. Open only to chemical and metallurgical engineers.* Four hours credit.

100. Seminar in Engineering Mechanics.

PRIMARYLY FOR NONENGINEERING STUDENTS

102. Strength and Elasticity of Materials. Same as Eng. Mech. 2 with extra material and extra reading requirements for graduate students.

103. Dynamics. Same as Eng. Mech. 3 with extra material and extra reading requirements for graduate students.

104. Fluid Mechanics. Same as Eng. Mech. 4 with extra material and extra reading requirements for graduate students.

120 (10a). Research in Theory of Elasticity. Special problems involving application of theory and experimental investigation. Credit to be arranged.

121 (10b). Research in Theory of Structures. Special problems such as arches, arch dams, suspension bridges, elastic stability of columns and framed structures, impact effect and vibration of bridges. Credit to be arranged.

122 (7). Research in Testing Materials. *Prerequisite: Eng. Mech. 2.* Credit to be arranged.

123 (9 and 18). Advanced Theory of Strength. 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. *Prerequisite: Eng. Mech. 2.* Three hours credit.

124 (13a). Applied Elasticity. Fundamentals of the theory of elasticity with its application to stress analysis in machine parts. Stress and strain. General equations of equilibrium. Two-dimensional problems of the theory of elasticity and the photoelastic method of stress analysis. Stress concentration produced by fillets and holes. Stress in curved bars. Torsion of prismatical bars. Torsion of circular shafts of variable diameter. Bending of prismatical bars. *Prerequisites: Eng. Mech. 1, 2, and 3 and Math. 105.* Two hours credit.

125 (13b). Applied Elasticity; Theory of Thin Plates. General equation for deflection of thin plates. Bending of circular plates under various loading conditions. Bending of rectangular plates. Buckling of plates. Application in design of tubular built-up sections and girders. Plates of elastic foundation. Designed principally for graduate students. *Prerequisites: Eng. Mech. 1, 2, and 3 and Math. 105.* Two hours credit.

126 (14). Advanced Stress Analysis. Stress concentration in tension and compression produced by fillets and holes. Photoelastic method of studying stress concentration. Stresses in shafts of variable cross-sections. Stresses due to shrink-fit pressure. Stresses in curved bars, theory and applications. Stresses in flywheels, rotating discs, and rotors. Critical speeds. Designed principally for students interested in machine design. *Prerequisite: Eng. Mech. 2.* Two hours credit.

127 (15). Theory of Structures in Ship Design. With application to the solution of such problems as bending of beams on elastic foundation; combined bending and tension or compression; buckling of solid, tubular, and built-up columns under various conditions; buckling of thin plates, such as flanges and webs of built-up sections, and the web of a plate girder; bending of slabs under various conditions, with application to ship decks. Designed principally for students interested in naval architecture and marine engineering. *Prerequisite: Eng. Mech. 2.* Three hours credit.

128 (25). Stability of Elastic Structures. Bending of bars under the action of lateral and direct load. Buckling of slender bars; buckling of comparatively short 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. Application in plate-girder design. Stability of thin-walled structures. *Prerequisites: Eng. Mech. 1, 2, and 3 and Math. 105.* Two hours credit.

130 (10c). **Research in Dynamical Problems.** Original investigations in the field of body motions. Such 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, internal hysteresis of materials, and viscosity of liquids. Hours and credit to be arranged.

131 (12). **Vibration Problems in Engineering.** Vibration of systems with one degree of freedom. Balancing of rotating machines; calculations of critical speeds of rotating shafts; theory of vibration-recording instruments; springs of variable flexibility. Systems with several degrees of freedom, and elastic bodies. Vibration of cars; torsional and lateral vibration of shafts; vibration of beams; vibration of bridges, turbine blades, and turbine discs. *Prerequisites: Eng. Mech. 1, 2, and 3, and Math. 105.* Three hours credit.

132 (8). **Advanced Dynamics.** Advanced dynamics of rigid bodies in systems of engineering interest. Lagrange's equations. *Prerequisites: Eng. Mech. 3 and 131 (12).* Two hours credit.

133 (21). **History of Dynamics.** 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. *Prerequisites: Eng. Mech. 3 and Math. 105.* One hour credit.

140. **Research in Flow of Fluids.** Reading and laboratory experiments pertaining to special problems in fluid flow. Hours and credit to be arranged.

71.

MATHEMATICS

Professors HILDEBRANDT, FIELD,* LOVE,† and CHURCHILL; Associate Professors HOPKINS, and STEENROD; Assistant Professors ROUSE, DUSHNIK, RAINVILLE, THRALL,† HAY, KAPLAN, and ROTHE; Mr. KAZARINOFF, Dr. BARTELS, Dr. GOLDSTONE,† Dr. PIRANIAN, and Dr. SCHAFER.

* On retirement furlough, 1945-46.

† On leave.

The object of the work of 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 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 as early as possible.

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 will be found in the *Announcements* of the College of Literature, Science, and the Arts and 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:

<i>a) Preparatory Courses</i>	<i>Hours</i>
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
Met. Proc. 2 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
Elec. Eng. 5 (2a)	4
Mech. Eng. 13 (3)	4
	<hr/>
Total	18

c) *Advanced Courses*

Options in mathematics including 103 or 105 and 106, and 151 or 150	12
Options in engineering	10
Electives in astronomy, chemistry, economics, engineering, engineering mechanics, drawing, mathematics, metal processing, natural science, physics, and surveying	20
Free electives	20
	<hr/>
Total	62

Summary:

Preparatory courses	60
Secondary courses	18
Advanced courses	62
	<hr/>
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.
2. In the chemical or metallurgical curriculum, substitute three hours of advanced mathematics for Economics 173.

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.** Postulates; basic constructions and propositions; original exercises; mensuration. *Prerequisite: one year of plane geometry.* Two hours for no credit. Each semester.

* Students entering with credit in trigonometry will take Mathematics 13. Students entering without trigonometry will take Mathematics 7 except that those whose high-school records show unusual proficiency in mathematics may take Mathematics 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 Mathematics 6 without credit.

***7. Algebra and Trigonometry.** Review of elementary operations; linear equations; exponents; radicals; quadratic equations; simultaneous quadratics; progressions; binomial theorem. Trigonometry—the same as in Math. 8. Four hours for two hours credit. Each semester.

***8. Trigonometry.** 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. Two hours credit. Each semester.

10. Spherical Trigonometry. Fundamental properties of spherical triangles and trihedral angles; solution of spherical triangles, tetrahedra, and parallelepipeds; Napier's and Delambre's analogies; applications to navigation. *Prerequisites: solid geometry and plane trigonometry.* One hour credit. Each semester.

***13. Algebra and Analytic Geometry.** 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. Four hours credit. Each semester.

14. Plane and Solid Analytic Geometry. Properties of conics involving tangents, diameters, asymptotes, parametric equations; surface tracing and locus problems in space; plane; straight line; quadric surfaces; space curves; introduction to calculus; differentiation of algebraic functions. Four hours credit. Each semester.

15. Solid Analytic Geometry. Surface tracing and locus problems in space; planes; straight lines; quadric surfaces; space curves. Two hours credit. Each semester.

20. Introduction to Air Navigation. 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. Four hours credit. Each semester.

52. Calculus I. This course is to be elected by students who have not had an introduction to calculus in their freshman course. It will start 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. Five hours credit. Each semester.

* Students entering with credit in trigonometry will take Mathematics 13. Students entering without trigonometry will take Mathematics 7 except that those whose high-school records show unusual proficiency in mathematics may take Mathematics 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 Mathematics 6 without credit.

53. Calculus I. Functions; limits; continuity; derivative; differentiation of algebraic functions; trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; introduction to the indefinite integral. Four hours credit. Each semester.

54. Calculus II. 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. *Prerequisite: Math. 53, or equivalent.* Four hours credit. Each semester.

57. Differential Equations. Simple types of ordinary equations of the first and second order; linear equations with constant coefficients; applications to geometry, mechanics, and electrical circuits. *Prerequisite: Math. 54.* Two hours credit. Each semester.

103. Differential Equations. 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. *Prerequisite: one year of calculus.* Three hours credit. Each semester.

105. Differential Equations. Solutions of differential equations by elementary methods. *Prerequisite: Math. 54.* Two hours credit. First semester.

106. Advanced Differential Equations. Solution of differential equations by infinite series; functions defined by differential equations. Two hours credit. Second semester.

109. Graphical Calculus and Differential Equations. Graphical differentiation and integration; method of least squares; graduation of data; determination of weights of data; graphical solution of differential equations. This is mostly a problem course planned for chemical engineers. *Prerequisite: calculus.* Three hours credit. First semester.

110. Introduction to Functions of a Complex Variable, with Applications. Complex numbers; limit; continuity; derivative; conformal representation; integration; Cauchy theorems; power series; singularities; applications to engineering and mathematical physics. *Prerequisite: calculus.* Three hours credit. Second semester.

113. Introduction to Matrices. Polynomials; symmetric functions; transformations and matrices; equivalence of matrices and forms; linear spaces; functional matrices and canonical forms; application to linear differential equations. *Prerequisite: Math. 62.* Three hours credit. Second semester.

126. Quality Control. Elementary statistical methods as they are applied to the control of quality of manufactured products and

to acceptance sampling. Control charts, statistical analysis of inspection, and test data; sampling inspection, and the use of standard acceptance sampling tables. Three hours credit. First semester.

127. Theory of Statistics I. Averages and moment characteristics of frequency distributions. Frequency functions. *Prerequisite: one year of calculus.* Three hours credit. Each semester.

128. Theory of Statistics II. Correlation and sampling theory. *Prerequisite: Math. 127.* Three hours credit. Second semester.

130. Significance Tests. Theory and applications of statistical methods suitable for small samples, including quality control and the analysis of variance. *Prerequisites: Math. 127 and 128 or their equivalent.* Three hours credit. Second semester.

141. Statics. The fundamental concepts of mechanics, vectors, velocity, acceleration, mass and force, work and energy, center of gravity, moments of inertia. Statics of a particle, of rigid bodies, and of deformable bodies. *Prerequisites: Math. 53 and 54.* Three hours credit. First semester.

142. Dynamics. Motion in a straight line, curvilinear motion, central forces, constrained motion. Generalized co-ordinates of Lagrange, canonical equations of Hamilton, general principles of mechanics. Three hours credit. Second semester.

143. Applications of Mathematics to Engineering Problems. Dynamics; the gyroscope, the ballistic problem, the motion of an airplane, etc. Small oscillations. The mechanics of strings; the suspension bridge. The vibration and buckling of beams. *Prerequisites: differential equations, advanced calculus recommended.* Three hours credit. First semester.

145. 146. Celestial Mechanics. 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. Two hours credit each.

147. Modern Operational Mathematics. The Laplace transformation, with emphasis on its applications 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. *Prerequisite: elementary differential equations or advanced calculus (or Math. 150).* Two hours credit. Each semester.

148. Fluid Dynamics. Motion on the surface of the earth, forces on air foils, viscous fluids, dynamic similarity, turbulence. This course will meet the needs of students of meteorology. *Prerequisite: Math. 54.* Three hours credit.

149. Exterior Ballistics. The nature of the data on which range tables are based, the equations of motion in vacuo and in air, numerical integration, corrections for variations from range table conditions. Two hours credit.

150. Advanced Mathematics for Engineers. Topics in advanced calculus including infinite series, Fourier series, partial derivatives, directional derivatives, line integrals, Green's theorem, vector analysis and complex variables. Introduction to differential equations. *Required in aeronautical engineering. Prerequisite: Math. 54.* Four hours credit. Each semester.

151. Advanced Calculus. Review of the fundamental theory of elementary calculus. Taylor's theorem. Explicit and implicit functions. Simple, multiple, and improper integrals. Functions defined by integrals and other selected topics. Three hours credit. Each semester.

152. Fourier Series and Applications. Orthogonal functions, Fourier series, Bessel functions, Legendre polynomials and their applications to boundary value problems in mathematical physics. *Prerequisite: Math. 150 or 151.* Three hours credit. Each semester.

154. Advanced Calculus II. Selected topics from elliptic integrals, calculus of variations, Fourier series, and complex valued functions. *Prerequisite: Math. 151.* Three hours credit. Second semester.

157. Intermediate Course in Differential Equations. Linear equations of the second order. The generalized Riccati equation, the hypergeometric equation, and the confluent hypergeometric equation. Use of divergent summable series. *Prerequisites: Math. 103 or 105, and 151 or 153, or their equivalents.* Three hours credit. Second semester.

169. Graphical Methods. Graphical representation of functions; construction of graphical charts; graphical solution of equations; graphical methods applied to the solution of differential equations. Two hours credit. First semester.

170. Empirical Formulas. Curve fitting; graphical determination of constants in empirical formulas; application of the method of least squares; interpolation; numerical integration. Two hours credit. Second semester.

172. Graphical Methods and Empirical Formulas. Graphical representation of functions, construction and 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. *Prerequisites: Math. 53 and 54.* Three hours credit. Second semester.

175. Theory of the Potential Function. Newtonian attraction, Newtonian and logarithmic potentials, the equations of Laplace and Poisson, harmonic functions, the principles of Dirichlet, the problems of Dirichlet and Neumann, and Green's function. Three hours credit.

176. Vector Analysis. A study of the formal processes of vector analysis, followed by applications to problems in mechanics and geometry. Three hours credit. Second semester.

247. Mechanics of Continua. Derivation of the equations of motion. Application to some cases of a vibrating elastic body. The motion of a perfect fluid. Bernoulli's theorem. Vortex motion. Three hours credit.

249. Methods in Partial-Differential Equations. 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. Three hours credit. First semester.

250. Topics in Mathematical Physics. 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. Three hours credit. Second semester.

347, 348. Seminar in Applied Mathematics. One hour credit. Each semester.

72. MECHANICAL ENGINEERING

Professors HAWLEY, BURSLEY, LAY, SHERZER, KEELER, GORDY, VINCENT, NICKELSEN, GOOD, and MARIN; Associate Professors LLOYD, CALHOON, KESSLER, PORTER, and SCHWARTZ; Assistant Professors WATSON, KOHLER,* WILSON, and EPPLE.

Mechanical Engineering includes the fields of heat, power, design of machinery, management, and industrial problems. It may be divided into thermodynamics, steampower, 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, chem-

* On leave, 1945-46.

istry, 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 located 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 located 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 ample facilities for research work. A small laboratory for testing aircraft motors is located at the Ann Arbor Airport. Facilities are available also for laboratory instruction in time and motion study.

The Motion and Time Study Laboratory situated in the West Engineering Annex contains projectors, films, and other equipment for detailed studies in this field of work.

Advice to Students of other colleges and universities, with regard to planning their courses before coming to the University, is to be found in section 14.

Military and Naval Science.—Students who plan to take courses in military or naval science are urged to enroll in 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 section 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 37.

CURRICULUM

<i>a) Preparatory Courses</i>	<i>Hours</i>
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. (2), and Ch. and Met. Eng. 1	5
Metal Proc. (3), Foundry	4
Metal Proc. (4), Machine Shop	4
Economics 53, 54	6
Total	74
 <i>b) Secondary and Technical Courses</i>	
Civil Eng. 4 (Surv. 4), Use of Instruments	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2a, Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 1, Introduction to Mech. Eng.	1
Mech. Eng. 13 (3), Heat Engines	4
Mech. Eng. 80 (1a), Mechanism	2
Mech. Eng. 82 (2), Machine Design	3
Mech. Eng. 104 (4), Hydraulic Machinery	3
Mech. Eng. 105 (5), Thermodynamics	3
Mech. Eng. 17 (7), Laboratory, First Course	2
Mech. Eng. 86 (6), Advanced Machine Design	3
Mech. Eng. 108 (8), Laboratory, Second Course	3
Mech. Eng. 109 (9), Power Plants	3
Civil Eng. 21 (2), Theory of Structures	3
Elec. Eng. 5 (2a), D.C. App. and Cir.	4
Ch. and Met. Eng. 10, Utilization of Fuels	1
Total	51
 <i>Summary:</i>	
Preparatory courses	74
Secondary and technical courses	51
Electives, restricted and free	15
Total	140

SELECTION OF ELECTIVE COURSES

The fifteen hours of elective work are to be filled partly by "Restricted electives" and partly by "Free electives."

a) *Restricted Electives:*

Students taking the regular curriculum must elect at least one theory course from the following group: Mech. Eng. 111 (11), 113 (13), 115 (15), 120 (19), 125 (25), 130 (20), 135 (35), 140 (16), 142 (17), 151 (30), 153 (31), 205 (14); and must complete a design requirement from Mech. Eng. 110 (9a), 112 (11a), 116 (15a), 126 (25a), 131 (20a), 141 (16a), 143 (17a), 152 (30a), 154 (31a), 162-163 (62-63), 172-173 (72-73), 181 (21a). Some of the design courses require the corresponding theory course as a prerequisite. In others certain freedom of choice is permitted. In all elections, prerequisites must be followed.

b) *Free Electives:*

The remaining elective hours may be filled by courses offered by any department in the Engineering College or by any college or school in the University to which the student is eligible, subject to the approval of the head of the Mechanical Engineering Department.

In the selection of his elective hours the student is urged to broaden his training by making elections in other departments of work, and in so doing should consult freely with the members of the Mechanical Engineering staff.

PROGRAM IN MECHANICAL ENGINEERING

FIRST YEAR

For uniform first-year program see section 48.

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	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. 2a	1
Mech. Eng. 1	1	Mech. Eng. 80 (1a)	2
Mil. or Nav. Science	(1)	Mil. or Nav. Science	(1)
	(16) or 15		(17) or 16

SUMMER SESSION

Elec. Eng. 5 (2a)	4
Metal Proc. 3	4
	8

THIRD YEAR

Mech. Eng. 82 (2)	3	Mech. Eng. 105 (5)	3
Mech. Eng. 13 (3)	4	Metal Proc. 4	4
Mech. Eng. 17 (7) and Ch. and Met. 10	3	Eng. Mech. 4	3
Econ. 53	3	Econ. 54	3
Eng. Mech. 3	3	Civil Eng. 122 (4)	2
Electives	2	Electives	3
	<hr/>		<hr/>
	18		18

FOURTH YEAR

Mech. Eng. 86 (6)	3	Mech. Eng. 109 (9)	3
Mech. Eng. 104 (4)	3	Mech. Eng. Design	3
Mech. Eng. Theory . . . 2 or 3		Mech. Eng. 108 (8)	3
Civil Eng. 21 (2)	3	Electives	6
English (Group III)	2		
Electives	4		
	<hr/>		<hr/>
	17 or 18		15

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 37.

a) *Preparatory Courses*

(See Curriculum in Mechanical Engineering, page ???)

Total hours 74

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 of Mech. Eng.	1
Mech. Eng. 13 (3), Heat Engines	4
Mech. Eng. 17 (7), Mech. Laboratory	2
Mech. Eng. 80 (1a), Mechanism	2
Mech. Eng. 82 (2), Machine Design	3
Mech. Eng. 86 (6), Advanced Machine Design	3
Mech. Eng. 105 (5), Thermodynamics	3
Mech. Eng. 125 (25), Heating and Air Conditioning	2
Ch. and Met. Eng. 10, Fuel Testing	1
Elec. Eng. 5 (2a), D.C. and A.C. App. and Cir.	4

c) *Industrial Courses*

*Econ. 71, Accounting	3
*Econ. 72, Accounting	3
*Bus. Ad. 121, Business Statistics	3
Met. Proc. 107, Metal Stamping, or 108, Jigs, Fixtures, and Mach. 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

19

d) **Electives* 9

Total140

PROGRAM IN INDUSTRIAL-MECHANICAL ENGINEERING

For uniform first-year program see section 48.

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	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 (1a)	2
Mil. or Nav. Science..0 or 1		Mil. or Nav. Science..0 or 1	
	15 or 16		17 or 18

SUMMER SESSION

Eng. Mech. 2	4
Met. Proc. 3	4

8

THIRD YEAR

Mech. Eng. 82 (2)	3	Eng. Mech. 3	3
Mech. Eng. 13 (3)	4	Mech. Eng. 105 (5)	3
Mech. Eng. 17 (7) and Ch. and Met. Eng. 10..	3	Metal Proc. 4	4
Econ. 71	3	Econ. 72	3
Electives	3	English (Group III)	2
	16	Electives	3
			18

* Graduates of this program are 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 starred courses 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.

FOURTH YEAR

Mech. Eng. 135 (35) ...	3	Mech. Eng. 136 (36) ...	3
Bus. Ad. 121	3	Mech. Eng. 130 (20) ...	2
Eng. Mech. 4	3	Metal Proc. 107	2
Elec. Eng. 5 (2a)	4	Mech. Eng. 86 (6)	3
Mech. Eng. 125 (25)	2	Electives	6
Electives	3		
	18		16

COURSES IN MECHANICAL ENGINEERING

Some of the advanced elective courses are offered only in alternate semesters. Students are advised to consult the *Special Announcement* for each semester.

1. Introductory Course in Mechanical Engineering. Intended to acquaint the student with the field of mechanical engineering. Lectures, bluebooks, and written assignments. Two one-hour periods a week. *Must precede or accompany Mech. Eng. 80 (1a)*. One hour credit. Each semester.

13 (3) Heat Engines. 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. *Required of all engineering students. Prerequisites: Phys. 45 and Math. 53*. Four hours credit. Each semester.

14 (3a). Mechanical Engineering Laboratory. An elective course 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. *Prerequisite: preceded or accompanied by Mech. Eng. 13 (3)*. One hour credit. Each semester.

17 (7). Mechanical Engineering Laboratory. 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 a few reports; two periods of four and one-half hours each a week. *Prerequisites: Eng. Mech. 1, preceded or accompanied by Mech. Eng. 13 (3) and accompanied by Ch. and Met. Eng. 10*. Two hours credit. Each semester.

80. (1a). Mechanism. Elementary course covering linkages, cams and followers, gear trains, wrapping connectors, and other mechanisms. Two two-hour periods per week. *Prerequisites: Physics 45 and Drawing 2*. Two hours credit. Each semester.

82 (2). **Elements of Machine Design.** The 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 per week. *Prerequisites: Drawing 3, Mech. Eng. 80 (1a), and Eng. Mech. 2.* Three hours credit. Each semester.

86 (6). **Advanced Machine Design.** Analysis, layout, and design of machines and machine parts. Two four-hour periods per week. *Prerequisite: Mech. Eng. 82 (2).* Three hours credit. Each semester.

104 (4). **Hydraulic Machinery.** General consideration of the theory, construction, and operation of the principal types of hydraulic machinery. Lectures, problems, and written recitations. *Prerequisite: preceded or accompanied by Eng. Mech. 4.* Three hours credit. Each semester.

105 (5). **Thermodynamics.** Principles of energy transformation in steam and internal-combustion engines, air compressors, and refrigerating apparatus. Lectures, recitations. *Prerequisite: Mech. Eng. 13 (3).* Three hours credit. Each semester.

108 (8). **Mechanical Engineering Laboratory. Second Course.** Experimental study of a steam turbine, Diesel engine, fan, steam injector, air compressor, refrigerating plant, Unaflo steam engine, centrifugal pump, and impulse water turbine. Laboratory, computations, and a few reports; two periods of four and one-half hours each a week. *Prerequisites: Mech. Eng. 17 (7), and preceded or accompanied by Mech. Eng. 105 (5).* Three hours credit. Each semester.

109 (9). **Power Plants.** A study of the engineering, operation, and economics of power plants. Lectures, recitations, and problems. *Prerequisite: Mech. Eng. 13 (3).* Three hours credit. Each semester.

110 (9a). **Design of Power Plants.** A study of the 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. *Prerequisites: Mech. Eng. 109 (9) and Eng. Mech. 4.* Three hours credit.

111 (11). **Steam-Generating Equipment.** A study of commercial types of boilers, stokers, and superheaters; principles of boiler economy and operation; combustion of fuels; theory of heat transference; purchase of coal by specifications; storage of coal; feed-water treatment; problems of design. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 13 (3).* Three hours credit.

112 (11a). **Design of Steam-Generating Equipment.** This course covers the design of boilers of different types, including calcu-

lations and drawing of important details. Drawing problems; two four-hour periods a week. *Prerequisite: Mech. Eng. 82 (2)*. Three hours credit.

113. (13). **Steam Turbines.** A study in the 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 the general principles of governing. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 105 (5)*. Three hours credit.

115 (15). **Internal-Combustion Engines.** Theory of Otto and Diesel engines; thermodynamics; fuel; combustion; carburetion; ignition; injection; cooling; lubrication; starting; performance; engine mechanics; balancing and vibration. Discussions, problems. *Must be preceded by Eng. Mech. 3, and preceded or accompanied by Mech. Eng. 105 (5)*. Three hours credit. Each semester.

116 (15a). **Design of Internal-Combustion Engines.** 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. *Prerequisites: Mech. Eng. 82 (2), and preceded or accompanied by Mech. Eng. 115 (15)*. Three hours credit. Each semester.

120 (19). **Refrigeration and Air Conditioning.** 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. *Prerequisite: Mech. Eng. 105 (5)*. Three hours credit.

125 (25). **Heating and Air Conditioning.** Theory, design, and installation of hot-air, direct- and indirect-steam, hot-water, and fan heating systems; central heating; air conditioning; and temperature control. Lectures, recitations. *Prerequisite: Mech. Eng. 13 (3)*. Two hours credit.

126 (25a). **Design of Heating and Air-Conditioning Systems.** 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. *Prerequisite: Mech. Eng. 13 (3)*. Three hours credit.

127 (26). **Air-Conditioning Laboratory.** Opportunity for advanced experimental study in the field of air conditioning. *Prerequisites: Mech. Eng. 108 (8) and 125 (25)*. Two or three hours credit.

128 (18). **Heating and Ventilation.** A study of the 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.* Two hours credit.

130 (20). Materials Handling and Factory Transportation. A study of 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. *Prerequisite: Mech. Eng. 82 (2).* Two hours credit.

131 (20a). Design of Hoisting and Conveying Machinery. Calculations and layout work on hoists, cranes, and conveyors. Two four-hour periods a week. *Prerequisite: Mech. Eng. 82 (2).* Three hours credit.

135 (35). Factory Management. 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.* Three hours credit.

136 (36). Factory Management—Motion and Time Study. Attention is devoted to operating methods, to work-center layout according to the laws of motion economy, and to time-study technique. Exercises in the laboratory and in a co-operating manufacturing plant constitute the work of the course. *Prerequisite: Mech. Eng. 135 (35).* Three hours credit.

140 (16). Water Turbines. Covers the hydrodynamic theory of the operation of the various types of water turbines. Considerable attention is given to the analysis of test data and the selection of turbines for various operating conditions. Lectures, recitations, problems. *Must be preceded or accompanied by Mech. Eng. 104 (4).* Three hours credit.

141 (16a). Design of Water Turbines. Includes calculations and drawings for runners, guide vanes, draft tubes, etc., with special attention given to the layout of runners. Two four-hour periods a week. *Prerequisite: Mech. Eng. 82 (2).* Three hours credit.

142 (17). Pumping Machinery. An advanced course covering the theory and operation of reciprocating and centrifugal pumps, the application of pumps to definite pumping problems, economic considerations, and graphical methods. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 104 (4).* Three hours credit.

143 (17a). Design of Pumping Machinery. Includes 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. *Prerequisites: Mech. Eng. 82 (2) and 104 (4) and preferably accompanied or preceded by Mech. Eng. 142 (17)*. Three hours credit.

150 (29). Automobile and Motor Trucks. 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. *Not open to students below junior year*. Three hours credit.

151 (30). Automobile and Truck Engines. 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. *Prerequisites: Mech. Eng. 82 (2) and 150 (29)*. Three hours credit.

152 (30a). Design of Automobile and Motor-Truck Engines. Continuation of Mech. Eng. 151 (30). Lectures, assembly drawing, and details. Two four-hour periods a week. *Prerequisite: Mech. Eng. 151 (30)*. Three hours credit.

153 (31). Design of Automobile and Motor-Truck Chassis. 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. *Prerequisites: Mech. Eng. 82 (2) and 150 (29)*. Three hours credit.

154 (31a). Design of Automobile and Motor-Truck Chassis. Continuation of Mech. Eng. 153 (31). Lectures, assembly drawings, and details. *Prerequisite: Mech. Eng. 153 (31)*. Three hours credit.

155 (32). Automotive Laboratory. 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. *Prerequisites: Mech. Eng. 17 (7) and 150 (29) or 115 (15)*. May be elected for three hours credit and continued a second semester.

160 (60). Aircraft Power Plants. A study of the 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. *Must be preceded or accompanied by Mech. Eng. 13 (3)*. Three hours credit.

161 (61). Aircraft Power Plants—Experimental Tests. 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. *Prerequisites: Mech. Eng. 17 (7) and 160 (60)*. Three hours credit.

162 (62). Design of Aircraft Engines. A study of 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. *Prerequisites: Mech. Eng. 82 (2) and preceded or accompanied by Mech. Eng. 115 (15)*. Two hours credit.

163 (63). Design of Aircraft Engines. 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. *Prerequisites: Mech. Eng. 82 (2) and 162 (62)*. Two hours credit.

170 (70). Diesel Power Plants. A descriptive course covering the construction and operation of Diesel engines for marine, stationary, and automotive purposes, together with their auxiliaries. *Prerequisite: Mech. Eng. 13 (3)*. Two hours credit.

172 (72). Design of Diesel Engines. A study of 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. *Prerequisites: Mech. Eng. 82 (2) and preceded or accompanied by Mech. Eng. 115 (15)*. Two hours credit.

173 (73). Design of Diesel Engines. 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. *Prerequisites: Mech. Eng. 82 (2) and 172 (72)*. Two hours credit.

181 (21a). Design of Machine Tools. 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. *Prerequisite: Mech. Eng. 82 (2)*. Three hours credit.

182. Process Equipment Selection and Design. This course covers the mechanical design of process equipment on a flowsheet selected by or given to the student. A variety of problems will be solved and will include calculations for strength of equipment under working conditions. Dimensioned arrangement drawings will be pre-

pared for a better appreciation of design details and suitable proportions. Two four-hour design periods per week. *Prerequisites: Eng. Mech. 2 and Mech. Eng. 82 (2) or Ch. and Met. 113 (13)*. Open to seniors and graduate students only. Three hours credit.

PRIMARYLY FOR GRADUATES

204 (104). Research in Hydromechanical Engineering. Opportunity for advanced study in the hydromechanical field. Theory, design, equipment performance, or laboratory research. *Prerequisite: Mech. Eng. 104 (4) and 108 (8)*. May be elected for two or three hours credit and continued a second semester.

205 (14). Advanced Thermodynamics. A continuation of Mech. Eng. 5 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. *Prerequisites: Mech. Eng. 105 (5) and 108 (8)*. Three hours credit.

208 (108). Research in Heat-Power Engineering. Opportunity for advanced study in special lines of work in which the student may be interested. Theory, design, equipment performance, or laboratory research. *Prerequisites: Mech. Eng. 105 (5) and 108 (8)*. May be elected for two or three hours credit and continued a second semester.

211. Heat Transmission. 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. *Prerequisites: Mech. Eng. 105 (5), Eng. Mech. 4 and Math. 54*. Three hours credit.

215 (137). Research in Internal-Combustion Engineering. Opportunity for investigation of the theory, design, and construction of internal-combustion engines, and for laboratory research. *Prerequisite: Mech. Eng. 115 (15)*. Credit and hours to be arranged.

228 (27). Studies in Natural Ventilation. 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. *Prerequisite: Mech. Eng. 108 (8)*. Two hours credit.

237 (40). Factory Management—Field Work. The principles of production developed in Mech. Eng. 135 (35) and 136 (36) are in this course applied to specific problems in factory management. The course will consist of inspection trips to manufacturing plants,

with problems and discussions based on these trips. Three hours credit.

238 (42). **Factory Management—Purchasing.** The following topics are considered: inventory management, selection of sources, price analysis, standards and specifications, organization of a purchasing department, government regulations, buying policies, and economics of freight transportation. Lectures, recitations, and term report. *Prerequisite: Mech. Eng. 135 (35).* Three hours credit.

251 (41). **Automobile Engineering Seminar.** The student prepares one paper on current topics of the automobile industry and one covering an investigation of some special subject. Reading, preparation of papers, and class discussions. One hour credit.

253 (134). **Advanced Automobile Design and Research.** Special problems in the design of some automobile or truck unit. Drawing. *Prerequisites: Mech. Eng. 151 (30) and 153 (31).* Credit and hours to be arranged.

255 (133). **Advanced Automobile Testing and Research.** An opportunity for advanced experimental and research work. Laboratory, reports. *Prerequisite: Mech. Eng. 155 (32).* May be elected for three hours credit and continued a second semester.

280 (180). **Balancing, Critical Speeds, and Gyroscopic Action.** 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. *Prerequisite: Eng. Mech. 3.* Two hours credit.

282. **Superpressure Process Equipment and Technique.** Principles of mechanical design for plant size equipment suitable to withstand pressures of 2,000 atmospheres or higher. Liquid and gas pressure generation apparatus, pressure vessels, piping and valves, protective devices, safety practices, and all phases of practical super pressure plant design and operation will be considered. Lectures, recitations, problems. *Prerequisites: Eng. Mech. 2, Mech. Eng. 82 (2), and Mech. Eng. 105 (5) or Ch. and Met. 111 (11).* Three hours credit.

73. NAVAL ARCHITECTURE AND MARINE ENGINEERING

Professor BAIER; Associate Professor ADAMS; Assistant Professors EASTON and SPOONER.

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 embraces all questions relating 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 problem 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. This tank is three hundred 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 from 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 steel 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 to be found 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 37.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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. 2 and Ch. and Met. Eng. 1	5
Economics 53, 54	6
Total	66
<i>b) Secondary and Technical Courses</i>	
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. 2a, Laboratory—Strength of Materials	1
Eng. Mech. 3, Dynamics	3

	<i>Hours</i>
Eng. Mech. 4, Fluid Mechanics	3
Eng. Mech. 127 (15), Theory of Structures in Ship Design	3
Mech. Eng. 80 (1a), Mechanism	2
Mech. Eng. 82 (2), Elements of Machine Design	3
Mech. Eng. 13 (3), Heat Engines	4
Mech. Eng. 17 (7), Mechanical Laboratory	2
Elec. Eng. 5 (2a), Electric Apparatus and Circuits	4
Civil Eng. 21 (2), Theory of Structures	3
Nav. Arch. 11, Introduction to Practice	2
Nav. Arch. 12, Form Calculations I	3
Nav. Arch. 141 (41), Marine Machinery ..	3
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 and 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)

Mech. Eng. 104 (4), Hydraulic Machinery	3
Mech. Eng. 105 (5), Thermodynamics	3
Mech. Eng. 108 (8), Mechanical Laboratory	3
Mech. Eng. 113 (13), Steam Turbines	3
Mech. Eng. 115 (15), Gas 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, (Mech. Eng. 110), Heat Balance	} 3
Free electives	8
Total	26

Summary:

Preparatory courses	66
Secondary and technical courses	48
Group options	26
<hr/>	<hr/>
Total	140

PROGRAM

For uniform first year program see section 48.

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	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
Mech. Eng. 80 (1a), or		Naval Arch. 11 or	
Naval Arch. 11	2	Mech. Eng. 80 (1a) ...	2
(Mil. Science)	(1)	(Mil. Science)	(1)
	<hr/>		<hr/>
	16 or (17)		16 or (17)

SUMMER SESSION

COURSES	HOURS
Mech. Eng. 13 (3)	4
Elec. Eng. 5 (2a)	4
	<hr/>
	8

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER			
COURSES	HOURS		COURSES	HOURS	
	Option A	Option B		Option A	Option B
Naval Arch. 12 ...	3	3	Naval Arch. 21 ...	3	
Naval Arch. 13 ...	3		Eng. Mech. 3	3	3
Mech. Eng. 105 (5)	3	3	Mech. Eng. 104 (4)		3
Eng. Mech. 4	3	3	Naval Arch. 22 ...	2	
Mech. Eng. 82, (2) .	3	3	Mech. Eng. 108 (8)		3
Eng. Mech. 127 (15)	3	3	Naval Arch.		
Mech. Eng. 17 (7) .	2	2	141 (41)	3	3
<hr/>	<hr/>	<hr/>	Civ. Eng. 21 (2) ...	3	3
17	17		*Elective	3	
			Mech. Eng. 113		
			(13) or 115 (15)		3
			<hr/>	<hr/>	<hr/>
			17	18	

FOURTH YEAR					
FIRST SEMESTER			SECOND SEMESTER		
COURSES	HOURS		COURSES	HOURS	
	<i>Option A</i>	<i>Option B</i>		<i>Option A</i>	<i>Option B</i>
	Econ. 53	3		3	Econ. 54
Naval Arch. 131 (31)	3		Naval Arch. 151 (51)	3	3
Mech. Eng. 115 (15) or 11 ² (13)		3	Naval Arch. 132 (32)	3	
Naval Arch. 152 (52)	2		Naval Arch. 33 . . .	1	
*Electives	6	7	Naval Arch. 34 . . .	1	
Civil Eng. 4 (Surv. 4)	2	2	†Design course		3
English (Group III)	2	2	*Electives	5	7
				16	16
	18	17			

COURSES IN NAVAL ARCHITECTURE AND MARINE
ENGINEERING

GROUP 10

11. Introduction to Practice. 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 of simple ship structures. Details of shell expansion and other mold loft work are discussed. Lectures, recitations, and drawing room. *Prerequisites:* *Draw. 1 and 2.* Two hours credit. Each semester.

12. Form Calculations I. This course takes up the study of methods of determining areas, volumes, centers of buoyancy, displacement and wetted surface; the use of hydrostatic curves; trim; initial and statical stability; stability in damaged condition; and watertight subdivision. Lectures and recitations. *Prerequisites:* *Nav. Arch. 11, Math. 54, and Eng. Mech. 1.* Three hours credit. Each semester.

13. Form Calculations II. In this course the student prepares a body plan from given offsets and makes the necessary calculations for the preparation of hydrostatic, launching, and flooding curves.

* Total electives, fourteen hours, are to be made up of six hours nontechnical and the balance 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 Naval Arch. 142(42), 143(43), or (44) as the design course in Option B.

Drawing room. *Preceded or accompanied by Nav. Arch. 12.* Three hours credit. Each semester.

GROUP 20

21. **Structural Design I.** Comprises a 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. *Prerequisites: Eng. Mech. 2 and Nav. Arch. 12. Preceded or accompanied by Nav. Arch. 13, Eng. Mech. 127 (15), and Civ. Eng. 21 (2).* Three hours credit. Each semester.

22. **Structural Design II.** In this course the student develops the weight, buoyancy, shear, and bending moment curves for a vessel, develops the midship section and other structural items according to the requirements of the classification societies' rules. Drawing room. *Preceded or accompanied by Nav. Arch. 21.* Two hours credit. Each semester.

123. **Advanced Structural Design.** Credit to be arranged.

GROUP 30

131 (31). **Ship Design I.** Includes a review of statical stability and continues with the dynamical stability of ships. Discussions follow concerning 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. *Prerequisites: Nav. Arch. 13 and 21.* Three hours credit. First semester.

132 (32). **Ship Design II.** In this course 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. *Prerequisites: Nav. Arch. 22 and preceded or accompanied by Nav. Arch. 131 (31).* Three hours credit. Each semester.

33. **Contracts and Specifications.** Covers a discussion of the principal features of ship specifications and contracts. Lectures and recitations. One hour credit. First half of the second semester.

34. **Cost Estimating.** Includes methods and practice of estimating costs of repair work and new construction. Lectures and recitations. One hour credit. Second half of the second semester.

135 (35). **Advanced Ship Drawing and Design.** Credit to be arranged.

GROUP 40

141 (41). **Marine Machinery.** Familiarizes the student with

the different types of machinery used for propelling vessels. A complete study is made of the principles of heat transference 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. *Prerequisites: Mech. Eng. 13 (3) and Eng. Mech. 1.* Three hours credit. Second semester.

142 (42). **Marine Steam Generators.** Heat transfer calculations, design, and layout drawings are prepared for a modern type of marine steam generator. Drawing room. Three hours credit. Each semester.

143 (43). **Marine Propulsion Machinery.** Design calculations and principal drawings are prepared for either a triple expansion steam engine or a main propulsion turbine. Drawing room. Three hours credit. Each semester.

144 (44). **Heat Balance.** Detail design calculations and engine and fire room layouts are prepared for a large steam- or motor-ship. Drawing room. Three hours credit. Each semester.

145 (45). **Advanced Reading and Seminar in Marine Engineering.** Credit to be arranged.

GROUP 50

151 (51). **Resistance; Power; Propellers.** In this course 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. *Prerequisite: Nav. Arch. 12.* Three hours credit. Second semester.

152 (52). **Naval Tank.** 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. *Prerequisites: Eng. Mech. 4. Preceded or accompanied by Nav. Arch. 131 (31).* Two hours credit. Each semester.

153 (53). **Research in Naval Tank.** Credit to be arranged.

154 (54). **Advanced Reading and Seminar in Naval Architecture.** Credit to be arranged.

55. **Piloting and Celonavigation.** (Elect as Astronomy 72). Three hours credit. (Nontechnical elective).

74.

PHYSICS

Professors BARKER, COLBY, SAWYER, GOUDSMIT, DENNISON, LINDSAY, CORK, UHLENBECK, and LAPORTE; Associate Professors MEYER, RICH, SLEATOR, CRANE, and WILLIAMS; Assistant Professors ADEL and WIEDENBECK.

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 Department of Engineering Research.

The introductory courses (45 and 46) consisting of three recitations, two demonstration lectures, and a two-hour laboratory period each week for two terms, 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, and is continually increasing. Anyone finding the subject attractive may become an industrial physicist, confident that his profession is one of great usefulness and ever-expanding possibilities.

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, both as to 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 Engineers' 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 37.

<i>a) Preparatory Courses</i>	<i>Hours</i>
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. 2	5
<hr/>	
Total	77
b) <i>Secondary and Technical Courses</i>	Hours
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
<hr/>	
Total	15
c) <i>Options and Electives</i>	
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
<hr/>	
Total	48
<i>Summary:</i>	
Preparatory courses	77
Secondary and technical courses	15
Options and electives	48
<hr/>	
Total	140

COURSES IN PHYSICS

45. Mechanics, Sound, and Heat. Two lectures, three recitations, and one two-hour laboratory period each week. *Prerequisites:* one year of high-school physics or college chemistry; trigonometry is essential, and calculus should be elected simultaneously with physics. Five hours credit. Each semester.

46. Electricity and Light. A continuation of Physics 45, which must precede it. Two lectures, three recitations, and one two-hour laboratory period a week. Five hours credit. Each semester.

85. Modern Physics. A discussion of fundamental experiments on the nature of light, electricity, and matter. *Prerequisite:* Physics 46. Two hours credit. First semester.

* Students in this curriculum may elect Chemistry 188 without having had Chemistry 21E.

147. Electrical Measurements. Methods of measuring current, resistance, electromotive force, capacitance, inductance, and hysteresis of iron, and the calibration of the instruments employed. This course is in the curriculum in electrical engineering. *Must be preceded or accompanied by Elec. Eng. 3.* Two lectures and one four-hour laboratory period a week. Four hours credit. Second semester.

165. Electron Tubes. The characteristics of electron tubes and their functions as detectors, amplifiers, and generators. Three hours credit. First semester.

166. High-Frequency Electrical Measurements. A laboratory course dealing with radio-frequency problems. *Prerequisite: Physics 165.* Two hours credit. Second semester.

171. Mechanics of Solids. Statics and dynamics; the equations of d'Alembert, Poisson, Laplace, and Lagrange. Three hours credit. First semester.

175. Sound. Mathematical study of waves and of vibrating mechanical systems using complex numbers. Two hours credit. First semester.

176. Laboratory Work in Sound. Use of vacuum-tube oscillators and amplifiers in the measurement of sound intensity and the calibration of acoustical instruments. *Must be preceded by Physics 175, and it is recommended that Physics 165 (electron tubes) be taken before Physics 176.* Two hours credit. Second semester.

181. Heat. Thermal expansion, specific heats, change of state, and van der Waals' equation; elementary kinetic theory, and the absolute scale of temperature. Two hours credit. First semester.

183. Laboratory Work in Heat. To follow or accompany Physics 181. Use of modern methods and instruments for the measurement of thermal quantities. Two hours credit. First semester.

186. Light. Theory of interference, diffraction, polarization, double refraction, etc. Two hours credit. Second semester.

188. Laboratory Work in Light. To accompany or follow Physics 186. Experiments on interference, diffraction, polarization, double refraction, and the fundamental properties in light. Two hours credit. Second semester.

190. X Rays. The emission, absorption, refraction, and diffraction of X rays, with special emphasis on the interpretation of spectroscopic results. Three hours credit. Second semester.

191, 192. Introduction to Theoretical Physics. 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. Two hours credit. First semester, Physics 191; second semester, Physics 192.

196. Atomic and Molecular Structure. A review of recent developments, based on fundamental experiments. This includes the determination and description of characteristic energy levels, and the classification of electrons. Three hours credit. Second semester.

197. Nuclear Physics. Natural radioactivity; nuclear physics; apparatus and methods of nuclear physics. Artificial transmutations and cosmic rays. *Prerequisite: Physics 85 or 196.* Two hours credit. Second semester.

199. Nuclear Physics Laboratory. The properties of alpha, beta, and gamma rays; the half-life periods and chemical properties of radio-active materials. *To be preceded or accompanied by Physics 197.* One hour credit. Second semester.

205, 206. Electricity and Magnetism. A fundamental treatment of electromagnetic theory. Maxwell's equations and the radiation from a Hertzian oscillator. The connection with the special relativity theory. *Prerequisite: Physics 147.* Three hours credit each. First semester, Physics 205; second semester, Physics 206.

207, 208. Theoretical Mechanics. The Lagrange equations of motion, the principle of least action, Hamilton's principle, the Hamilton-Jacobi equation, Poisson brackets. *Prerequisite: an adequate knowledge of differential equations. Physics 207 is a prerequisite for Physics 208. An introductory course in mechanics is desirable.* Three hours credit each. First semester, Physics 207; second semester, Physics 208.

209. Thermodynamics. The two laws and their foundation. Gas equilibria and dilute solutions. The phase rule of Gibbs. Theory of binary mixtures. *Prerequisite: Physics 181.* Three hours credit. Second semester.

210. The Kinetic Theory of Matter. 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. *Prerequisite: Physics 209.* Three hours credit. First semester.

211, 212. Quantum Theory and Atomic Structure. The quantization of multiple periodic systems with applications to atomic spectra (optical and X-ray) and molecular spectra. Heisenberg's uncertainty principle, matrix mechanics, de Broglie waves and the Schrödinger wave equation. *Prerequisite: Physics 196. Physics 211 is a prerequisite for Physics 212.* Three hours credit each. First semester, Physics 211; second semester, Physics 212.

[213, 214. **Introduction to Theoretical Physics.** The partial differential equations of mathematical physics. Three hours credit each. Omitted in 1946-47.]

215, 216. **Special Problems.** Qualified graduate students who desire to obtain research experience in work supervised by members of the staff may, upon consultation, elect these courses. Hours and credit to be arranged. First semester, Physics 215; second semester, Physics 216.

238. **Nuclear Theory.** Forces between elementary particles; nuclear statistics. Scattering and capture problems. Nuclear models. *Prerequisites: Physics 211, or 197 or its equivalent.* Three hours credit. Second semester.

**COLLEGE OF ENGINEERING
SUMMARY OF CIVILIAN STUDENTS**

1944-1945

Summer, Fall, and Spring Terms

	1st Year	2nd Year	3rd Year	4th Year	Special	Total
Civil		16	10	6	4	36
Mechanical		43	31	46	4	124
Electrical		31	14	17		62
Chemical		32	24	34	4	94
Naval Arch. & Marine		9	1	7		17
Aeronautical		33	16	30		79
Engineering Mechanics			1	1		2
Mathematics		1	2	8		11
Physics		7	5	2		14
Mechanical & Industrial ...		2	1	1		4
Engineering—Law		3				3
Transportation			1	1		2
Engineering—Bus. Ad.		2				2
Metallurgical		5	3	2	1	11
Metal Processing					1	1
Unclassified, First Year ...	292				2	294
Grand total	292	184	109	155	16	756
Counted twice		9	9	15		33
Net total in engineering	292	175	100	140	16	723

Undergraduates, College of Engineering723

Students in Engineering enrolled in Graduate School165

Students enrolled in Engineering *Extension Courses 35

Net total of students in Engineering917

* 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.

**COLLEGE OF ENGINEERING
SUMMARY OF NAVY STUDENTS**

1944-1945

Summer, Fall, and Spring Terms

	1st Year	2nd Year	3rd Year	4th Year	Special	Total
Civil		4	13	20		37
Mechanical		15	28	54	1	98
Electrical		9	16	24		49
Chemical		7	21	50		78
Naval Arch. & Marine ...			5	23		28
Aeronautical		12	18	45		75
Engineering Mechanics				5		5
Mathematics			4	7		11
Physics		4	11	11		26
Mechanical & Industrial ...			1	5		6
Metallurgical			3	6		9
Astronomy				1		1
Grand total		51	120	251	1	423
Counted twice		3	6	15		24
Net total		48	114	236	1	399
Term I—unclassified						126
Term II—unclassified						83
Term III—unclassified						68
Term IV—unclassified						140
Term V—unclassified						121
Term VI—unclassified						188
Term VIII—unclassified						1
Net total in Engineering						1,126*

**COLLEGE OF ENGINEERING
SUMMARY OF STUDENTS**

1944-1945

Summer, Fall, and Spring Terms

Civilian students—net total	917
Navy students—net total	1,126
Net total students in Engineering (Navy and civilian)	2,043

* Not including 154 students enrolled in the Reserve Officers Naval Architecture Group.

INDEX

- Absence:
assembly, 24
excuses for, 29
leave of, 30
- Accrediting by Engineers' Council for Professional Development, 8, 69
- Administrative officers, 5
- Admission, 11
advanced credits, adjustment of, 15
to advanced standing, 14
on certificate, 12
on combined program, 15
on credits from another college, 14
deficiencies, 26
on examination, 13
as a graduate student, 16
requirements, 11, 12
as a senior, 15
as a special student, 16
of veterans, 16
- Advanced standing:
adjustment of credits, 15
admission to, 14
- Aeronautical engineering:
courses offered, 73-76
description of work, 69-70
laboratories, 70
program, 71-73
requirements for graduation, 30, 71-72
- Albion College, 9, 15
- Algebra, 11, 138
- Assembly, the, 24
absence from, 29
- Assistantships, 20
- Astronomy:
courses offered, 78-80
requirements for graduation, 30, 77-78
- Automotive engineering, 152, 155
- Average grade, 28
- Bacteriology, 42-43
- Bequests, 38
- Board, rooms, 10
- Business administration, 43-44
- Calendar, 4
- Camp Davis, 99
- Chemical engineering:
courses in, 92-97
description of work, 80-82
elective groups, 89-92
graduate work, 81
laboratories, 82-84
program, 87-89
program, industrial, 87
requirements for graduation, 30, 85-87
summer employment, 84
- Chemistry:
courses offered, 44-46
- Civil authorities, relation of students to, 31
- Civil engineering:
courses offered, 108-115
description of work, 97-100
electives, major, 101-2
graduate work, 99
laboratories, 99
program, 102
requirements for graduation, 30, 100-101
- Classification, 25-26
- Class standing, 14, 29
- Clubs, *see* Organizations and Societies
- Combined programs with other institutions, 9, 15
- Commencement, date of, 4
- Committees, 5, 6
- Communication laboratories, 116
- Co-operative course: electrical engineering and industry, 123
- Courses:
in nonprofessional departments, 41-67
in professional departments, 69-167
- Credit for advanced standing, 14-15
- Credit hour, 30
- Curriculums in professional departments, 8-9
aeronautical engineering, 71-73
astronomy, 77-78
chemical engineering, 85-87
chemical and industrial engineering, 87
civil engineering, 100-102
electrical engineering, 120-22
engineering mechanics, 131-32
industrial-mechanical engineering, 146-47
marine engineering, 157-59
mathematics, 136-37
mechanical engineering, 143-45
metallurgical engineering, 85-87
metallurgical and industrial engineering, 87
municipal, 105-7
naval architecture, 157-59
physics, 163-64
transportation engineering, 103-4
- Deficiencies, removal of, 26
- Degrees conferred, 31
- Departments of instruction:
nonprofessional, 41-67
professional, 69-167
- Dismissal, honorable, 30
- Donovan scholarship, 36

- Drawing:
 description of work, 55
 mechanism and engineering, 55-56
 Dynamo laboratory, 116
- Economics, 46-48
 Election of studies, rules governing, 25-26
 Electives:
 group system of, 69
 nontechnical, 26 -
- Electrical communication, 115
 Electrical engineering:
 co-operative course with industry, 123
 courses offered, 124-29
 description of work, 115-20
 elective groups, 117-19
 program, 122-23
 laboratories, 116
 requirements for graduation, 30, 120-22
 Electrical power engineering, 115
 Employment of students, 10
 Engineering camp, 99
 Engineering Council, 33
 Engineering mechanics:
 courses offered, 132-35
 description of work, 130
 laboratory, 130-31
 requirements for graduation, 30, 131-32
 Engineering research, 66-67
 Engineers' Council for Professional Development accredited curriculum, 8, 69
 English:
 courses offered, 49-51
 facilities, 49
 for foreign students, 10
 general requirements, 49
 library, 49
 Enrollment, 167-68
 Entrance, *see* Admission
 Examinations, 27
 rules governing, 27
 Excuses for absence, 29
 Executive Committee, 5
 Expenses, 16-19
 Experimental tank, 156
 Extracurricular opportunities, 7
- Faculty, 5
 Fees, 16
 Fellowships, 20, 35
 First-year studies in engineering, 41-42
 Foreign students, 10
 Forestry and Conservation:
 courses in, 51-54
 Foundry laboratory, 57
 French:
 courses offered, 63-64
 description of work, 63
 nontechnical electives, 27
 Freshman program, 41-42
- Gaging laboratory, 57
 Gemmel memorial scholarship, 36
 Geodesy and surveying:
 Camp Davis, 99
 courses offered, 108-10
 description of work, 98
 Geology, 54, 55
 German:
 courses offered, 64-65
 description of work, 63
 nontechnical electives, 27
 Grade average, 28
 Graduate work, 16, 31, 81, 99, 117, 143, 156
 Graduation requirements, 30
 Group electives, 69
- Health Service, 20-21
 Heating, ventilating and refrigerating engineering, 150
 Highway engineering, 109, 112-13, 115
 Highway laboratories, 99
 Historical information, 7
 Holidays, 4
 Honorable dismissal, 30
 Honor system, 25
 Hour of credit, 30
 Hunt scholarship, 37
 Hydraulic engineering, 111, 114
- Illuminating engineering, 126-27, 129
 Incomplete, 27
 Indebtedness to University, 18
 Industrial-mechanical engineering, 146-148
 Instruction, departments of:
 nonprofessional, 41-67
 professional, 69-167
 Instrument shop, 57
 Internal-combustion engineering, 150
 152-54
 International Center, 33
- Kalamazoo College, 9, 15
- Laboratories:
 aeronautical engineering, 70
 automotive, 143
 chemical engineering, 82
 civil engineering, 99
 electrical engineering, 116
 fluid flow, 131
 foundry, 57
 gaging, 57
 highway, 99
 instrument shop, 57
 machine tool, 56
 mechanical engineering, 143

- metallurgical, 83
- metal processing, 56
- mineralogical, 62
- naval tank, 156
- physical testing, 130
- physics, 163
- Laboratory fees, 18
- Late registration, 18
- League, Michigan, 32
- Leave of absence, 30
- Libraries:
 - English, 49
 - transportation, 99
- Loan funds, 37

- Machine tool laboratory, 56
- Mandelbaum scholarship, 37
- Marine engineering:
 - courses offered, 160-62
 - description of work, 155-57
 - group options, 158-59
 - laboratory, 156
 - program, 159-60
 - requirements for graduation, 30, 157-59
- Marking system, 27
- Mathematics, courses in, 137-42
 - description of work, 135-36
 - requirements for graduation, 30, 136-37
- Mechanical engineering:
 - courses offered, 148-55
 - description of work, 142-43
 - laboratories, 143
 - program, 145-46
 - program, industrial mechanical, 147-148
 - requirements for graduation, 30, 143-45, 146-47
- Mechanism and engineering drawing, 55
- Mentor system, 24
- Metallurgical engineering:
 - courses in, 92-97
 - graduate work, 81
 - laboratories, 82-84
 - program, 87-89
 - program, industrial, 87
 - requirements for graduation, 30, 85-87
- Metal processing:
 - courses offered, 57-60
 - description of work, 56
 - laboratories, 56-57
- Metal working and treating laboratory, 57
- Michigan Technic*, 33
- Military science and tactics, 60-61
 - for first-year students, 41
- Mineralogical laboratory, 62
- Mineralogy and petrography, 62

- Modern languages:
 - courses offered, 63-65
 - description of work, 63
- Modern languages and nontechnical electives, 27, 63
- Municipal engineering, 98, 101, 105-7

- Naval architecture :
 - courses offered, 160-62
 - description of work, 155-57
 - group options, 158 59
 - laboratory, 157
 - program, 159-60
 - requirements for graduation, 30, 157-59
- Naval science and tactics, 65-66
 - for first-year students, 41
- Naval tank, 156
- Nonprofessional departments, 41-67
- Nontechnical electives, 26

- Occupational information, 10
- Officers, administrative, 5
- Organizations, 33-35
- Orientation period, 9

- Part-time fees, 17
- Petrography and mineralogy, 62
- Phi Eta Sigma, 35
- Phi Kappa Phi, 35
- Photography, 109-10
- Photometric laboratory, 116
- Physical testing laboratory, 130
- Physical training, 14, 21-24, 41
- Physics:
 - courses offered, 164-67
 - description of work, 163
 - laboratory, 163
 - requirements for graduation, 30, 163-64
- Placement, 10, 25
- Prizes, 36
- Probation, 28
- Professional departments, 69-167
- Programs of study, *see* Curriculums

- Quartermaster Society, 34

- Railway engineering, 109, 113, 115
- Refrigerating engineering, 150
- Refunding of fees, 19
- Registration dates, 4
 - late, 18
- Requirements for admission, *see* Admission
- Requirements for graduation, 30
- Research, Department of Engineering, 66-67
- Reserve officers, 60, 65-67
- R.O.T.C., *see* Military Science and Naval Science
- Residence, legal, 17

- Residence requirement, 30
 Rooms, board, 10
 Rules:
 governing election of studies, 25-26
 relating to examinations and entrance deficiencies, 26, 27
 governing grades and scholarship, 28-29
- Sanitary engineering, 98, 101, 108-15
 Scholarship, unsatisfactory, 28
 Scholarships, 20, 36
 Self-supporting students, 10
 Sheehan scholarship, 37
 Shop practice, *see* Metal processing
 Sigma Rho Tau, 35
 Sigma Xi, 35
 Smith fund, 37
 Societies, 33
 Spanish:
 courses offered, 65
 description of work, 63
 Special students, 16
 Standing committee, 5
 Steam power engineering, 149-50
 Structural engineering, 98, 101, 108-15
 Student branch:
 A.S.C.E., 34
 A.S.M.E., 34
 A.I.E.E., 34
 A.I.Ch.E., 34
 I.A.S., 34
 Student employment, 10
 Students enrolled, 167-68
 Stump Speakers Society, 35
 Summary of students, 167-68
- Summer camps:
 surveying, 99
 Surveying:
 Camp Davis, 99
 courses offered, 108-10
 description of work, 98
- Tank, experimental, 156
 Tau Beta Pi, 35
Technic, Michigan, 33
 Term fees, 16
 Transportation Club, 35
 Transportation engineering, 98, 103-5
 Trigonometry, 12
 Tuition, 17
- Union, Michigan, 32
 Units for admission, 11
 University Health Service, 21
 University of Michigan, 7
 Unsatisfactory scholarship, 28
 Upperclassmen, 29
- Vacations, 4
 Ventilating engineering, 150
 Veterans:
 admission of, 16
 service bureau, 8
- Warned, 28
 Water analysis, 42
 Western Michigan College of Education 9, 15
 Withdrawal from the College, 19, 30
 Women students, 10
 Work for students, 10



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