UNIVERSITY OF MICHIGAN
OFFICIAL PUBLICATION
VOL. 39, NO. 60 APRIL 27, 1938

College of Engineering

Announcement
1937-1938
and
1938-1939

ANN ARBOR, MICHIGAN
PUBLISHED BY THE UNIVERSITY

Entered as second-class matter at the Post Office at Ann Arbor, Michigan. Issued by the University of Michigan semiweekly from March to August, inclusive, and weekly from September to February, inclusive.

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THE CAMPUS OF THE UNIVERSITY OF MICHIGAN

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The days that the University is in session are printed in light-face type; Sundays, holidays, and vacations in bold face.

UNIVERSITY CALENDAR

Academic Year, 1937–38

1937

September 20–24, Monday–Friday.....Examinations for admission
September 21–25, Tuesday–Saturday.....Orientation Period
September 24 and 25, Friday and Saturday.....Classification of all Engineering students
September 27, Monday, morning.....FIRST SEMESTER BEGINS
November 25, Thursday.....Thanksgiving Day, holiday
December 17, Friday, evening.....Holiday vacation begins

1938

January 3, Monday, morning.....Classes resume
January 29, Saturday.....Final examinations begin
February 9–11, Wednesday–Friday.....Examinations for admission
February 11 and 12, Friday and Saturday.....Classification of all Engineering students
February 11, Friday, evening.....FIRST SEMESTER CLOSES*
February 14, Monday, morning.....SECOND SEMESTER BEGINS*
February 22, Tuesday.....Washington's Birthday, holiday
April 8, Friday, evening.....Spring vacation begins
April 18, Monday, morning.....Classes resume
May 30, Monday .....Memorial Day, Holiday
June 4, Saturday.....Final examinations begin
June 18, Saturday.....COMMENCEMENT

Summer Session, 1938

June 20, Monday—August 31, Wednesday.....In the Law School
June 27, Monday—August 5 and 19, Friday..In the Medical School
June 27, Monday—August 19, Friday.....In all other divisions

Academic Year, 1938–39

September 12–16, Monday–Friday.....Examinations for admission
September 20–24, Tuesday–Saturday.....Orientation Period and freshman registration
September 23 and 24, Friday and Saturday.....Classification of all Engineering students
September 26, Monday, morning.....FIRST SEMESTER BEGINS
November 24, Thursday.....Thanksgiving Day, holiday
December 16, Friday, evening.....Holiday vacation begins

1939

January 3, Tuesday, morning.....Classes resume
January 28, Saturday.....Final examinations begin
February 8–10, Wednesday–Friday.....Examinations for admission
February 10 and 11, Friday and Saturday.....Classification of all Engineering students
February 10, Friday, evening.....FIRST SEMESTER CLOSES*
February 13, Monday, morning.....SECOND SEMESTER BEGINS*
February 22, Wednesday.....Washington's Birthday, holiday
April 7, Friday, evening.....Spring vacation begins
April 17, Monday, morning.....Classes resume
May 30, Tuesday.....Memorial Day, holiday
June 3, Saturday.....Final examinations begin
June 17, Saturday.....COMMENCEMENT

*Except in the Law School, for which the date is one week earlier.

Part I

OFFICERS AND FACULTY

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Hon. RALPH STONE, Detroit.....Dec. 31, 1939
Hon. FRANKLIN M. COOK, Hillsdale.....Dec. 31, 1941
Hon. CHARLES F. HEMANS, Lansing.....Dec. 31, 1941
Hon. ESTHER M. CRAM, Flint.....Dec. 31, 1943
Hon. DAVID H. CROWLEY, Detroit.....Dec. 31, 1943
Hon. JOHN D. LYNCH, Detroit.....Dec. 31, 1945
Hon. EDMUND C. SHIELDS, Lansing.....Dec. 31. 1945

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* In this list are included the names of certain instructors in other Colleges offering courses of interest to students in engineering.

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FRANKLIN LELAND EVERETT, Ph.D., *Assistant Professor of Engineering Mechanics* 303 Wildwood Avenue
WALTER B. FARISS, Major, U.S.A., *Assistant Professor of Military Science and Tactics* 1809 Hill Street
FLOYD ALBURN FIRESTONE, Ph.D., *Assistant Professor of Physics* 619 East University Avenue
JAMES SHERMAN GAULT, M.S., *Assistant Professor of Electrical Engineering* 1508 Westminster Place
HOLGER MADS HANSEN, B.C.E., *Assistant Professor of Engineering Mechanics* 1210 Wells Street
ROSWELL E. HARDY, C.E., M.B.A., Major, U.S.A., *Assistant Professor of Military Science and Tactics* 703 South Forest Avenue
DEAN ESTES HOBART, B.S., *Assistant Professor of Mechanism and Engineering Drawing* 1314 Minerva Road
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EXECUTIVE COMMITTEE

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Professor R. H. SHERLOCK, term, 1937–1941
Professor A. H. WHITE, term, 1936–1940
Professor J. E. EMSWILER, term, 1936–1939
Professor H. W. MILLER, term, 1936–1938

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COMMITTEES OF THE COLLEGE OF ENGINEERING

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Assistant Professor C. F. KESSLER, Professors C. E. LOVE, J. C. BRIER, H. J. GOULDING, and S. S. ATTWOOD, and Assistant Professor G. L. ALT

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EAST ENGINEERING BUILDING

Part II

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 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 Music, and the Horace H. Rackham School of Graduate Studies, each of which publishes a separate Announcement. The various Faculties include over eight hundred officers of instruction. During the past year, over fifteen thousand students, representing all the states and territories and many foreign countries, were registered at the University of Michigan.

In the legislative act of 1837, under which the University was organized in its present form, provision was made for instruction in engineering. There are few older technical schools in the United States. 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.

The aim of the College of Engineering is to lay a foundation of sound theory, sufficiently broad and deep to enable their 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. While the adaptation of theory to practice can be thoroughly learned only by experience, there are many matters in which the routine work of an engineering field party, office, or drafting room can be carried out, on a greater or less scale, in a training school. 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 coöperate in every proper manner with the industries of the State.

2. Students at the University of Michigan enjoy many privileges outside their curriculum. 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 price 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 during the year several loan exhibitions.

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.

PROGRAMS OF STUDY

3. The College of Engineering has four-year programs of study which were accredited by the Engineers' Council for Professional Development on October 1, 1937, in aeronautical, chemical, civil (including transportation), electrical, mechanical, and metallurgical engineering, naval architecture and marine engineering, and engineering mechanics. In addition four-year curricula, not accredited by the Engineers' Council for Professional Development, are offered in the specialized fields of astronomy, geodesy and surveying, 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 structural, hydraulic, transportation, sanitary, and municipal engineering; under Electrical Engineering will be found power, communication, and illumination engineering and electrical design; under Geodesy and Surveying will be found geodesy, topographic and boundary surveying, and courses on the legal and administrative problems involved in titles and boundaries; under Mechanical Engineering will be found steam power, internal combustion, hydromechanical,

heating, ventilating and refrigerating, automobile and industrial engineering, and machine design; under Naval Architecture and Marine Engineering will be found in addition water transportation.

The College of Engineering and the Schools of Business Administration, Forestry, and Law, of the University, offer five- or six-year combined courses to meet the needs of those who expect to follow a career in which an engineering background is desirable.

The student in the combined course is registered for the first three years in the College of Engineering, and for the subsequent two or three years in one of the other schools. On the completion of the three-year curriculum in the College of Engineering with a minimum average of 2.5,* the student is recommended for transfer to one of the other schools.

On the satisfactory completion of the first year in one of the other Schools, the student will be recommended for the degree of Bachelor of Science in Engineering. The diploma given will bear the legend of the School to which transfer is made. It should be understood that such a degree is not a professional engineering degree and is not so regarded by the Engineers' Council for Professional Development. It is a recognition that the student has completed four years of work composed chiefly of basic engineering training, which has been accepted as preparation for professional degrees and later professional activities in fields other than engineering.

Students in the College of Engineering transferring to one of the other Schools without having completed the first three years of the combined course with the required grade will not be recommended by the College of Engineering for its degree.

Attention is called to the fact that the College of Engineering requires a higher average grade for its recommendation for transfer to one of the other Schools on the combined course than it does for graduation in the general four-year curricula.

For details see sections 83, 84, and 85.

In coöperation with the School of Education, the College has programs in which, after the student earns his degree of Bachelor of Science in Engineering, he may meet the requirements for a Teacher's Certificate by additional work under the direction of the Faculty of the School of Education.

For details see section 58.

The Civil Engineering Department offers a coöperative program in highway engineering in which the summer is spent with the Highway Department of the State or of an important county. For details see section 75.

The Electrical and Mechanical Engineering Departments offer a five-year coöperative program with industry, conforming substantially to the following principles: coöperative 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

* For grading system, see section 35.

will undertake the coöperative work during periods of an entire semester or of an entire summer session. Credit for the coöperative work will be given only on completion of the entire prescribed program. For details see section 76.

COMBINED PROGRAMS WITH OTHER INSTITUTIONS

4. The College of Engineering has an agreement with Albion, Olivet, and Battle Creek Colleges under which a student who has been in residence at one of these colleges for three years and 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.

A college under this agreement accepts the first year at the College of Engineering in lieu of its senior year, and if the student's record is satisfactory, graduates him.

ORIENTATION PERIOD

5. During Orientation Period, before the opening of school, the campus is virtually turned over to new students. Each group of twenty 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.

ACADEMIC YEAR AND SUMMER SESSION

6. The academic year extends from September to June of the following year. See the University calendar, pages 4 and 5. The Summer Session, between the student's first and second, second and third, or third and fourth years, extends eight weeks, from the Monday of the second week following Commencement.

Every student in the College of Engineering, in order to finish his program in four years, generally finds it necessary to attend one Summer Session.

SUGGESTIONS AND DIRECTIONS

7. New students expecting to take the examinations for admission to the University must present themselves on the dates specified for examinations for admission. See section 13.

All freshmen are required to report in September for registration and the activities of Orientation Period. No freshman will be excused from attendance during Orientation Period except on account of illness. A complete program will be furnished to all freshmen accepted for admission.

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 conduct a free employment bureau for the benefit of students.

When admitted, every student will be furnished with a booklet containing directions for subsequent procedure.

ADMISSION

8. 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.

FOREIGN STUDENTS

9. All students whose native language is other than English shall, upon matriculation and registration in the College of Engineering, be required to report at once to Professor J. R. Nelson, Counselor to Foreign Students. Such students shall satisfy him that they possess a sufficient knowledge of English to carry on work in the College of Engineering before they may be classified.

On the recommendation of the Counselor they may be referred to the proper classifier, who will give them such a program of work as he deems best. For his first semester, however, every foreign student is considered as on trial. If at the end of the semester he passes his work, credit will be given; if, however, in spite of conscientious effort he fails, and his difficulties are, in the judgment of his instructors and of the Counselor, due primarily to his lack of facility in the use of the English language, his record will be disregarded but he will then be remanded to the Department of English for such work in English as he needs, to the limit of eight hours.

If a student is judged by the Counselor to be unfitted even for such a trial program as that outlined above, he will be required to take for one semester such work in English as the Counselor thinks necessary, and may be allowed to visit such classes as may in the judgment of the Counselor be profitable to him.

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 one hundred and

twenty sixty-minute hours of classroom work. Two to three hours of laboratory, drawing, or shop work are counted as equivalent to one 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.

	UNITS
A. English	
A major sequence of at least 3 units is required	3
B. Foreign Language Group	
A minor sequence of 2 units of a single language, Greek, Latin, French, German, or Spanish is required	2
C. Mathematics Group	
A major sequence of at least 3 units is required. This shall include algebra 1 unit, advanced algebra ½ unit, plane geometry 1 unit, and solid geometry ½ unit (In addition, trigonometry ½ unit is urgently advised, because if not offered for admission, it must be elected in the first year of college.)	3
D. Science Group	
A minor sequence of 2 units is required. This shall consist of 1 unit of physics and preferably 1 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 15 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 1 unit of history, or ½ unit of American government and ½ 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 who, in addition to fulfilling the above conditions, are unqualifiedly recommended by their principals for admission.

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.

11. **Preparatory Work Expected by the University.**—When one or more units are offered for admission in any subject the work done in that subject should have been of such a character as to qualify the student to pursue it in the University as a continuation study.

Detailed descriptive outlines of the amount of preparation expected in the admission subjects are given in the annual report of the University Bureau of Coöperation with Educational Institutions, a copy of which may be had upon request to the director of the bureau. In general, the standards set up by the Commission on Accredited Schools and Colleges of the North Central Association of Colleges and Secondary Schools will be recognized in adjusting high-school credits.

ADMISSION ON CERTIFICATE

12. Only those applicants are admitted on 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

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

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

As a general rule no advanced credit will be given for work done in the usual high-school course. However, college credit may by 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.

A student who for any reason has failed to secure a certificate of graduation and his principal's recommendation will be required to pass the regular examinations for entrance in all subjects.

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

ADMISSION BY EXAMINATION

13. Fifteen units are required for admission. Ten of these units are prescribed as shown in the four sequences of section 10. The five units remaining may be presented in any of the other subjects mentioned under admission requirements in section 10.*

Candidates for admission who are graduates of accredited high schools and whose principals are willing to certify them in a part of the required 15 units may, at the discretion of the Registrar, be admitted by certificate covering the units satisfactorily completed plus examinations covering the remaining units required for admission. For this purpose examinations will be provided only in the subjects listed under the specific groups in the requirements for admission of this College.

Candidates for admission who have passed College Board, New York State 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 the Secretary, 431 West 117th Street, New York, N.Y., and must be made on a blank form to be obtained from its Secretary on application.

Those applicants for admission who are not entitled to enter on certificate, and who wish to take the entrance examinations given by the University should make definite arrangements with the Regis-

* The conditions under which an applicant may be admitted provisionally are given in section 10.

trar *at least one month* in advance of the dates set for the examination. Entrance examinations are held each year in September, February, and June.

The applicant may divide the examinations, taking one part either a year or a semester before the date of his admission, and the second part at the time of admission. But 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 presenting themselves too late for the scheduled examinations are required to pay an examination fee of five dollars.

Students desiring to validate credits in zoology by the examination method must present laboratory notebooks at the time of the examinations.

An applicant who fails in some of the examinations, but passes fifteen units, may be admitted provisionally; but all deficiencies must be made up within one year.

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. Unless he has had one year of physical education or is granted at least sixty hours of advanced credit, he will be required to complete a year of physical education in the College of Engineering. One year of military science will be accepted in lieu of physical education.

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. Students in the College of Literature, Science, and the Arts who desire 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 head 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 twenty-four 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 Head 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 12 or 13.

ADMISSION ON COMBINED PROGRAMS

15. Students who have completed the first three years of the combined programs arranged by the College of Engineering with Albion, Olivet, and Battle Creek Colleges are admitted as juniors. For the admission of other students from these colleges see the regulations in section 14.

ADJUSTMENT OF ADVANCED CREDITS

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 enrolled in this College alone. 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.

Advanced credits should be secured upon entrance. To apply for advanced credit at a later date, students must secure the permission of the Assistant Dean, giving a satisfactory reason for the delay in making the application.

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 heads 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 head 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.

Candidates for admission as special students should state their age and what their education and experience have been. They should

send letters of recommendation from former employers and bring drawings to demonstrate their experience and ability.

Special students pay the same fees as regular students. Their work is assigned and regulated by the heads 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.

FEES AND EXPENSES

19. *The semester fees must be paid before classifying for studies, 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 traveler's 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 traveler's 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 $60 for each semester; for non-Michigan students, $80 for each semester.

These fees cover class instruction, use of libraries, outdoor physical education, and admission to all athletic events, membership in the Michigan Union or Michigan League, as well as medical attention from the University Health Service and dispensary.

Part-Time Fees.—Persons whose occupations are such as to afford them only a limited part of their time for study, but who are duly accredited for admission to any College or School of the University and who also give evidence of an interest in study wholly accordant with the purpose of the College or School to which they are accredited, may be admitted as part-time students. Based on the payment of either $15 or $25 a semester, part-time fees are divided into two groups. The payment of $15 a semester entitles the student to the following privileges: (1) the election of not more than three hours a semester; (2) consultation with faculty members while working on theses or preparing for doctoral examinations and also the use of the library; and (3) a combination of the privileges listed under (1) and (2). The payment of $25 a semester entitles the student to elect four, five, or six hours a semester. Students in these two groups pay a Health Service fee of $7.50 a semester unless

exempted under regulations governing the Health Service. They may also obtain privileges of outdoor physical education and Michigan Union or Michigan League upon payment of the appropriate incidental fees at the time of *registration.*

Determination of Legal Residence.—Residence in Michigan for the purpose of registration shall be determined according to the State constitutional provision governing the residence of electors (see Article III, Sections 1 and 2); that is, no one shall be deemed a resident of Michigan for the purpose of registration in the University of Michigan unless he is a citizen of the United States who has resided in this State the six months next preceding the date of his proposed enrollment, and no person shall be deemed to have gained or lost a residence in this State while a student in the University. The residence of a minor shall follow that of the parent 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 shall, when discovered, be required to pay not only the proper nonresident fees, but shall be assessed, as an addition to the semester fee, the sum of $10.00. Discretion to adjust individual cases within the spirit of these rules shall be lodged with the Secretary, 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.

Fee for Special Entrance Examination.—An applicant for admission who desires to take the entrance examination at a time other than that announced is required to pay to the University Cashier a fee of $5.00 before permission to take one or more examinations can be granted him.

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 $5.00 to $20.00, 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 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 transcripts of credits will be issued.

b) Students owing such accounts will not be allowed to register in any subsequent semester or summer session until payment has been made.

Graduation.—The by-laws of the Board of Regents prescribe that no person shall be recommended for a degree until he has paid all 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.

Other Expenses.—Fletcher Hall, Allen House, and Rumsey House, dormitories accommodating approximately 178 men, are owned and operated by the University, but rooming houses provide for the majority of the men students during their first year in Ann Arbor. The office of the Dean of Students maintains lists of approved houses for men students. In order to avoid, so far as possible, misunderstandings between landlord and student, a uniform lease or memorandum of agreement has been prepared. Such agreements are issued by the University and should be used by the student. Students are required to make their own reservations, since the University feels that the student should see rooms before engaging them.

All freshman men are required to live in dormitories or approved men's rooming houses, and no unmarried male student is allowed to live in an apartment or in a rooming house in which there is no landlady in residence without permission of the Dean of Students. Students in approved houses rent their rooms for the semester, and are not to move without permission of the Dean of Students or his representative.

Room rent varies from $2.00 to as high as $5.00 a week for each student. The cost of board is from $5.00 to $7.00 a week.

Annual Expenses.—The expenses of the *average* student, during his first year in the College, not including clothing, railroad fare,

and vacations, are estimated at $600 for residents of Michigan, $640 for nonresidents. Many students are enabled to complete their courses by withdrawing for a year or two to earn money to carry them through the remaining years.

Estimated Expenses

Board, 36 weeks at $5	$180
Room, 38 weeks at $3	114
Tuition, Michigan student	
2 x $60 per semester	120
Set of drawing instruments, board,	
T-square, triangles, scales	40
Slide rule, notebook, paper	15
Textbooks 2 x $25 per semester	50
Laundry, sundries	81
Total	$600

To ensure work of the required standard the drawing equipment and slide rule should not be bought before coming to Ann Arbor.

The cost of attending the Camp Davis Summer Session is about $150. See section 78.

REFUND OF FEES

20. 1. No student will be entitled to a refund in accordance with scale below except upon (*a*) 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 (*b*) surrender to the Cashier of the University of the student receipt, the outdoor-physical-education 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.

2. No refund will be granted unless applied for within one year after withdrawal.

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

4. 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 his semester fee.

5. 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 his semester fee.

6. A student who transfers from one School or College to another will receive a full refund of his 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 he transfers.

7. A student who transfers from full-time to part-time status will receive a refund in accordance with regulations 3, 4, and 5 above and will be required to pay the entire part-time semester fee.

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

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

SELF-SUPPORTING STUDENTS AND STUDENT EMPLOYMENT

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

The University does not undertake to furnish manual labor to students; yet a considerable number find opportunities in the city to meet a portion of their expenses. Students desiring employment should apply in person or by letter before they come to Ann Arbor, to the Dean of Students, Room 2, University Hall.

FELLOWSHIPS AND SCHOLARSHIPS

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

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.

RELATION OF STUDENTS TO THE CIVIL AUTHORITIES

23. 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 is convicted by the civil authorities, he shall be cited to appear before the University Committee on Student Conduct or Faculty of the College

in which he is matriculated, and shall be liable to suspension or expulsion.

MICHIGAN UNION AND MICHIGAN LEAGUE

24. 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 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, 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 one hundred sixty 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.

UNIVERSITY HEALTH SERVICE

25. The University Health Service, which is located on North University Avenue, concerns itself with many factors that are important in preventive medicine, as well as with curative measures, in its efforts to conserve the health of students. The Health Service provides for practically all medical attention the student needs during the school year, and is open also to students of the Summer Session and to students remaining during the regular vacations.

The Health Service Dispensary, where students may receive any office medical attention, including special examinations and the usual medicines, is open regularly during class hours. A student may consult any physician of the Health Service at choice. If a student receives attention from a Health Service physician at his room, a charge of $1.00 for a day call and $2.00 for a night call is made. The corps of physicians in the Medical School coöperates with the Health Service whenever students need the attention of such specialists. Health Service attention is extended to full-time students and to part-time students who pay the Health Service fee at the time of enrollment.

Provision is made for the care of sick students requiring bed care. If the care of such a student is previously approved by the Health Service, thirty days' service may be obtained. The extra expense of private rooms at the University Hospital and special nursing is charged to the student patient.

FACILITIES AND REQUIREMENTS FOR PHYSICAL EDUCATION

26. a) **Facilities.**—The University is provided with excellent gymnasiums, Waterman Gymnasium for men, and Barbour Gymnasium for women. The main floor of Waterman Gymnasium, which is a rectangle with truncated corners and dimensions of 246 by 90 feet, is well equipped with the various kinds of apparatus usually found in the best modern gymnasiums. A number of smaller rooms are devoted to administration, fencing, boxing, and other special purposes, while the basement is given up to baths, lockers, handball, and boxing. The main hall is lighted in the daytime by means of a large skylight 60 feet above the floor, and in the evening by electricity. A gallery makes room for an elliptical running track, ten laps to the mile, making it one of the largest gallery running tracks in the country.

Barbour Gymnasium, for women, contains, in addition to the gymnasium proper, the offices of the Dean of Women and the Director of the Gymnasium; a club room and parlors; and a hall

(Sarah Caswell Angell Hall) accommodating 550 people, for lectures, meetings, theatrical entertainments, etc. The basement contains dressing rooms and shower baths. 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. Several football fields and baseball diamonds, running tracks, soccer fields, indoor baseball diamonds, tennis courts, and space for numerous other games afford possibilities for complete programs of intramural and intercollegiate athletics. 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 Intramural Sports Building.

The Yost Field House provides accommodations for all kinds of athletics during the winter months when they cannot be conducted out of doors. The building is 342 feet long by 165 feet wide. It contains ample locker and shower facilities and seats 8,000 spectators in the main activities room. The activities room itself is 286 feet long by 160 feet wide and contains an eighth-of-a-mile track, a 75-yard straight-away, a basketball court, and provisions for indoor practice in football and baseball. There are also provisions for handball, indoor golf, and wrestling.

The Intramural Sports Building, similar in design and construction to Yost Field House, contains almost every conceivable facility for indoor sport and recreation. It is not planned to provide facilities for spectators, but to utilize every foot of space for athletic activity. This building forms the north side of a quadrangle which includes the Administration Building, concrete stand for track and field athletics, west tennis court unit, and Yost Field House.

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

b) Required Physical Education—Men.—All first-year students in the College of Engineering are required to attend two practice periods a week in physical education. Active participation depends on the outcome of a health examination. Six hygiene lectures are also given at the beginning of the college year. Students electing military science are excused from physical education but not from the hygiene lectures.

As a result of the health examination all students are classified in the following health groups, a health card being issued for those who pass—

Group 1. No Defects. Can participate in all activities.

Group 2. Minor Defects. Can participate in all activities, but must report to the Health Service for a checkup on minor ailments.

Group 3. Restricted and Corrective Exercise Group. Given modified exercise for correction. A part of this group is referred to the Health Service for exercise.
Group 4. Reconstruction Group. No exercise until advised by the Health Service.
Group 5. Excused Group. Chronic defects that allow no exercise.

A measurement and corrective chart of each student is issued at the time of the health examination. Necessary advice is given regarding proper exercises for correction.

In arranging an activities program we feel from experience that the college freshman still needs a certain amount of guidance in the way of instruction and selection, rather than deciding from his own emotional standpoint what he would like to do. Again, the requirement being for one year only, the class-grouping arrangement of activities forms a concentrated means of presenting the greatest number of the best selective activities for future use in a short space of time.

Participation Program. For all men in good physical condition, participation is offered in two ways—class groups and athletic groups. This method not only allows opportunity for selection but ensures a continuous exercise program for all, as men in athletic groups are transferred to the classes whenever a sport is discontinued or to another athletic activity in season at the time of transfer, in which he may be interested. Transfers are made through the office of the Director of Waterman Gymnasium. From time to time men are excused from class groups for participation in intramural athletics on the days of contest.

Class Groups. These are organized during the indoor season at convenient hours. All classes take place in Waterman Gymnasium. A variable program of activities is arranged. *Drill work has disappeared entirely from the picture for college men.* Both the individual and team method of approach is used. From general observation in practice we find many students use poor body mechanics in the natural movements of the body, one out of five uses fairly good form in sprinting, one out of ten can do the high jump satisfactorily, few men have been taught the technique of popular games like basketball, handball, etc. For the greater enjoyment of these activities and others, considerable instruction is necessary in the technique and rules of all the more highly coördinated games, contests, and exercises.

Method of Class Instruction. Activities for the first semester are—track and field, boxing, wrestling, gymnastics, basketball, fencing. For the second semester—tennis, golf, handball, volleyball, badminton, basketball, gymnastics.

Each class is divided into five groups (about 25 men in each group), with a special instructor for each group. Every group remains at an activity for about three weeks. By a Round Robin

method of participation every class is made familiar with all activities for the semester. This method eliminates mass drills and the monotony of mass participation, introducing the same system of instruction now being used for Varsity athletic teams.

After-Spring Recess for Class Groups. Because of favorable weather at this time, students are reclassified from an entirely selective standpoint for either outdoor or indoor activities as they prefer.

Athletic Group. These activities give freshmen an opportunity to participate in the Varsity type of athletics. Preliminary experience is of advantage but not necessary. Competition is limited to Varsity teams at home and telegraphic track meets with other institutions. Organized teams to which transfers are made are: football, track and field, swimming, wrestling, boxing, basketball, baseball, golf, tennis, hockey, gymnastics, and fencing.

Medical and Physical Defectives. (Health Group 3). Certain types of medical defectives derive considerable benefit in general body tone from modified active exercise. These are referred to the Health Service. Physical defectives considered in this group are—poor posture, flat feet, tendencies to hernia, overweight, underweight, underdevelopment, injuries, etc. A shadowgraph is taken of all poor posture defectives. Corrective work is done during regular class hours, but under separate group supervision.

Passing Requirements. Passing the requirements in physical education is based on the following: Comprehensive Activities Test, Attendance, and Attitude.

Comprehensive Activities Test. At the end of each three weeks' participation in a class activity, a comprehensive test is given each student to determine his knowledge in the technique of that activity. Those who fail are required to practice for perfection.

In addition to the test a satisfactory passing record is necessary in attendance and attitude.

The passing of medical and physical defectives is determined by individual circumstances.

Health Knowledge. Six lectures are given during the first three weeks of college. The sections for instruction are made as small as possible. An examination is required to demonstrate proficiency in health knowledge. The Health Service is responsible for the lectures and the determination of proficiency.

Absences. All unexcused absences in physical education must be made up. All excuses should be presented to the Director of Waterman Gymnasium for approval. If for sickness the excuse must come from the physician in charge.

Exemptions. The Admission Officer has charge of making the necessary adjustments for students entering with advanced credit.

Costume. The regulation suit required of all students is a sleeveless white gymnasium shirt, white running pants, and tennis shoes.

Lockers. Each student taking work in the gymnasium must have his own locker. Tickets are purchased at the time the regular college fee is paid or at the office of the University Cashier. The locker fee is $2.00.

Towels. Tickets can be secured at the Cashier's office. The fee is fifty cents, and it is refunded when the last towel is returned.

ASSEMBLY, MENTOR, AND PLACEMENT SYSTEM

27. *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 head of 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 coöperation the placement officer can give, either as to placing a graduate in his first position, or as to enabling him to find a better position if he so desires. During the depression, college placement officers devoted a very great deal of time and effort to the business of finding work for graduates.

The University Bureau of Appointments and Occupational Information, dealing chiefly with placement of teachers, will also render service upon request.

HONOR SYSTEM

28. 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 Honor Committee consists of one student elected annually from each class in the College of Engineering, each member to serve two years.

WOMEN STUDENTS

29. 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.

Matters of scholarship and attendance are handled by Assistant Dean Lovell. Assistant Secretary Camilla B. Green acts as educational mentor for the women in Engineering.

RULES GOVERNING ELECTION OF STUDIES

30. *a*) No student shall be permitted to elect fewer than 12 hours, and no student whose grade average for the preceding semester is less than 3 shall be permitted to elect more than 18 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 six 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 six 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.

EXCUSES FOR ABSENCES

31. 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 their return to classes. 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 is warned by the Discipline Committee. After two more unexcused absences, the Discipline Committee places the student upon probation for insubordination, the probationary period to last for the remainder of the freshman year. Two more unexcused absences will subject the student to the penalty of suspension in the usual manner for the remainder of the school year.

UPPERCLASSMEN

32. The Faculty recognizes as upperclassmen: *a*) those students in good standing, i.e., not on probation, who have obtained at least 65 hours of credit, with an average grade of at least C for all work taken at the University of Michigan; *b*) all new students who have completed a four-year program at approved colleges and other like institutions; and *c*) other new students with good previous record 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

* For the definition of upperclassmen, see section 32.

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.

EXAMINATIONS AND ENTRANCE DEFICIENCIES

33. Examinations for admission are held before the beginning of each semester. See section 13.

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 as far as possible during the first semester of residence.

No student who has an admission deficiency 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.

Examinations in college work are held at the end of each semester, but classes are liable to be examined at any time, without notice, or with one week's notice, on any portion 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

34. 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

35. *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, B equals 3, C equals 2, D equals 1, 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 considered. 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. It is permissible for a student to repeat a subject without credit in order to raise his grade average.

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

e) When the average semester or summer session grade of a student falls below 1.6 he is automatically placed on probation.

f) Students on probation must elect at least 12 hours of work a semester or 6 hours a summer session.

g) Students on probation who obtain an average semester or summer session grade of 2.0 or more are automatically removed from probation.

h) A student will be placed on the home list for any one of the following reasons:

(1) If his average semester or summer session grade falls below 1.0.

(2) If he is on probation and fails to obtain an average semester or summer session grade of 2.0.

(3) If he has been on probation during any two semesters and subsequently fails to obtain an average semester or summer session grade of 1.6.

i) In cases of extenuating circumstances, at the discretion of the Committee on Scholastic Standing, students placed on probation may be removed from probation, and students placed on the home list may be continued on probation.

REGENTS' RULE GOVERNING OPERATION OF MOTOR VEHICLES BY STUDENTS

36. "No student in attendance at the University shall operate any motor vehicle. In exceptional and extraordinary cases at the discretion of the Dean of Students this rule may be relaxed."

WITHDRAWAL FROM THE COLLEGE

37. 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.

Part III

GENERAL STATEMENT

DEPARTMENTS OF INSTRUCTION

38. The broad subject of engineering has been defined as "the art and science of directing the great sources of power in nature to the use and convenience of man." It includes the discovery, conservation, and utilization of the resources of the earth, the waters, and the air. Discovery includes not only the exploration of mineral, timber, and other visible resources of the world, but also the experimental investigations of the laws controlling important phenomena and processes. Conservation includes the prevention of waste of all sorts, whether of natural resources or in manufacturing processes. Utilization includes the generation and transmission as well as the actual application of heat, light, and electricity by mechanical, electrical, and chemical means to serve useful purposes; the design and erection of structures and machines of all types, and the efficient operation of all processes, involving preparation, manufacture, transportation, or utilization of materials on a large scale. In the newer conception of engineering, efficient operation must consider not only the physical property but also the relation of the industry to the outside world, including its duty to stockholders, employees, clients, and the community in which it is situated.

Until a century ago engineering was divided into two branches, military and civil engineering. Since then civil engineering has developed in so many directions and to such an extent that new designations have come into use for its various branches.

The name "civil engineering" has been retained at the University of Michigan to designate the courses given by its Department of Civil Engineering.

The other Departments, some of which are outgrowths of civil engineering and others of different origin, are Engineering Mechanics, Geodesy and Surveying, Mechanical Engineering, Electrical Engineering, Naval Architecture and Marine Engineering, Chemical Engineering, Metallurgical Engineering, and Aeronautical Engineering, all degree-conferring departments.

The Departments of Astronomy, Mathematics, and Physics, which serve the whole University, coöperate with the College of Engineering in its programs leading to the degree of Bachelor of Science in Engineering with specialization in Astronomy, Mathematics, or Physics.

In addition to the degree-conferring departments, the College of

Engineering has departments of instruction in English, Mechanism, and Engineering Drawing, and in Metal Processing; and it uses, with the rest of the University, the Departments of Modern Languages, Chemistry, Military Science, etc., which give special courses for engineering students. Engineering students are allowed wide liberty to elect courses in history, philosophy, economics, and other nontechnical subjects without additional cost.

Besides the departments of instruction, the College of Engineering includes the Department of Engineering Research which was established by an act of the Regents in October, 1920. The purpose of this act was to establish a point of contact between the University and the technical and industrial interests in the State in the field of research. This department, because of the extensive laboratory and library facilities available at the University, in addition to its ability to call upon members of the teaching staff to direct and supervise research, is in a position to undertake and investigate a large number of problems of varied character.

Full descriptions of the various departments, their scope, facilities for instruction, and the courses offered, will be found elsewhere in this bulletin.

BUILDINGS AND OTHER EQUIPMENT

39. The work of the College of Engineering is carried on in several buildings belonging to the College, viz., the West Engineering and the East Engineering Buildings, the West Engineering Annex, and East Hall. The College also shares with the rest of the University in the use of the Library, the East and the West Physics Buildings, the Chemistry Building, the Astronomical Observatory, the Gymnasiums, etc. The summer work in surveying is carried on at Camp Davis. See section 78.

The West Engineering Building, built in 1903, is used for the Departments of Civil, Mechanical, Electrical, and Marine Engineering, Geodesy and Surveying, Mechanism and Engineering Drawing, Engineering Mechanics, and Mathematics.

The East Engineering Building, completed in 1923, houses the Chemical and Metallurgical Engineering Department, the Department of Metal Processing, the Department of Engineering Research, the Division of Transportation Engineering, the State Highway Laboratories, and the Department of Aeronautical Engineering.

The West Engineering Annex provides additional space for Mechanical Engineering (automotive engineering), Engineering Mechanics, and Geodesy and Surveying; and East Hall is used for offices and classrooms for the nontechnical subjects.

For the equipment of these buildings and Camp Davis, see later articles concerning the various departments of instruction.

The College recognizes that the benefits of instruction are far more dependent on the character of the instructors than upon any

adjunct in the way of laboratory apparatus or of physical illustration, and with this in view the instructing staff has been selected from among those qualified both by technical training and practical experience; in addition, extensive use is made of the ordinary supplementary aids.

40. The Libraries.—A large, modern library building, erected at a cost of $615,000, was opened in January, 1920. This building has general and special reading rooms accommodating a thousand students at a time, and is equipped with modern appliances for the housing and serving of books.

The University Libraries contain at present about 956,000 volumes, of which many are of importance to engineers. The periodicals regularly received number 4,400.

THE WEST ENGINEERING LIBRARY, comprising 20,000 volumes, is housed in the West Engineering Building. The latest and best books on professional subjects are added yearly to the library, where they are accessible to all, and frequent references are made to them in the classroom as the various subjects are brought forward. The collection contains files of professional periodicals and proceedings of engineering societies.

THE EAST ENGINEERING LIBRARY, opened in 1924, is housed on the third floor of the East Engineering Building. It is provided with 9,000 books and over one hundred periodicals of particular interest to students in Chemical and Metallurgical Engineering, Metal Processing, and Aeronautics. A special collection of books is available to those students pursuing courses in English.

TRANSPORTATION LIBRARY.—The Transportation Library contains 100,000 items dealing with every phase of transportation. It is housed in the East Engineering Building. In this library are many rare books and pamphlets relating to the origin, history, and development of our various transportation systems. It also contains very complete files of the various technical-engineering associations; the modern and current periodicals dealing with railways, highways, waterways, and other engineering subjects; state and national, public utility, highway, and special commission reports; annual reports of railways and other transportation companies; proceedings of various transportation associations; and the latest books on the technical and economic phases of transportation.

41. University Power Plant.—The University Power Plant is an example of modern power-plant construction and is used for purposes of instruction as well as to furnish heat, power, and light to the University buildings. The boiler-room equipment consists of ten boilers totaling 6,600 rated horsepower with all necessary auxiliaries and a complete coal- and ash-handling system. Coal is brought directly from the Michigan Central Railroad to the plant over an

electrically operated road. The generating equipment has a total capacity of 4,350 kw. in turboalternator units. Tunnels are provided for the underground distribution of steam, hot water, and electrical energy. There is available alternating current at 2,300 volts, 230 volts for lighting, and other voltages for power; also direct current at 220 volts and 500 volts; high- and low-pressure steam; and hot water. The station operates in parallel with the system of the Detroit Edison Company.

42. Visits of Inspection.—The University is well situated for excursions to engineering industries. In Ann Arbor there is a modern, machine-switching telephone exchange. The Detroit Edison Company has four hydroelectric power stations, one at Ann Arbor and the others within a distance of four miles. These stations are of recent construction and illustrate the latest engineering practice in hydraulic and electrical design.

At Detroit there is much of interest to students of engineering, including the main power houses and substations of the Detroit Edison Company, and of the Detroit Street Railway, the electrically operated Michigan Central Railroad tunnel under the Detroit River, and the new railroad terminal.

There are, within forty miles, two of the most complete modern classification yards in the United States, illustrating all types of humps and other modern sorting, the New York Central freight terminals at Toledo and the Michigan Central passenger terminals at Detroit. The Detroit River tunnel and the street railway properties in both cities afford exceptional opportunities for the inspection of important work.

From the standpoint of automobile engineering, the University of Michigan has a strategic location at the very center of the automobile industry of the country. Detroit, Toledo, Flint, Jackson, Lansing, and Indianapolis, with the greatest automobile factories in the world, are within easy excursion distances and each year inspection trips are made under the direction of the automobile department.

The classes in Chemical and Metallurgical Engineering visit each year about forty industrial plants illustrating the transition from raw materials to finished products. The list includes large and modern plants illustrating the manufacture and treatment of iron and steel, copper, brass, and aluminum; Portland cement, clay products, and glass, salts, acids and alkalies, electrolytic and electric-furnace products; gas, ammonia, tar, and other products from the destructive distillation of coal; petroleum; the vegetable fats and oils, including paint, varnish, and soap; sugar; food products, leather, and paper.

The students in Marine and Aeronautical Engineering have opportunities of visiting both Detroit and Toledo where various shipyards and aircraft factories are situated. The airports at the same places also afford an opportunity to inspect the various types of aircraft and port equipment both for water and air transportation.

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 coördinate the activities of the various technical societies and clubs, to assure continuity in policy for the classes, and to develop coöperation 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 business men 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 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.

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 insure 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.

Students should write personally to Dr. Clarence S. Yoakum, Dean of The Horace H. Rackham School of Graduate Studies, for information and application forms. Applications must be made before March 1.

University Fellowships

A limited number of fellowships and scholarships, ranging according to circumstances from $350 to $600, are maintained by special appropriation made annually by the Regents of the University. Properly qualified students from any college or university, or from any part of the world, may apply for appointment.

State College Fellowships

By action of the Board of Regents, each of the faculties of the accredited colleges of the state of Michigan is authorized to nominate annually to the administrative officers of the Graduate School some member of the graduating class or some one of their graduates of not more than four years' standing as a suitable candidate for a State College Fellowship. In each case a second nomination may also be made. All nominations should be sent to the Dean of the Graduate School not later than March 15, and accompanying each should be an official record of the candidate's undergraduate work and several letters of testimony and recommendation. The stipends will vary from $300 to $400. The State College appointees, it should be understood, will be placed on the same footing and be subject to the same regulations and enjoy the same privileges as the University Fellowship appointees.

Lawton Fellowship in Astronomy and Mathematics.—The stipend varies from $200 to $400. Preference is given to Astronomy if there is a suitable candidate.

Michigan Gas Association Fellowship.—This fellowship has been maintained continuously since 1900 with the exception of interruptions during the war. The holder of the fellowship receives $600.

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 the

highest average for the last two years of the curriculum, in the regularly prescribed courses.

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 is to be partially or entirely supporting himself in college, and shall 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, partially or entirely self-supporting, and must have completed a minimum of forty-five units 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 half of the award when the recipients have enrolled for the first and second semesters 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, partially or entirely self-supporting, and must have completed a minimum of fifteen units 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 Engineering 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, partially 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 in September.

Simon Mandelbaum Scholarships.—These scholarships were established in 1929 by the late Mary S. Mandlebaum (Mary S. Mandelle) of Detroit, Michigan, in memory of her father, Simon Mandlebaum. These scholarships are awarded in amounts of about $400 each. To be eligible students must be American citizens, partially 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 Head 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, 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 the 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 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.

DEGREES CONFERRED IN THE COLLEGE OF ENGINEERING

48. 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.

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

49. 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, Geodetic Engineer, and Public Health Engineer.

All students who have 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 appplication.

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.

REQUIREMENTS FOR GRADUATION

50. 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 35.

A credit hour represents as a rule 1 hour of recitation or lecture a week for one semester, preparation for which should require 2 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 home work.

c) He must spend one year in residence and complete at the University of Michigan a minimum of 30 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.

NONTECHNICAL ELECTIVES

51. All regular students in the College of Engineering are required to complete not fewer than 6 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.

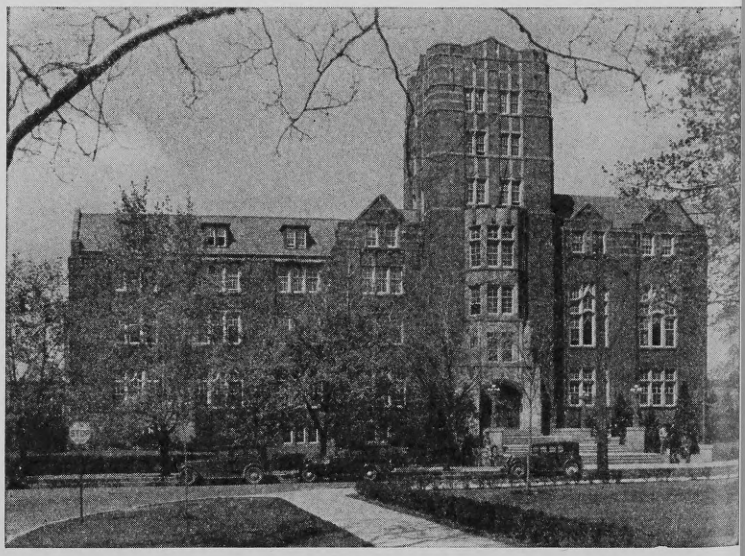
Not more than four semester hours of military science shall be considered as nontechnical.

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 non-technical.

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.



MICHIGAN UNION

Part IV

NONPROFESSIONAL DEPARTMENTS

STUDIES OF THE FIRST YEAR

52. 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 curricula 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.

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

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
Physical Ed. or Mil. Science	0 or 1	Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

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

Schedules of studies for later years will be found under the work of the various degree-conferring departments.

The above schedule assumes that the student has presented for admission the full requirement in algebra and geometry, and also trigonometry and chemistry as described in section 10. Should the student have entered without trigonometry or chemistry, or both,

* If modern language is elected, it may be classified here and the English postponed. See section 51.
† See note, section 56.

the schedule will be modified by substituting Mathematics 7 or 8 for Mathematics 3 and (or) Chemistry 3, first semester, followed by Chemistry 6, second semester, in place of Chemistry 5E.

In case the admission requirements have been fully met on entrance, the above trigonometry and Chemistry 3 taken in college will give credit toward graduation as nontechnical subjects. See section 51.

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 33.

NONPROFESSIONAL COURSES

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

A course in another college that is listed in any engineering curriculum may be elected by our students without special formality; but the approval of the deans, readily obtained, may be required when the course is not intended for engineers. Lack of proper preparation for the course is sufficient reason for approval to be refused.

Besides the departments listed below, in which our students make frequent elections, there are many others which freely and hospitably receive our students. The College of Engineering in the same way receives students from other colleges of the University.

54. BACTERIOLOGY AND WATER ANALYSIS

Professor SOULE, Assistant Professor EMERSON, and Mr. KLIMEK.

105. Water Analysis. This course is 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 in Water Analysis. Hours and credit to be arranged. Each semester.

111E. Practical Bacteriology. This course is 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.

55. BUSINESS ADMINISTRATION

Professors GRIFFIN, PATON, RODKEY, JAMISON, BLACKETT, ELLIOTT, and GAULT; Associate Professors TAGGART, RIEGEL, WOLAVER, PHELPS, WATERMAN, and others.

The courses listed below are those which are deemed 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 fourth-year standing.
2. Seniors may elect courses numbered 102 to 199 inclusive, and 205 and 206, provided they have a scholastic rating equal to that required for the combined curriculum with the college in which the student is enrolled. (In the case of the Engineering College, this is a minimum average grade of 2.5.)
3. Courses numbered above 200 (except 205 and 206, as noted above) may be elected only by properly qualified graduate students and are *not* open to seniors.

For full list of courses in Business Administration, see the *Announcement* of that School.

102. **Industrial Relations.** This introductory course deals broadly with the problems arising out of the relations of employers and employees. Among these are the employment of personnel, a problem which is considered both from the point of view of the employer and of the prospective employee seeking a position. Other basic problems of personnel management, such as training of workers, the control of working conditions, the provision of incentives for workers, the maintenance of adequate contact between supervisors and employees through employee representation plans, and other devices are considered from the point of view of the operating executive. The course also reviews a number of industrial relations questions that are of public concern, such as the promotion of economic security, the maintenance of standards of working conditions, and the development of labor legislation. Three hours credit.

113. **Cost Accounting I.** The subject matter of this course is confined to industrial cost accounting. Both job order and process systems are considered at length. Particular attention is given to the methods of allocating indirect expense to departments, processes, jobs, and classes of product. The principles of costing are illustrated in a complete cost set which the student is required to work out as a laboratory exercise. In addition, numerous shorter problems are assigned. *Prerequisites: Econ. 171 and 172.* Three hours credit. First semester.

121. **Business Statistics I.** This course introduces the student to the use of frequency distributions, index numbers, times series, and correlation in the solution of business problems. Illustrations and problems are drawn from actual business records. Three hours credit. First semester.

151. **Marketing Principles I.** This course, together with Course 152, has a twofold aim: to introduce all students of business to the leading principles and business problems involved in the transferring of goods from producers to consumers, and to provide a basis for the more intensive study of the special phases of marketing for those students who elect to devote themselves especially to this aspect of business. Course 151 includes a consideration of the following subjects: (1) the general principles of marketing; (2) the marketing of agricultural products, including grading, the use of central markets, speculation, and the organized commodity exchanges; (3) manufacturers' buying problems; (4) manufacturers' selling problems, such as the choice of channels of distribution and of methods of sale, and the functions of middlemen of the wholesale and retail markets. The course is conducted by the study of concrete business problems and supplementary readings. *Prerequisite: principles of economics.* Three hours credit. First semester.

152. **Marketing Principles II.** This course is a continuation of Course 151 and has the same general aims. It specifically considers the following subjects: (1) the functions of advertising and its place in a general distribution plan; (2) price policies; (3) standardization of products; (4) retailing; (5) the state and marketing, including a discussion of "unfair competition." The method of instruction is the same as that in Course 151. *Prerequisite: Bus. Ad. 151.* Three hours credit. Second semester.

161. **Financial Principles I.** This course undertakes an analysis of the financial principles underlying the promotion, organization, and management of business enterprises. A thorough study is made of the characteristics of the several types of securities with particular attention to their use in the original financing of concerns in various lines of industry. Methods of obtaining and managing working capital, as distinguished from problems of permanent capital, are considered, with special emphasis on such matters of current financial management as temporary borrowing, and the financial aspects of the purchase, production, and sale of goods. *Prerequisites: Econ. 171 and 172 or equivalent.* Three hours credit. First semester.

162. **Financial Principles II.** This course is a continuation of Course 161 and proceeds with a study of the financial problems of going concerns. Problems of administration of income receive specific attention, and an attempt is made to show the relationship of accounting to finance in this important phase of administration. The problems of expansion are next considered, raising the questions of the profitableness of expansion and means of financing such moves. Finally, this course undertakes a study of the problems involved in the financial reorganizations of businesses and an examination of procedures used in refinancing and reorganizing unprofitable or bank-

rupt concerns. *Prerequisite: Bus. Ad. 161.* Three hours credit. Second semester.

202. **Business Conditions.** This course deals with the analysis of general business conditions. The theory of business cycles is considered and the statistical materials used to measure the general level of business are examined. Particular attention is given to the trend in American business since the War and the causes and characteristics of the depressions beginning in 1920 and 1929. Familiarity with the techniques of statistics is presupposed. Three hours credit.

205. **Business Law I.** It is the purpose of this course to give a general survey of the fundamental principles of the law governing business transactions. The course will consider the main principles of contract; offer; acceptance, consideration, capacity of the parties; legality of object; the formal requisites of agreements under the statute of frauds; the operation of contracts in business, and their interpretation by the courts; breach of contract and damage. The law of business organization, and the nature and formation of relations in agency, partnership, and corporations will also be considered. Although this course is designed for second-year students, by special permission it may be elected by first-year students in the School, and by students of senior standing in other divisions of the University. Three hours credit. First semester.

206. **Business Law II.** This course is devoted to specialized problems in credit; modes of safeguarding credit; negotiable instruments; guaranty and suretyship; mortgages; pledges; sales and conditional sales; problems in bankruptcy and insolvency; and receiverships. Students will be given topics for reports and discussion. This course should be of special interest to students specializing in accounting, finance, and banking. Three hours credit. Second semester.

Summer Session

Courses 102*s*, 111*s*, 151*s*, 152*s*, 161*s*, 162*s*, and 205*s*, or similar courses, will be given during the Summer Session.

56. CHEMISTRY

Professors SCHOEPFLE, WILLARD, SMEATON, BARTELL, and FAJANS; Associate Professors BACHMAN and ANDERSON; Assistant Professors CARNEY, MELOCHE, MCALPINE, FERGUSON, HODGES, WEATHERILL, HALFORD, CASE, and SOULE; Dr. BROWN and Dr. GILLETTE.

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

physical chemistry are required of students in chemical engineering.

The Chemistry Building provides excellent facilities for the work in 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 10,000 volumes and is especially rich in complete sets of journals; 120 journals are currently received.

COURSES IN CHEMISTRY

3, 6. General and Inorganic Chemistry.* A study of the descriptive chemistry of the nonmetallic elements (Course 3) and of the metallic elements (Course 6), 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. 6.* Four hours credit each. Chem. 3 is given each semester; Chem. 6, second semester only.

5E. General and Inorganic Chemistry.* The fundamental principles of chemistry are developed in such a way as to illustrate the scientific method. The descriptive chemistry of some of the nonmetallic elements and of all the more important metallic elements is studied, special emphasis being placed on such facts as are of importance to the engineer. Two lectures, two recitations, and two three-hour laboratory periods. Open to students who have presented a unit of chemistry for entrance. An examination may be given to students enrolling in this course, and those whose preparation is shown to be inadequate will be transferred to Course 3, credit for which will be counted as a nontechnical elective. Five hours credit. Each semester.

15E. General and Analytical Chemistry. This course includes the study of the systematic qualitative analysis of 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 6, or equivalent.* Four hours credit. Each semester.

43. 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. 45 and 57.* Two to four hours credit. Each semester.

* Engineering students entering without chemistry will elect Chem. 3 and 6. The credit for Chem. 3 will be allowed as a nontechnical elective if the student presents full entrance requirements, but otherwise will be entered as an admission requirement. Students presenting an approved unit of chemistry for entrance will take Chem. 5E, unless they are advised to elect Chem. 3 and 6. College credit for Chem. 3 will be allowed as a nontechnical elective for students presenting an entrance unit of chemistry.

45. **Elementary Theoretical and Physical Chemistry.** The fundamentals of physical chemistry are developed with particular emphasis on the solution of problems. The subjects treated include the gaseous, liquid, and solid states, solutions and thermochemistry. Three lectures or recitations. *Prerequisites: Chem. 15E or equivalent, Phys. 46, and a knowledge of calculus.* Three hours credit. Each semester.

47. **Elementary Theoretical and Physical Chemistry.** This course is a continuation of Course 45. Special emphasis will be placed on the subjects of chemical equilibrium and chemical kinetics. Three lectures or recitations. *Prerequisite: Chem. 45 or its equivalent.* Three hours credit. Each semester.

57. **Quantitative Analysis.** This course includes the study of gravimetric, volumetric, and electrolytic methods, and the analysis of simple mixtures. The solution of stoichiometric problems is emphasized. Two recitations and three four-hour laboratory periods. *Prerequisite: Chem. 15E.* Four hours credit required. May be taken for five hours. Each semester.

63. **Organic Chemistry.** This course is intended for students who desire a more elementary course than Chem. 67E and 69E. Four lectures or recitations. *Prerequisites: Chem. 3 and 6, or Chem. 15E.* Four hours credit. Each semester.

67E. **Organic Chemistry.** The properties and classification of carbon compounds. Lectures and recitations. *Prerequisite: Chem. 15E.* Three hours credit. Each semester.

69E. **Organic Chemistry.** A continuation of Course 67E. Lectures, recitation, and laboratory. *Prerequisites: Chem. 15E and 67E.* Five hours credit. Each semester.

105. **History of Chemistry and Development of Chemical Theory.** Lectures and seminar. Two hours credit. Each semester.

111. **Electrochemistry.** An elementary treatment of the fundamentals of the subject. Two lectures. *Prerequisite: Chem. 47.* Two hours credit. First semester.

125. **Colloid Chemistry.** In this course the student will be given the fundamental principles of colloid chemistry. Two lectures. *Open only to those obtaining permission of the instructor.* Two hours credit. First semester.

127. **Colloid Chemistry Laboratory.** An application in the laboratory of the principles of colloid chemistry. Laboratory work *Must be preceded or accompanied by Chem. 125.* Two hours credit. First semester.

131. **Physicochemical Measurements.** A continuation of Course 43. 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.

145. **Advanced Quantitative Analysis.** Application is made of the principles laid down in Course 57 to the analysis of some technical products, including coal, iron, and other ores, a silicate rock, and ferrous and nonferrous alloys. Lectures and quiz, twice a week; laboratory, two or three periods a week. *Prerequisites: Chem. 57 and Phys. 36.* Four or five hours credit. Each semester.

163. **Advanced Organic Chemistry and Ultimate Analysis.** Laboratory work and reading. *Prerequisite: Chem. 69E.* Two to five hours credit. Each semester.

165. **Advanced Organic Chemistry.** Two lectures, and reading. *Prerequisite: Chem. 69E.* Two hours credit. First semester.

166. **Advanced Organic Chemistry.** Two lectures, and reading. *Prerequisite: Chem. 69E.* Two hours credit. Second semester.

242. **Physicochemical Methods in Quantitative Analysis.** Lectures and laboratory work. *Prerequisites: Chem. 47 and 145.* Two hours credit. Second semester.

Summer Session

Courses 3, 6, 15E, 43, 57, 63, 69, 125, 127, 131, 145, 163, and 242, as described for the regular session, or similar courses, will be given in the Summer Session.

57. ECONOMICS

Professors SHARFMAN, PATON, WATKINS, HABER and ELLIOTT; Associate Professor PETERSON; Assistant Professors BRIGGS, HOOVER and FORD; Mr. LAING, Mr. HORNER and Dr. SIMMONS.

Courses 53 and 54 are introductory courses designed especially for students in the College of Engineering and are prerequisites to the election by engineering students of the more advanced courses in the Department of Economics listed below. However, upperclassmen may take Courses 171 and 173 without having had Courses 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 Colleges of Engineering, of Architecture, and of other professional schools or 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. Not open to freshmen. Three hours credit each. First semester, Course 53; second semester, Course 54.

101, 102. Money and Credit. This course undertakes a study of the functions of money and credit in our economic system. Commercial banking and the Federal Reserve System, credit control, the foreign exchanges, monetary standards, inflation and monetary and banking reform are among other topics considered. *Prerequisites: Econ. 53 and 54. Econ. 101 is a prerequisite to Econ. 102.* Three hours credit each. First semester, Course 101; second semester, Course 102.

121. Labor I. This course is intended as an approach to the understanding of the problems of the workers and of the problem of labor efficiency. Subjects considered include wages, insecurity, strikes, and the growth of the labor movement. Possible remedies by employers, unions, and the government are briefly examined. Discussion and lectures. *Prerequisites: Econ. 53 and 54.* Thursday at 3 is to be reserved for examinations and occasional lectures. Three hours credit. First semester.

122. Labor II. This course will consider employers, unions, and the government as possible agents in attempting to meet the problems raised in the preceding course. Subjects considered include personnel management, employee representation, trade unions, social insurance, and protective legislation. *Prerequisites: Econ. 121, or permission of instructor.* Three hours credit. Second semester.

123. Social Insurance. This course will study the application of the principles of social insurance to the problem of economic insecurity. It will compare the development of the several phases of social insurance in European countries, the methods of administration, and the economic implications of the various measures. It will examine particularly the economic basis for the development of social insurance in the United States, the specific nature of the legislation in the states and the Federal Government, the special problems presented by the economic aspects of the legislation, and the methods of administration. *Prerequisite: Econ. 121.* Three hours credit. First semester.

124. Unemployment. This course surveys the extent of the problem of unemployment in its national aspects, compares the conditions under which the dislocation of labor has taken place,

examines the special factors which account for the unusual severity of the problem in recent years, and the measures taken by governments to meet the situation. These measures and others proposed are examined in relation to their validity from the viewpoint of economic theory. *Prerequisite: Econ. 53 and 54, or equivalent.* Three hours credit. Second semester.

131. **Corporations and Combinations.** Concerned, first, with the corporation and its public significance; and, second, with monopolistic organizations and competitive practices, and with public policy respecting them. *Prerequisites: Econ. 53 and 54.* Three hours credit. Second semester.

133. **Railroad Regulation.** This course deals with the nature and problems of the railroad industry from the standpoint of government regulation. *Prerequisites: Econ. 53 and 54.* Three hours credit. First semester.

134. **Public Utility Regulation.** This course deals with the nature and problems of the so-called public utilities from the standpoint of government regulation. *Prerequisites: Econ. 53 and 54.* Three hours credit. Second semester.

171. **Principles of Accounting I.** This course consists primarily of a study of business transactions and operations in terms of the fundamental devices of accounting. Special attention is given to periodic operations, including the construction of work sheets and financial statements, and to the classification of accounts for managerial and other purposes. Three hours credit. Each semester.

172. **Principles of Accounting II.** This course, a continuation of Course 171, includes a study of the principal forms of income statements and reports of financial position, a survey of the problems of valuation and income determination, and a consideration of the special features of partnership and corporation accounting. Three hours credit. Each semester.

173. **Elements of Accounting.** A survey course in which, in addition to covering the underlying features of accounting technique, considerable attention is devoted to the interpretation of financial reports. Three hours credit. Each semester.

175. **Elementary Economic Statistics.** This course is intended to give critical knowledge of the chief sources and methods of economic statistics. About half of the work consists of laboratory practice. Three hours credit. Each semester.

181. **Public Finance.** Principles of public finance and a general survey of public expenditures, public revenues, including taxation, federal and state tax systems, public credit, and the effects of govern-

mental indebtedness. *Prerequisites: Econ. 53 and 54.* Three hours credit. First semester.

Summer Session

Courses 51*s*, 52*s*, 101*s*-102*s*, 131*s*, 141*s*, 144*s*, 157*s*, 171*s*-172*s*, 175*s*, 176*s*, 181*s*, 198*s*, 244*s*, and 300, or similar courses, are generally offered in the Summer Session.

58. EDUCATION

Graduates of the College of Engineering who complete Psychology 31 or its equivalent, Speech 31 or its equivalent, and the specified 17 hours in Education; who offer a major and a minor (two minors after July 1, 1939) in academic subjects; who have maintained a scholastic average of at least 2.25; and who meet the general requirements respecting citizenship, residence, health, character, personality, and professional spirit may be recommended for a Teacher's Certificate for the state of Michigan. Such Teacher's Certificates are granted by the State Board of Education on recommendation of the Faculty of the School of Education.

Psychology 31 and a maximum of 9 hours of Education will be accepted as general electives in Engineering; the remaining hours in Education must be completed in addition to the 140 hours required for graduation. The Speech requirement may be satisfied by Engineering English 2.

For further details regarding the requirements for the Michigan Teacher's Certificate, consult the *Announcement* of the School of Education.

59. ENGLISH

Professor NELSON; Associate Professors BRANDT (Chairman), THORNTON, WENGER, DAHLSTROM, BURKLUND, and BRACKETT; Assistant Professors EGLY and WALTON; Dr. KIRSCHBAUM, Mr. MACK, Mr. COOKE, Mr. BRITTON, and Mr. DICKENS.

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

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

Special Requirement for Foreign Students.—All foreign students must take English 1*a* and 2*a* until they have demonstrated their ability to do the regular freshman work in English 1 and 2. In addition to the general requirement of ten hours, foreign students will, at the discretion of the Committee on English for Foreign Students, be required to continue their work in English until, in the judgment of the English faculty, they have a satisfactory working knowledge of English. The maximum total assignment in English for such students is seventeen hours. For further regulations regarding foreign students, see section 9.

Grouping of Courses.—Groups I and II include courses which satisfy the freshman requirement and the special courses for foreign students. 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.—In addition to the facilities of the General Library and of the various departmental libraries, the English Department has accumulated a special collection of approximately one 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 1, 2, and 3 are required of all engineering students; English 1 and 2 should be taken in a student's first semester, English 3 in his second semester.

1. **Theme-Writing.** An introductory course in composition and the appreciative study of literature. Prepared themes; frequent impromptus; readings in essays, prose fiction, drama, and poetry. *This course is a prerequisite for all courses in English except English 2.* Three hours credit. Each semester.

1a. **Theme-Writing for Foreign Students.** A special course in writing and reading which all foreign students must take until they have demonstrated their ability to take Course 1. Courses 1*a* and 2*a* are to be taken at the same time. Five hours of class work, two hours of credit for the two courses. Each semester.

2. **Oral Exposition.** A practice course in public speaking which must be taken with Course 1. Written outlines, extempore and impromptu speaking, informal debates, and other oral exercises. Each student presents about ten five-minute speeches during the semester. Two hours of class work. One hour credit. Each semester.

2a. **Oral Exposition for Foreign Students.** A special course in speech which all foreign students must take until they have been judged ready to take Course 2. Practice in conversation and in reading aloud; short expository speeches; dictation; correction of individual speech defects; drill on pronunciation. Each semester.

3. **Expository Writing.** A continuation of English 1 with special emphasis on exposition. *Prerequisites: English 1 and 2.* Every freshman, in his second semester, must choose, in addition to English 3, one of the courses listed in Group II. Two hours credit. Second semester.

GROUP II

One of these courses must be elected to complete the freshman requirement; the others give credit as nontechnical electives. Except for Courses 4 and 5, in which the work is of a specialized nature, three to five papers, besides impromptus, are required. *Prerequisites: English 1 and 2.*

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. Each semester.

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. Second semester.

8. **Advanced Composition.** A course devoted exclusively to writing for those students who desire additional practice in the various forms of composition. Two hours credit. Each semester.

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

20. **Contemporary Literature.** Readings in contemporary prose fiction, drama, and poetry. Two hours credit. Each semester.

21. **Contemporary Drama.** A study of modern drama from the time of Ibsen to the present day. Two hours credit. Each semester.

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

23. **The Short Story.** Reading and analysis of a large number of short stories. Two hours credit. Each semester.

GROUP III

These courses, which are open to juniors, seniors, and graduates only, may be taken to satisfy the junior-senior requirement in English and may also be taken as nontechnical electives. Students in civil engineering must take Course 6. Courses marked with an asterisk (*) may be taken for graduate credit provided that additional work be satisfactorily done. Except for English 6, there is a requirement of four to six prepared papers besides impromptus. *Prerequisites: English 1, 2, and 3, and one course in Group II.*

*6. **Report-Writing.** The engineering report as a special type of exposition to which are applicable the fundamental principles of general exposition. Lectures, conferences, daily exercises, and two major assignments correlated as closely as possible with the technical work of the student. *Open to seniors and graduates only.* Two hours credit. Each semester.

6a. **Seminar in Thesis Problems.** For graduates who are preparing their theses. To be taken without credit.

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. Each semester.

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

*25. **The Drama.** An appreciative study of significant dramas in classical and western civilizations. Two hours credit. Each semester.

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

*27. **The Literature of Science.** Review of the work of the great historic figures in the scientific field: ancient, modern, and contemporary. Two hours credit. Each semester.

28. **American Prose Literature.** Readings in the works of representative American essayists, dramatists, and writers of fiction. Two hours credit. Each semester.

*29. **Literary Masterpieces.** Studies in the works of exceptional merit in the various literary forms. Two hours credit. Each semester.

30. **Shakespeare.** A study of eight of the principal plays. Two hours credit. Each semester.

Summer Session

Courses 1, 2, 6, and 23, or similar courses, will be given during the Summer Session.

60. FINE ARTS

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

61. FORESTRY AND CONSERVATION

Professors DANA, MATTHEWS, ALLEN, GRAHAM, RAMSDELL, and YOUNG, KYNOCH; Associate Professors CRAIG, BAXTER, WIGHT, and O'ROKE.

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

COURSES IN FORESTRY

2. **The Profession of Forestry.** A general survey of the various branches of forestry; character of the work; professional opportunities. One hour credit. Second semester.

31. **Introduction to Forestry.** Economic and social importance of forestry; history of forestry in the United States and abroad; character, distribution, and utilization of our timber resources; factors influencing tree growth; how the forest is reproduced and cared for; influence of forests on climate, stream flow, and erosion; forestry as a profession. Three hours credit. Each semester.

101. **Dendrology.** Classification, identification, and characteristics of the more important forest trees of the United States; development and growth of the individual tree; usual occurrence of different species and their share in the formation of forest types. *Prerequisite: systematic botany.* Three hours credit. First semester

122. **Forest Improvements.** Improvements for which provision should be made in ordinary forest management; the priority of their construction; estimates of cost; principles of labor management; cost-keeping systems for forest projects. Three hours credit. First semester.

128. **Pathology of Wood.** Recognition of the important agents which cause decay and stain in wood, with special studies of their growth requirements. Consideration is given to different methods of control, with laboratory practice in determining the toxicity of various preservatives. Three or four hours credit. Second semester.

131. **Wood-Products Insects.** Characteristics, life histories, type of injury, and control of insects injurious to wood products. *Prerequisite: Zoology 1.* Not open to students who have had or expect to take Forestry 130. Three hours credit. First semester.

154. **Logging and Wood Utilization.** Methods and costs of logging under different forest conditions and different silvicultural treatment; layout of logging operations; methods and costs of lumber manufacture; brief survey of other major wood products. *Prerequisite: surveying.* Four hours credit. Second semester.

159. **Wood-Using Industries.** Wood-using industries of the United States; location and economic importance; kind, amount, and source of wood used by representative industries; methods and costs of manufacture; seasoning, preservation, marketing, and utilization of product. Two hours credit. First semester.

163. **Anatomy and Properties of Woods.** Anatomy of our native woods with special reference to properties and identification; relation of properties to industrial utilization. *Prerequisites: Physics 35 and Forestry 101.* Four hours credit. First semester.

164. **Structure and Identification of Woods.** Structure of North American woods with particular attention to features used in identifying the commercial timbers. *Prerequisite: Forestry 101.* Two hours credit. Second semester.

165. **Conditioning and Preservative Treatment of Woods.** Air seasoning, kiln drying, and preservative treatment of woods. The laboratory work includes operation of a semicommercial kiln and wood-preserving plant. *Prerequisite: Forestry 163 or 164.* Four hours credit. First semester.

166. **Timber Mechanics.** Study of the mechanical properties of woods and of the methods used in obtaining data on these properties; practical application of strength data. The laboratory work includes standard strength tests on native woods in a well-equipped timber-testing laboratory. *Prerequisite: Forestry 163 or 164.* Two hours credit. Second semester.

168. **Chemical Utilization of Woods.** Utilization of woods for the making of pulp and paper, artificial silk, and other cellulose products, and for distillation and miscellaneous products. *Prerequisites: Forestry 163 or 164 and Chemistry 5 or 6.* Three hours credit. Second semester.

170. **Principles of Lumber Grading.** Detailed discussion of American Lumber Standards; relation of these standards to the various lumber associations, the retailer, and the ultimate consumer; and

their use in specifications. Actual practice in lumber grading and identification. Two or three hours credit. Second semester .

172. **Plywood and Laminated Construction.** Sources, characteristics, properties, preparation, and testing of adhesives used in ply and laminated construction; structural and physical properties of woods in relation to adhesive work; preparation, assembly, and bonding of wood plies; drying and conditioning of ply and laminated work; physical properties and utilization of plywood. *Prerequisite: Forestry 163 or 164.* Three hours credit. Second semester.

176. **Forest Economics.** Forest resources of the United States and other countries; forestry as a land problem; economic importance of wood and other forest products; timber trade; exports and imports; economics of the lumber industry and other wood-using industries; forest influences; forestry and community development. *Prerequisite: Economics 51, 53, or 153.* Three hours credit. Second semester.

181. **Elements of Forest Management.** A brief consideration of the basic principles involved in the organization, valuation, and business administration of forest properties, with particular reference to the possibilities of sustained-yield management. Three hours credit. First semester.

187. **Plantation Management in the Tropics.** Economic and administrative problems of plantation management in the tropics, with special attention to rubber production. Selection and administration of large land holdings in the various countries of the tropics; labor and other practical problems involved. Valuation of tropical land and timber properties. Two hours credit. First semester.

191. **Forest Land Policy.** Land policies of the United States from colonial days to the present; development of federal and state forest policies and legislation; status of private forestry; forestry abroad. Two hours credit. First semester.

194. **Conservation of National Resources.** Natural resources of the United States in soil, forests, minerals, and water; their contribution to the economic and social development of the country; importance and methods of conserving them. Application of the conservation philosophy to human resources, labor, industry, and commerce in general; its importance as the basis of permanent national prosperity. Three hours credit. Each semester.

62. GEOLOGY

Professor CASE and others

The Department of Geology is located in the Natural Science Building, occupying the northern half of the eastern front and extending through the four floors 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 Courses 12 (Historical Geology), 131 (Soil Geology), 133, and 134 (Economic Geology) are especially useful courses for engineering students.

Summer Session

Courses 11, 12, 105, and 203, or similar courses, are generally given during the Summer Session.

63. LANDSCAPE DESIGN

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

64. MECHANISM AND ENGINEERING DRAWING

Professor MILLER; Associate Professors GOULDING, FINCH, and PALMER; Assistant Professors POTTS, BUKOVSKY, CLARK, COLE, EICHELBERGER, HOBART, and ORBECK.

The subjects of Engineering Drawing 1, 2, and 3 comprise the total course in engineering drawing in the four-year curriculum. The content of these three subjects has been arranged to include elementary engineering drawing, descriptive geometry, and advanced engineering drawing or peculiar professional adaptations and practices. 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.

It is an interesting fact that engineering drawing constitutes the sole universal language among all civilized nations. This is so because of the necessary interrelation of interests in design, manufacture, operation, and maintenance of everything with which engineering deals in all civilized nations. Common materials, common engineering problems, the trend toward common practices and foreign commerce have all worked to the end of making this the first universally understood language. It is highly important then that each engineering student understand thoroughly the basic principles, commonly used practices, and peculiar professional applications. These classifications

furnished the basis of the subdivision of the total course into its three subjects which are given in the first three semesters of the four-year curriculum. A careful introduction has been prepared for each subject in order that the student may comprehend the reasons for and the exact nature of the outline of work. This permits a maximum of coöperation between the instructor and student to the end that the instructor is essentially the chief of a squad of engineers while the students are members of his staff. It is fortunate that the basic outline of each of the three subjects can be made so simple and obvious to the student engineer because it works to a clear comprehension on his part of the importance and necessity of these subjects in his undergraduate curriculum.

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 home work a week. Three hours credit. Each semester.

2. **Descriptive Geometry.** This course 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 curricula 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 home work a week. *Prerequisite: Draw. 1.* Three hours credit. Each semester.

3. **Advanced Engineering Drawing.** Instruction in this course includes engineering sketching of die-cast 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 dynamic structures, tracing the transmission of motion and power; tracing and lettering. Two two-hour

drafting-room periods, two hours home work a week. *Prerequisites: Draw. 1 and 2.* Two hours credit. Each 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: Draw. 1, 2, and 3.* Two hours credit. Each semester.

Summer Session

Courses 1, 2, and 3, or similar courses, are generally offered during the Summer Session.

65. METAL PROCESSING

Professor BOSTON; Assistant Professors ASH and SPINDLER; Dr. GILBERT, Mr. COLWELL, Mr. SMITH, Mr. GERHARD, Mr. TELFER, Mr. GRENNAN, and Mr. PARKER.

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. Each course consists of classroom periods in which texts, notes, lectures, lantern slides, etc., are used, and laboratory periods during which the application of principles and methods are demonstrated. As occasion permits, trips are made to industrial plants to observe the practice which is treated in these courses.

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. Special care has been taken in the selection and arrangement of equipment to facilitate instructional and research work. A chemical laboratory is provided to aid in the control of foundry operations. An electric freight elevator serves all floors. Materials, such as core and molding sands, refractories, smithing coal, cupola coke, iron and steel scrap, and pig iron, are stored in bins under the court of the building. Electric power is used throughout the laboratories, furnishing good examples of group and individual drives.

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, tool room and production. One part of the laboratory contains one or more of each of the principal types of machine tools, such as lathes, planers, grinders, shapers, drilling and milling machines, boring mills, and broaching machines, also many others of more special types, used in tool rooms. 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. Machine tools for this purpose are the turret lathe, screw machine, automatic-screw machine, punch press, die-casting machine, drill presses, and milling machines equipped with jigs and fixtures, automatic gear cutters, etc. Grinders are available for offhand, tool and cutter, drill, single-point tools, surface, and cylindrical grinding. A separate room, connected with an air-cleaning system, contains polishing and buffing machines and auxiliary equipment. Centrally located in the laboratory and under the supervision of an attendant is a well-organized tool crib, 25 by 36 feet, containing a comprehensive assortment of measuring instruments, gages, and small tools for machine and hand use. Adjoining this tool crib is a room in which student work in process of manufacture is stored. The equipment of the laboratory offers favorable opportunity for research work on the subject of forming and cutting metals.

The Machinability Laboratory, in a separate room 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. The profilograph, metallurgical microscopes, and photographic equipment are available for studying surface finish.

The University Instrument Shop, on the second floor at the east end, is equipped for fine instrument work. In this shop, research apparatus for the various departments of the University is constructed and also general service work rendered in the repair of equipment. This work is handled by a permanent staff of machinists and is independent of instruction given to students.

The Woodworking Laboratory, 45 by 60 feet, is located on the second floor. The north side of the laboratory contains the work benches and portable power tools needed for handwork, together with the tools necessary for pattern making. On the south side are arranged a variety of woodworking machines, making the laboratory a very complete unit.

The Working, Treating, and Welding Laboratory, 60 by 100 feet, on the third floor, is equipped with forges, a power shear, an abrasive cutoff wheel, and a power forging hammer with necessary gas furnace, hammer tools, and dies, grinding-wheel stands, engine lathe, shaper, drilling machine, and workbenches. For instruction in heat treating, electric- and gas-fired box-type and pot furnaces with necessary accessories, including thermoelectric pyrometers and controllers, are installed. Metallurgical microscopes are available for observation of structural changes of steel resulting from heat treatment and mechanical work. The welding equipment consists of 14 oxy-

acetylene welding stations, two alternating- and three direct-current electric-arc welders, atomic hydrogen arc, electric resistance, thermit welding installations, and brazing equipment. A universal testing machine of 50,000 pounds capacity, as well as the Shore scleroscope, Rockwell, and Brinell hardness-testing instruments, are provided for instructional and research purposes. Plating and metal-finishing equipment are available for demonstrations.

The Foundry Laboratory, 60 by 130 feet, on the fourth floor, is divided into the melting, molding, core-making, testing, and cleaning divisions. The melting equipment consists of an electric-arc furnace of 200 pounds capacity, a cupola lined to 32-inch diameter, and a crucible furnace. Special equipment is available for making castings in metal molds. Six standard types of molding machines are available for general uses. Benches, racks, ovens, and miscellaneous equipment are provided for the making of cores. The cleaning equipment consists of a sandblast machine, tumbling barrels, and grinding stands. A cyclone air-cleaning system is attached to all of these machines. Materials are delivered to the cupola charging floor by an electrically operated elevator. A two-ton electric traveling crane serves the molding floor. Sand-testing and core-testing machines are available for routine instruction and research.

The Gaging and Measuring Laboratory, 36 by 24 feet, is located in Room 2311 on the second floor, south wing of the East Engineering Building. This laboratory contains equipment furnished by the United States Army Ordnance Department which has been supplemented by additional equipment and devices of the Department of Metal Processing. It is available for instructional purposes to engineering students, ordnance students of the R.O.T.C., and reserve officers of the Army. It is available also to the industries for standardization work or for checking gages, measuring instruments, jigs and fixtures, and manufacturing equipment. A wide assortment of measuring and gaging devices is available for making measurements to millionths of an inch. A Pratt and Whitney universal measuring machine and supermicrometer are available for measuring, and also a wide variety of sizes of inside and outside micrometers reading in ten thousandths. A projection machine makes it possible to examine the profile of screw threads and gears at a high magnification. Surface plates, standard centers, sine-bar fixtures, microscopes, and other standards and accurate measuring devices complete the equipment for high-quality work.

COURSES IN METAL PROCESSING

1. **Woodwork.** This course includes bench, lathe, and simple pattern work, and may be varied to suit individual requirements. Especially for Engineering-Forestry students. Two three-hour laboratory periods a week. Two hours credit. First semester.

2. **The Working, Treating, and Welding of Steel.** 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 specification 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. Attention is given to the equipment and practice used in industry, as well as to the relation of design and application. About one-third of the course is devoted to the study of welding. One recitation and one three-hour laboratory period a week. *Must be accompanied by Chem. Eng. 1.* Two hours credit. Each semester.

3. **Foundry.** A study of the principles and practice relating to the production of gray iron, malleable, 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. Metallurgical principles are stressed in classroom work, while the laboratory periods are devoted to performing physical tests on sands and metal and the practical application of founding in production of various castings. Some attention is given to the design, production, welding, and heat treatment of castings. Two recitations and two three-hour laboratory periods a week. *Prerequisite: Metal Proc. 2.* Four hours credit. Each semester.

4. **Machine Shop.** This course is 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 the following subjects: the cutting of metals—lathe work, milling, drilling, reaming, threading, broaching, grinding, polishing, buffing, honing, and lapping—also gear-cutting machines, turret lathes, screw machines, automatic turning machines, cutting fluids, die casting, presses and dies, spinning, jigs, special tools, standards, measuring instruments, gages, as well as associated subjects, such as industrial organization, unit costs, standardization, time study, routings, and manufacturing layouts. Two recitations and two three-hour laboratory periods a week. *Prerequisite: Metal Proc. 2.* Four hours credit. Each semester.

5. **Welding.** The subject matter and laboratory work in this course are continuations of that part of Metal Proc. 2 which relates to welding. Studies are made of the following subjects: safe practices for welding, technical fundamentals of gas, arc, atomic-hydrogen, resistance, thermit and bronze welding, flame cutting, metallurgy of welding, residual stress distribution, and stress relief, shielded and

carbon arcs, alternating-current and direct-current arcs, economics of welding, automatic arc, weldability of ferrous and nonferrous alloys, filler metal specifications, qualification of operators, welding codes, destructive and nondestructive tests, physical properties and structure of welds, hard surfacing and metal spraying, and the application of welding in the various fields of engineering. Sufficient welding and testing equipment is available in the laboratory to provide a limited number of students with basic training in the engineering aspects of welding. One lecture and one three-hour laboratory period a week. *Prerequisite: Metal Proc. 2.* Two hours credit. Second semester.

6. **Pattern Making.** Construction of wood or metal patterns from working drawings, or advanced woodworking projects based on carefully prepared manufacturing drawings. Studies are made of all types of patterns and core boxes. Classroom and laboratory to be arranged. *Prerequisite: Metal Proc. 1.* Two hours credit. Each semester.

7. **Jigs, Fixtures, and Dies.** This course is designed to familiarize the student with the factors involved in determining what material and what process to use in manufacturing a certain product and also how to tool up completely for production through the final inspection. The course consists of a study of the fundamental principles of mass-production processes such as metal stamping, production machine tools, forging, welding, die casting, plastic molding, and the associated branches of jigs, fixtures, and inspection gages. Also, considerable attention is given to the factors involved in making economic comparisons of products as made from alternate materials and by alternate processes. Two recitation periods per week. *Prerequisites: Mech. Eng. 6 and Met. Proc. 4.* Two hours credit. Each semester.

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

9. **Foundry.** This is a study of the melting, molding, core-making, and cleaning divisions of foundry practice; of the manufacturing processes used in the production of gray iron, malleable iron, steel, and the nonferrous alloys; of the constitution and properties of the different cast metals; and of the methods used in controlling the operations in the foundry. The relationship of the design of castings to foundry practice and the application of cast metals for different uses also are considered. For students pursuing metallurgical engineering. One hour in the classroom and three hours in the laboratory each week. Two hours credit. Second semester.

10. **Measuring and Gaging.** This course consists of a study of the preparation of manufacturing drawings involving various

classes of fits, allowances, and tolerances. Types of gages and measuring instruments will be studied and their application in the gaging and measuring of gages, tools, jigs, and fixtures demonstrated. Working and inspection gages for a component part will be designed and practice obtained in the use of master gages. Two hours credit.

12. **Advanced Working, Treating, and Welding of Steel.** Further work on subjects scheduled in Courses 2 and 5 may be elected by making arrangements with the instructor.

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.

14. **Advanced Machine Shop.** This course may be elected to suit individual requirements. Special topics incidental to machine-shop practice, such as further work in machining processes, a determination of the most economical method for producing a part in quantities, and advanced toolroom work are included. 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.

109. **Machinability.** This course is for advanced students interested in research projects dealing with metal cutting. Factors such as cutting forces, tool life, accuracy, and surface finish relating to the machinability of metals or the performance of tools and cutting fluids may be investigated. The course is particularly suitable for thesis work. Hours to be arranged. Each semester.

110. **Materials for Aircraft Construction.** (Aero. Eng. 17). Designed for aeronautical engineering students to acquaint them with materials used in the design of aircraft. Numerous materials are studied as to their 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. This includes the treatment of fabrics; the forming, gluing, and joining of wood parts; the cutting, punching, bending, riveting, welding, brazing, heat treating, and actual testing of parts and structures. One class and one three-hour laboratory period each week. *Prerequisites: Metal Proc. 4 and Aero. 5.* Two hours credit. Second semester.

Summer Session

Courses 3, 4, 12, 13, 14, and 109 are generally given during the Summer Session.

66. MILITARY SCIENCE AND TACTICS

Professor EDWARDS; Assistant Professors FARISS, HARDY, WALLINGTON, SIMKINS, KELLY, and WIMER.

Courses in Military Science and Tactics are offered to physically fit male students who are citizens of the United States. Students electing courses in this department are not required to elect physical education. These courses are designed to give thorough groundwork in military subjects considered necessary as a part of the education of a commissioned officer in the Reserve Corps of the military forces of the United States. Successful completion of eight semesters' work will lead to a recommendation for a commission in the Officers' Reserve Corps.

The courses of the first four semesters comprise the basic group, and the courses of the last four semesters comprise the advanced group. Elections are for a period of four semesters; that is, for a complete basic or advanced group. Once elected, a group becomes a prerequisite to graduation unless the student is formally discharged from this obligation. While taking the advanced group, members of the Reserve Officers' Training Corps receive pay from the Government, which amounts to about $200.00.

Students who enroll late may double up their courses. Four semesters' time must be put in, however, before they become eligible for pay.

A deposit of $9.00 to cover property responsibility is required of each basic student. This deposit is returned at the completion of the basic course and the uniform furnished remains the property of the student.

A deposit of $12.50 is required of each advanced-course student. This deposit is returned at the completion of the advanced course and the officer's uniform furnished remains the property of the student.

Enrollment in an R.O.T.C. group is not an enlistment in a component of the Army nor does it carry with it any obligation for service at any time.

Students who wish to receive credit for work in Military Science and Tactics must do two things: (1) they must enroll at the office of the Military Department; (2) they must write on their official election blanks the name and number of the course they are entering.

Academic credit is given for this work.

CONSULTATION HOURS.—During registration period, 9 to 12 and 1 to 4 daily, at the Department Office.

Rifle and Pistol Practice.—Membership on the R.O.T.C. Rifle and Pistol Teams depends on both excellence in marksmanship and compliance with the rules governing attendance at practice and competitions. Hours of practice to be announced.

Courses leading to reserve commissions in the following branches of the Army are offered:

Infantry.—Theoretical and practical work which will enable a student to understand and make proper use of Infantry weapons and handle a company of Infantry according to modern tactical principles. Open to all students.

Ordnance.—Theoretical and practical work in the design, manufacture, inspection, and test of guns, ammunition, bombs, tanks, etc. In view of the fact that the Ordnance Department is a technical and manufacturing branch of the Army, a student during the advanced course takes certain technical subjects in his own college which tend to make him more of a specialist in his own line, and, therefore, of more value to the Ordnance Department. Open to engineering students.

Signal Corps.—Theoretical and practical work which will enable a student to apply his engineering knowledge to military communications. Open to students of the College of Engineering, particularly electrical engineers, and others interested in electrical communications.

Military Engineering.—Theoretical and practical work which will enable a student to apply his engineering knowledge to military work and handle an engineer company in combat. Open to students in the College of Engineering, in Architectural Design, and in Architecture Program I.

Upon election of a particular branch of engineering, R.O.T.C. students previously enrolled in an inappropriate unit may transfer to the unit to which their engineering department election makes them eligible, without loss of credit.

MILITARY SCIENCE AND TACTICS
FOUR-YEAR PROGRAMS

		INF.	ORD.	SIG. CORPS	ENGRS.
1st Yr.	1st Sem.	M. S. 1	M. S. 1	M. S. 1	M. S. 1
	2d Sem.	M. S. 2	M. S. 2	M. S. 42	M. S. 2
2d Yr.	1st Sem.	M. S. 3	M. S. 3	M. S. 3	M. S. 3
	2d Sem.	M. S. 4	M. S. 4	M. S. 44	M. S. 4
3d Yr.	1st Sem.	M. S. 5	M. S. 7	M. S. 7	M. S. 55
	2d Sem.	M. S. 6	M. S. 32	M. S. 46	M. S. 56
		Summer Training Camps, about June 15th to August 1st.			
4th Yr.	1st Sem.	M. S. 7	M. S. 33	M. S. 47	M. S. 7
	2d Sem.	M. S. 8	Electives: Consult with Ord. Officer	Elec. Engrs. E. E. 10 or E. E. 22 All others, E. E. 24	M. S. 58

Company Assembly: One hour of drill per week is required with every course in Military Science and Tactics.

Note: Freshman and Sophomore members of the R.O.T.C. Band are excused from Company Assembly.

Summer Camps

Attendance at an advanced camp is required and is a prerequisite to commission. Transportation, uniforms, equipment, quarters, rations, and medical attention are furnished by the Government. In addition the student is paid 70 cents a day.

Infantry—Camp Custer, Michigan.
Signal Corps—Camp Custer, Michigan.
Engineers—Camp Custer, Michigan.
Ordnance—Aberdeen Proving Ground, Maryland.

COURSES IN MILITARY SCIENCE

1. **Military Fundamentals and Rifle Marksmanship.** One hour credit. First semester.

2. **Military Fundamentals and Musketry.** (Continuation of Course 1). One hour credit. Second semester.

3. **Map and Aerial Photograph Reading, and Command and Leadership.** One hour credit. First semester.

4. **Automatic Rifle, Combat Principles, and Command and Leadership.** One hour credit. Second semester.

5. **Machine Guns, Command and Leadership, Military History, 37-mm. Gun and 3″ Mortar and Pistol Marksmanship.** Two hours credit. First semester.

6. **Combat Principles, Field Fortifications, and Rifle Marksmanship.** Two hours credit. Second semester.

7. **Military Law, Military History and Policy, Mechanization, and Company Administration.** Two hours credit. First semester.

8. **Minor Tactics.** Two hours credit. Second semester.

32. **Ordnance Materiel and Ammunition.** Two hours credit. Second semester.

33. **Inspection, Gages, and Measuring Instruments.** Two hours credit. First semester.

42. **Wire-Communication and Field-Wire Systems.** One hour credit. Second semester.

44. Field Radio Sets and Radio Communication. One hour credit. Second semester.

46. Signal Corps Organization and Tactics. Two hours credit. Second semester.

47. Military Cryptography and Signal Communication. Two hours credit. First semester.

55. Field Fortifications, Military Mining and Demolitions, Combat Principles, Engineers, and Command and Leadership. Two hours credit. First semester.

56. Military Roads and Floating Bridges, Explosives, Demolitions, and Mine Warfare. Two hours credit. Second semester.

58. Combat Principles, Organization of the Ground, Fixed Military Bridges, and Map Making. Two hours credit. Second semester.

67. MINERALOGY AND PETROGRAPHY

Professor HUNT; Associate Professors PECK and RAMSDELL; Assistant Professor SLAWSON.

The Mineralogical Laboratory comprises thirty-six rooms located in the northwest portion 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. These instruments are all of the most modern and approved types. The blowpipe and chemical laboratories possess every facility for the qualitative and quantitative determination of minerals and rocks.

COURSES IN MINERALOGY

31. Elements of Mineralogy. This course 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 laboratory a week. *Prerequisite: a knowledge of elementary inorganic chemistry.* Three hours credit. Each semester.

104. Useful Minerals, Building and Decorative Stones. This course is 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.

109. Elements of Crystallography. This course 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.

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

152. Physical Crystallography. Brief surveys of geometrical crystallography and the more important physical and chemical properties of minerals are followed by 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.

Summer Session

For Summer Session courses in mineralogy, see *Announcement* of the Summer Session.

68. MODERN LANGUAGES

The study of a modern foreign language is considered of particular value to the student in the technical school, as 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 both to himself and to 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. This is 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. The course is conducted partly in French. Four hours credit. Each semester.

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 11 is designed for upperclassmen who do not intend to continue more than two or three semesters. 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.

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 Course 11, or its equivalent. *Course 12 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.* Course 12 may be followed by Course 41. Four hours credit. Second semester.

31. **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. The course is conducted in French as far as possible. *Prerequisite: Course 2, or a two-year course in high school.* Four hours credit. Each semester.

32. **Second-Year French, Continued.** Course 32 may be followed by any or all of Courses 71 (four hours credit), 101 (three hours credit), 111 (two hours credit), or 113 (two hours credit). *Prerequisite: Course 31, or a three-year course in high school.* 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.

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 Course 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, as 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 for the specific needs of the class. *Prerequisite: Course 11 or its equivalent.* Three hours credit. Second semester.

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

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

41. **Special Reading Course.** This course is devoted exclusively to the development, through the use of graded texts, of a rapid and accurate reading knowledge of German. *Course 41 is arranged for seniors anticipating the use of German for graduate work and also for graduate students desiring additional training for the language requirement for the degree of Doctor of Philosophy. Prerequisites: Courses 11 and 12, or equivalent.* Three hours credit.

Summer Session

Courses will be offered during the Summer Session.

SPANISH

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

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

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

32. **Second-Year Spanish.** Continuation of Course 31. *Prerequisite: Course 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.

69. PHILOSOPHY

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

70. ENGINEERING RESEARCH

Professor A. E. WHITE, Director; Associate Professor GOOD, Assistant Director; Mr. POTTER, Assistant to the Director; Mr. SMALL, Assistant to the Director; Research Engineers CLARK, SCHNEIDEWIND, and WALKER; Research Physicists GEIGER, VINCENT, and WOLFE; Research Associates DELP and MURPHY.

The Department of Engineering Research was established in October, 1920, to afford an official department through which the laboratory facilities of the University, when not being utilized for instructional purposes, could be made available to the civic and technical interests in the State and elsewhere.

The Department does not offer course work to students in the University, but with the research problems brought to the University through the medium of the Department, opportunity is in many cases afforded graduate students to work on special research problems under the technical supervision of members of the faculty or the staff of the Department.

Besides such problems fellowships are administered through this Department, although the actual technical work is done in the various departments of the College.

The function of the Department is largely administrative, the actual technical direction of the researches in most cases being in the hands of members of the regular faculty.

The facilities available through the Department include the libraries of the University and the engineering and other technical laboratories. The work in the laboratories is conducted by members of the staff connected with those laboratories, thus ensuring a maximum of efficiency in their utilization.

Part V

PROFESSIONAL DEPARTMENTS

The following curricula 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.

71. 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 15 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 his 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.

72. AERONAUTICAL ENGINEERING

Professors STALKER and PAWLOWSKI; Associate Professor THOMPSON; Mr. SPRINGER.

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. In this connection the two main types are classified in the following groups:

Heavier-than-Air Craft, which comprises a study of general aerodynamics, the determination of stresses, and the general design of structure for all parts of an aircraft, and the design of propellers and propelling machinery.

Lighter-than-Air Craft, which includes all studies similar to those mentioned above, but with special reference to this type of machine; together with the principles involved in balloons and dirigibles, and their navigation.

The Courses offered by the Department are arranged to cover the essentials of aerodynamics necessary for the proper understanding of the action of wings, propellers, and 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.

From its inception the Department of Aeronautical Engineering has realized that the utilization of the air as a means of transportation, the settlement of problems confronting the designer, and the future development of this field must rest upon a thorough foundation of scientific theory. Hence preparatory courses in mathematics, theory of structures, hydromechanics, and mechanical engineering are essential. In the design of aircraft, the student is given an opportunity to apply such studies, so as to obtain the best solution to any given set of conditions.

The wind tunnels offer facilities for experimental work in all problems relating to this subject, and are available for research work for advanced students.

Aeronautical Laboratory.—The Aeronautical Laboratory consists primarily of a large wind tunnel of open-throat type with double ducts for the return of the air flow. The cross section of the tunnel is an octagon, and its minor diameter may be varied from five feet to eight feet. With the large diameter the wind velocity is approximately one hundred miles per hour, and models of fifty inches span are regularly used for experimentation. This wind tunnel is at present equipped with a six-component wire balance and another balance incorporating a rigid model support particularly suited to experimentation with boundary-layer control. Facilities for instruction in the testing of model propellers are now provided.

The large wind tunnel is used primarily for research work by seniors and graduate students, while a smaller rectangular-throat tunnel is provided for routine instruction.

Students taking aeronautical engineering regularly take work in the electrical, mechanical, strength of materials, and automotive laboratories. Work may also be elected in other special laboratories, such as the naval tank.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 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 science are urged to enroll at the beginning of their course. For further details see section 66.

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 50.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Economics 53, 54	6
Math. 3, 4, 36, 37, 103	19
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Total	69

b) *Secondary Courses*	
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. 2, Theory of Structures	3
Mech. Eng. 2, Machine Design	4
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 5, Thermodynamics	3
Mech. Eng. 7, Laboratory	2
Mech. Eng. 15, Internal Combustion Engines	3
Elec. Eng. *2a,* Electric Apparatus and Circuits	4
Aero. Eng. 1, General Aeronautics	3
Aero. Eng. 2, Theory of Aviation	3
Aero. Eng. 3, Theory and Design of Propellers	2
Aero. Eng. 4, Airplane Structures	3
Aero. Eng. 6, Experimental Aerodynamics	1
Total	53

Summary:

Preparatory Courses	69
Secondary and Technical Courses	53
Group Options and Electives	18
Total	140

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

Group A. Airplane Structure and Design	*Hours*
Aero. Eng. 5, Airplane Design	2
Aero. Eng. 23, Advanced Airplane Structure	3
Free Electives	13
	18

Group B. Aircraft Power Plants	
Mech. Eng. 14, Aircraft Power Plants	3
Mech. Eng. 26, Experimental Tests	3
Mech. Eng. 27, Design of Aircraft Engines	2
Mech. Eng. 27*a*, Design of Aircraft Engines	2
Free Electives	8
	18

PROGRAM

First Year

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5 or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

* If modern language is elected, it may be classified here and the English postponed. See section 51.
† See note, section 56.
‡ Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each semester) is elected as a substitute. Enrollment in military science is for a period of four semesters.

Second Year

First Semester		Second Semester	
Courses	Hours	Courses	Hours
Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Economics 53	3	Economics 54	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

Summer Session

Courses	Hours
Metal Proc.	4
Elec. Eng. 2*a*	4
	8

Third Year

Math. 103	3	Mech. Eng. 2	4
Eng. Mech. 3	3	Mech. Eng. 5	3
Eng. Mech. 4	3	Civil Eng. 2	3
Mech. Eng. 3	4	Aero. Eng. 2	3
Mech. Eng. 7	2	Aero. Eng. 3	2
Aero. Eng. 1	3	Mech. Eng. 14 or Electives	3
	18		18

Fourth Year

Group A

English (Group III)	2	Aero. Eng. 5	2
Aero. Eng. 4	3	Aero. Eng. 6	1
Mech. Eng. 15	3	Aero. Eng. 23	3
Electives, free or nontechnical	7	Electives, free or nontechnical	9
	15		15

Group B

Aero. Eng. 4	3	English (Group III)	2
Mech. Eng. 15	3	Aero. Eng. 6	1
Mech. Eng. 26	3	Mech. Eng. 27*a*	2
Mech. Eng. 27	2	Electives, free or nontechnical	10
Electives, free or nontechnical	4		
	15		15

COURSES IN AERONAUTICAL ENGINEERING

1. **General Aeronautics.** This is an introductory course giving briefly the essentials of aeronautics as applied to the airplane, airship, and other modern means of flight. The course begins with a brief history of the development of aeronautics, which is followed by a discussion of the fundamentals of aerodynamics and mechanics underlying the determination of the performance and stability of airplanes. Lectures and recitations. *Open to all students except freshmen.* Three hours credit. Each semester.

2. **Theory of Aviation.** In this course a development of the underlying mechanics which form the basis for the study of modern aircraft is presented. The course begins with a brief review of the fundamental experimental data and is followed by a development of the theory of airfoils, including the induced-drag theory. The application of these theories to the study of aircraft performance and design is brought out and some time is devoted to the discussion of the stability of airplanes. Lectures and recitations. *Must be preceded or accompanied by Math. 103 or Math. 105 and 106.* Three hours credit. Each semester.

3. **Theory and Design of Propellers.** This course deals with the aerodynamic theories of the propeller and with its strength. The selection of propellers for specific conditions is discussed. The simple blade-element theory, the multiplane-interference, and vortex theories are treated, and geared, controllable-pitch, and tandem propellers are included. Lectures and recitations. *Must be preceded by Eng. Mech. 2, and preceded or accompanied by Aero. Eng. 1.* Two hours credit. Each semester.

4. **Airplane Structures.** This course includes the investigation of the design of the airplane from the structural standpoint. The strength and design of details are discussed. Lectures and recitations. *Must be preceded or accompanied by Aero. Eng. 1 and preceded by Civil Eng. 2.* Three hours credit. Each semester.

5. **Airplane Design.** The design of an airplane from the aerodynamical and strength standpoints to meet certain specifications is discussed. Particular stress is placed on the aerodynamic design, especially for stability and control under all flight conditions, also on the choice of materials and mechanisms. Lectures and drawing. *Prerequisites: Aero. Eng. 2 and 4.* Two hours credit. Each semester.

6. **Experimental Aerodynamics.** This course is designed so as to illustrate experimentally the various basic principles of aerodynamics studied in Courses 1 and 2. The lectures cover such topics as the construction of wind tunnels, balances, devices for the measurement of air speed and other instruments, as well as the interpretation of wind-tunnel data and its use in the calculation of the

performance of a full-scale airplane. Such questions as scale and turbulence effects and jet-boundary corrections are considered in some detail, and mention is made of the methods for conducting flight tests and the correlation of the resulting data.

The experiments conducted in the laboratory illustrate the methods employed in the measurement of wind velocities, the determination of the aerodynamic characteristics of airfoils, and the effect of variations in their shape. Lectures and laboratory. *Prerequisites: Aero. Eng. 2. Open only to seniors and graduates.* One hour credit. Each semester.

7, 8. Lighter-than-Air Craft. This course is concerned with the following: aerostatics, and major aerodynamic and structural design problems of nonrigid, semirigid, and rigid aircraft. Lectures and recitations. Two hours credit. Second semester.

10. Airports. Planning and equipment of airports. General plans of an airport are prepared. Lectures, recitations, and drawing. *Prerequisites: Aero. Eng. 2 and 7.* Two hours credit. First or second semester if required.

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, following Bryan's treatment, with Bairstow's application of experimentally determined resistance derivatives and rotary coefficients. The subjects of spinning and the vibration and flutter of certain parts of the airplane are also discussed. Some attention is given to the methods used in obtaining experimental results and in interpreting them in the light of the theoretical developments. Lectures and recitations. *Prerequisites: Aero. Eng. 2 and Math. 39. Aero. Eng. 11 is a prerequisite for 11a, the former being offered during the first semester and the latter in the second.* Two hours credit for each course.

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.

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

14. Research. Continuation of Aero. Eng. 6, offering an opportunity for students to pursue experimental investigations. *Prerequisite: Aero. Eng. 6.* Credit to be arranged. Each semester.

15. Theoretical Aerodynamics. A brief summary of the fundamentals of the mathematical theory of hydrodynamics, including Helmholtz' laws of vortex motion, followed by a discussion of two-

dimensional fluid motion and its application to modern aerodynamics. The theory of the geometry and dynamics of airfoil sections is treated in considerable detail. This subject is followed by a discussion of the theory of thin-wing sections and a treatment of the mathematical details of the induced-drag theory of the monoplane. *Prerequisites: Aero. Eng. 2 and Math. 39.* A reading knowledge of French or German and some advanced work in mathematics is desirable but not necessary. Three hours credit. First semester.

15a. **Advanced Theoretical Aerodynamics.** This course is a continuation of Aeronautical Engineering 15 and begins with a detailed analysis of the flow field around a monoplane wing, followed by an exposition of the geometry and dynamics of the two-dimensional biplane. The calculation of the induced drag of a biplane is then taken up in detail; considerable time is also spent on the mechanics of viscous fluids, the boundary-layer theory, and their applications to aeronautics. The remainder of the course will discuss topics desired by the student, selected from some of the more recent developments in the flow of perfect and viscous fluids. Lectures and problems. *Prerequisite: Aero. Eng. 15.* Three hours credit. Second semester.

16. **Air Transportation.** Engineering and economic aspects. Two hours credit. First semester.

17. **Aircraft, Materials of Construction.** See Metal Proc. 10.

18. **Helicopters and Autogiros.** *Prerequisite: Aero. Eng. 2.* One hour credit. Second semester.

19. **Analytical Research.** A theoretical investigation of problems in aeronautical engineering which are particularly suited to treatment by analytical and mathematical methods. Problems may be selected from the fields of aerodynamics, structures, and airplane performance. Hours and credit to be arranged.

20. **Advanced Fluid Mechanics.** An advanced course in fluid mechanics covering much the same material as that included in Aero. Eng. 15 and 15*a*. The details of the mathematical development in the various theories studied are largely omitted, and the emphasis is mainly on the physical aspects of these problems and their applications in engineering. The course includes discussion of problems in the fields of aeronautical, hydraulic, marine, and mechanical engineering. Students wishing to specialize in aerodynamics should elect Aero. Eng 15 and 15*a*, while those wishing to make a general survey of the advanced work in this field should elect Aero Eng. 20. *Prerequisites: Eng. Mech. 4 and Math. 39.* Three hours credit. First semester.

21. **Advanced Theory of Propellers.** The content of Aero. Eng. 3, omitting routine investigations, is covered in a short time

and supplemented by a more critical investigation of the fundamental aerodynamic and strength theories of the propellor; special topics include windmills and blowers. Two hours credit.

22. **Propeller Research.** Investigation of special propeller and helicopter problems in the laboratory. Credit to be arranged.

23. **Advanced Airplane Structures.** This course deals with the structural analysis of metal airplanes. Lectures will cover the subject of stability of commonly used sections and shapes in aircraft structures under compression, bending, torsion, and combined stresses, and monocoque and semimonocoque structures. The practical design of Wagner, truss-type, corrugated, and composite-type shear webs will be considered. *Prerequisites: Aero. Eng. 4, or by special arrangement for students from other departments.* Three hours credit. Second semester.

24. **Advanced Experimental Aerodynamics.** This course covers the work presented in Aero. Eng. 6, but with considerably more attention to detail and a more elaborate discussion of the advanced theories and methods used in this field. The program of experimental work is adapted to the use of the large seven-foot wind tunnel and includes experiments illustrating the application of experimental methods to a number of fundamental aerodynamic problems. *Prerequisites: Eng. Mech. 4 and Math. 37.* Two hours credit.

25. **Advanced Airplane Performance.** The relationship of engine, propeller, and airplane are considered in this course. The effect of changes in these items on the performance of the airplane as a whole are treated in detail. Performance analyses based on theory, wind-tunnel tests, performance charts, and flight tests, are compared. Special investigations are made concerning the effect on airplane performance of the many kinds of controllable-pitch propellers and the various types of supercharged engines. Altitude flying, take-off and landing, single-engine performance of multiengined aircraft, and other related problems of vital interest in modern military and commercial aircraft operation receive special attention. *Prerequisites: Aero. 2 and 3.* Three hours credit. Second semester.

73. ASTRONOMY

Professor H. D. CURTIS; Associate Professors ROSSITER,* RUFUS, MCLAUGHLIN, and MAXWELL; Assistant Professor LOSH; Dr. WILLIAMS.

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

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

equatorial refractor; a 6-inch meridian circle; a comet seeker; 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 catalogs, 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 15-inch reflector, a 10-inch refractor, a 3-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 27-inch refractor and a 6-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 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 10½-inch reflector, with much auxiliary apparatus, and a new solar tower, for studies of solar phenomena.

CURRICULUM IN ASTRONOMY

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:

a) Preparatory Courses	*Hours*
English 1, 2, 3, and a course from Group II	8
English junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37, 39 or 103	18
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2	2
Economics 53, 54	6
Total	65

b) Secondary and Technical Courses

Eng. Mech. 1, 3	6
Civil Eng. 2	3
Surveying 1, 2	7
Surveying 5, or Astronomy 154	2
Astronomy 51, 53 (or 31, 32, 33), 101, 102, 151, 152, 201	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

Summary:

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

Courses 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 Course 51, with its accompanying laboratory Course 53, in place of 31, 32, and 33. Courses 35, 101, 102, 154, and 201 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 such students as have assigned problems requiring their use.

31. Descriptive Astronomy. The Solar System. A descriptive course, including 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. Each semester.

32. Descriptive Astronomy. Stars and Nebulae. A descriptive course, 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. Each semester.

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 Astron. 31, 32, or 35.* One hour credit. Each semester.

35. **Practical Astronomy.** The elements of spherical and geodetical 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. 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. Each semester.

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 Course 51.* One hour credit. Each semester.

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. First semester.

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

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. First semester.

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 possess a general knowledge of astronomy and physics.* Four hours credit. Second semester.

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. Second semester.

201. **Theoretical Astronomy.** The elements of celestial mechanics, and the determination of parabolic and elliptic orbits of comets and planets. *Prerequisite: Course 101 and calculus.* Three hours credit. First semester.

Summer Session

Courses 31, 32, 33, 101, 103, 151, 152, and 207, or similar courses, will be given during the Summer Session.

74. CHEMICAL AND METALLURGICAL ENGINEERING

Professors A. H. WHITE, A. E. WHITE, BRIER, UPTHEGROVE, BROWN, WOOD, and BAKER; Assistant Professors THOMASSEN, MCCREADY, KATZ, SIEBERT, PETTYJOHN, and SCHNEIDEWIND; Instructors TOWNSEND and FOUST; Research Engineer and Lecturer CLARK.*

THE CHEMICAL ENGINEER

The definition of chemical engineering approved by the American Institute of Chemical Engineers is as follows:

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. These processes may usually be resolved into a coördinated series of unit physical operations and unit chemical processes. The work of the chemical engineer is concerned primarily with the design, construction, and operation of equipment and plants in which series of these unit operations and processes are applied. Chemistry, physics, and mathematics are the underlying sciences of chemical engineering, and economics its guide in practice.

In our complex industries there must be specialization, and some chemical engineers become experts in design of equipment, some in the operation of particular manufacturing processes, and some in the development of processes from the laboratory to the manufacturing scale. The chemical engineer's work must be based on a thorough knowledge of chemistry, but he is not a laboratory chemist. He must apply mathematics and physics in almost the same degree that he does chemistry. His relation to the chemist is very similar to that of the electrical engineer to the physicist. Like all engineers, the mature chemical engineer may become a business executive, utilizing his scientific knowledge and manufacturing experience in directing industrial enterprises.

The activities of the chemical engineer cover a broad field. He finds his work not only in those industries usually thought of as purely chemical, such as the manufacture of acids, alkalies, and salts, but in such industries as the manufacture of sugar, paper, leather,

* Rank equivalent to Assistant Professor of Metallurgical Engineering.

rubber, soap, fuels, petroleum products, paints and varnishes, cement, plaster, glue, food products, dyes, textiles, and many others.

Statistics compiled in 1930 from 1,100 questionnaires filled out by graduates from various universities in the years 1920–30 showed that 23 per cent of chemical engineering graduates became teachers. were connected with research institutes, entered governmental employment, became consulting engineers, or entered the professions of law or medicine. Seventy-two per cent were directly connected with industry and were enrolled in the following industries, arranged according to the numbers employed. The industry which at that time was taking the largest proportion of chemical engineering graduates was petroleum, and it was followed by organic chemicals; heavy chemicals; rubber; iron and steel; gas and coke; paint, varnish, and lacquer; pulp and paper; nonferrous metals; vegetable oils and soap; automobiles; chemical equipment; power plants and public utilities other than gas; food; rayon; ceramics; cement and lime; textiles (natural); fertilizers; and leather.

The work of the chemical engineer is often thought of in connection with what are usually called "unit operations." These are such operations as heating, evaporating, filtering, distilling, crushing. extracting, and drying, as carried out on a commercial scale. Any manufacturing process with which the chemical engineer deals is made up of a sequence of such operations. His knowledge of these unit operations is one characteristic which distinguishes him from the chemist, and his understanding of what is actually taking place in a manufacturing process differentiates him from the mechanical engineer.

THE METALLURGICAL ENGINEER

Almost all that has been said of the chemical engineer applies with equal force to the metallurgical engineer, although the metallurgical engineer is more specially 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.

In extractive metallurgy the various steps proceed by unit operations just as in chemical engineering, with more emphasis placed upon handling and separation of solids, and operations in melting furnaces. Knowledge must be acquired of the methods of attaining and controlling the extreme temperatures required to melt refractory metals. The physical properties of metals and alloys must be studied

from the viewpoint of their inner structure as revealed by the metallographer's microscope and the x-rays, and processes of heat treatment and mechanical work must be adapted to give the structure which has been shown to be most desirable in the finished product.

CURRICULA IN CHEMICAL AND METALLURGICAL ENGINEERING

The first two years of undergraduate work are devoted largely to acquisition of fundamental subjects or tools required for an understanding of the more specialized subjects. In these years the student should become familiar with mechanical drawing, mathematics, physics, and chemistry. He also should acquire proficiency in the use of the English language. He will also obtain an introduction to the work in chemical and metallurgical engineering. There is no differentiation in the programs for these two groups until the third year.

In the last two years attention is divided between studies in chemical and metallurgical engineering, advanced work in chemistry, and the fundamentals of other pertinent engineering subjects, such as engineering mechanics, machine design, heat engines, and electrical machines and circuits. An introductory knowledge of economics is obtained and elective subjects provide opportunity for a limited amount of study in such fields as history, philosophy, and political science.

The work is designed to give the student as broad a foundation as possible, avoiding marked specialization, and yet carrying his training in one direction sufficiently far so that upon graduation he may be immediately useful to some organization. Graduates sometimes find themselves very soon in positions where they become responsible chemical or metallurgical engineers in the organization, and these men must consequently be fitted to accept and creditably carry such responsibility.

The required work in *chemical* engineering includes courses in engineering materials, fuels and combustion, heat treatment and properties of metals, inorganic and organic chemical technology, the unit operations of chemical engineering, and an introduction to research work. This research work may be in any field chosen by the student, and, taken with other elective work, offers opportunity for moderate specialization.

The required work in *metallurgical* engineering includes courses in engineering materials, fuels and combustion, heat treatment, structures and properties of metals, unit operations in chemical and metallurgical industries, extractive and physical metallurgy, and an introduction to research work. The requirements for chemical engineering and for metallurgical engineering differ in that the inorganic and organic technology of chemical engineering and a part of the organic chemistry is replaced by general and physical metallurgy.

THE CHEMICAL AND THE METALLURGICAL ENGINEER WITH GRADUATE TRAINING

The mere fact that the chemical or the metallurgical engineer must have considerable attainments in the important fields of chemistry, physics, and mathematics, as well as in chemical or metallurgical engineering, indicates the need of more than four years' study.

The formative state of these branches and their rapid development, which is certain to continue for many years, make it important that a young man entering the profession be equipped, not only to keep abreast of their progress, but also to do his part in advancing his chosen subject during his active professional life. This is definitely recognized by many of the larger corporations, who prefer a man with a master'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 it. They recognize this, not only by being more willing to employ men with advanced degrees, but by paying higher salaries to such men.

During the past three years there has been an average of seventy-five graduate students registered in these subjects at the University of Michigan. The size of this group makes it feasible to offer special courses, not only in chemical and metallurgical engineering, but also in mathematics and physics. A notable development of recent years has been the call for men with a Ph.D. degree. The demand for these men was larger than the supply even during the five years of the business depression.

No one should undertake graduate work unless his standing as an undergraduate has shown scholastic ability. In general, he should have ranked in the upper third of his class and have done well in mathematics and physics as well as in chemistry. All graduate students are enrolled in the Horace H. Rackham School of Graduate Studies of the University.

The Chemical and Metallurgical Engineering Library is shelved with other departmental libraries on the third floor of the East Engineering Building. The library is 33 by 60 feet and has shelves for 15,000 books and seats for 80 readers. Some of the most important journals of pure chemistry are duplicated in this library and there is a rich collection of journals dealing with industrial chemistry, chemical engineering, and metallurgical engineering. About one hundred journals are currently taken by the Department of Chemical and Metallurgical Engineering and most of them are represented by complete sets. In addition to 6,000 books dealing distinctly with chemical and metallurgical engineering, there are many others dealing with more general engineering lines.

Chemical and Metallurgical Engineering Facilities.—The Department is not only fortunate in having assigned to it over one-third of the 160,000 square feet of space in the East Engineering Building, but is also fortunate in its neighbors. The forge shop and

foundry of the Department of Metal Processing are adjacent to and coöperate closely with the metallurgical laboratories. The highway laboratories with their facilities for study of the properties of cement, brick, and asphalt are also in this building. The Department of Engineering Research with its many-sided activities has its headquarters here.

The Department has assigned to it over 80 rooms, including laboratories, classrooms, storerooms, and offices. There are 12 single-unit and 15 double-unit laboratories available for research workers, in addition to the laboratories reserved for members of the staff. There is a workshop with 2 mechanics who give their whole time to the departmental work, and a second shop for the use of graduate students who wish to make or repair their own apparatus.

The General Chemical Engineering Laboratory is devoted primarily to equipment for studying the fundamental elements of chemical engineering. It has facilities for the following unit operations:

Fluid Flow.—Extensive equipment is available for the study of characteristics of the flow of gases and liquids through pipes, ducts, and measuring instruments of all kinds.

Heat Transfer.—Heaters, double-pipe heat-exchange apparatus, and various types of multiple-pass condensers offer a wide variety of opportunity for instruction and research on problems pertaining to the interchange of heat between substances at high and low temperatures.

Evaporation.—The evaporator laboratory occupies a space 26 by 69 feet, extending from the basement through the first floor. The principal equipment is a set of evaporators and accessories which are the gift of the Swenson Evaporator Company of Harvey, Illinois. It is the most complete and extensive equipment of its kind in the country. The evaporators include a standard vertical-tube unit, a standard horizontal-tube type, and a forced-circulation unit. Each of these evaporators has a maximum evaporation capacity of 4,000 pounds of water per hour. Each is completely equipped with accessories for weighing and controlling feed, removing crystals, and measuring condensate; and each has the greatest possible flexibility to permit adaptation to process development. Two other special evaporators are available and are used for research purposes.

There is also a full complement of equipment for work in high-temperature evaporation. This includes a gas-fired diphenyl boiler rated at 150,000 B.t.u. per hour, a small forced-circulation evaporator, and an elaborate heat-interchange apparatus, both equipped for using diphenyl heat. These pieces of equipment are provided with measuring devices of all sorts, for making complete tests and for obtaining fundamental engineering data. Operations can be carried out at temperatures up to 850°F.

Distillation.—Facilities for the study of batch and continuous distillation, and of fractionation, are available. The equipment includes a 250-gallon still, provided with a 10-plate, 10-inch-diameter bubbler-cap column. Another 3-plate column, of the same size, equipped so that the distance between plates, height of overflow pipes, and design of caps can be varied at will, utilizes the same still as a source of vapor. A glass section can be inserted in the latter column to permit observation of the action of liquid and vapor on the plate. All of the apparatus is designed with a view to studying the fundamental principles of fractional distillation and fractional condensation. Complete analysis of products at various points, as well as temperatures and rates of flow, can be determined conveniently with apparatus at hand.

Absorption and Extraction.—A semicommercial-size absorption column for the study of liquid-vapor reactions is adaptable for stripping, scrubbing, and similar operations. Equipment is also set up for fundamental studies in solid-liquid and liquid-liquid extraction.

Humidifying, Dehumidifying, Water Cooling, and Air Conditioning.—Several pieces of equipment are used for the study of these types of operations. The equipment is used for instruction, research on fundamental characteristics, and in connection with the supply of air with carefully controlled moisture content for use with other equipment.

Drying.—A tunnel drier and several tray drivers comprise the equipment of this nature. Constant or variable conditions can be maintained and controlled as desired.

Refrigeration and Evaporative Cooling.—Two 5-ton ammonia compressors and one 3-ton methyl-chloride compressor complete with controls, evaporators, and condensers are useful for pressure and low-temperature studies, as well as sources of brine and cold liquids for other operations. A 3-stage, high-pressure steam jet complete with condensers and evaporating chamber is set up for studying this type of industrial operation.

Filtration.—The present equipment consists of a 24-inch washing plate-and-frame filter press, with an assortment of special frames; a small model pressure-leaf filter of ¼-square-foot filtering surface; a complete Vallez pressure-leaf filter of 4-square-feet filtering surface; a 10-inch portable Weston centrifuge; and a 30-inch bottom-discharge Tolhurst centrifuge.

Crystallization.—For this work there is a special 30-foot single-deck Swenson-Walker continuous crystallizer with dewatering attachment, a vacuum crystallizer with a jet injector for high vacua, a semicommercial classifying crystallizer, and a vertical batch crystallizer.

General Equipment.—In addition to special equipment of the types enumerated, the laboratory is well equipped with storage, reaction, and weighing tanks, pumps, blowers, motors, scales, condensers, digesters, autoclaves, and all necessary accessories. Soft water may be obtained from two Zeolite water softeners, and a supply of condensed water nearly as pure as distilled water is also on hand. The aim at all times is to provide facilities for fundamental investigations rather than to equip a museum of chemical machinery.

Metallurgical Engineering Laboratories.—The Metallurgical Engineering Laboratories are located on the fourth floor of the East Engineering Building, adjacent to the Gas and Fuel Laboratories and to the Foundry and Metal Working and Treating Laboratory of the Department of Metal Processing, so that the facilities of these laboratories are conveniently available.

Melting and Heat-Treating Laboratory.—The equipment in this laboratory includes a number of electric and gas-fired furnaces. A 35 kva Ajax high-frequency converter which can be connected to a number of different types of furnaces makes it possible to carry out a large variety of melting operations, including the determination of the gas content of metals. Electric furnaces equipped with automatic temperature control provide excellent facilities for experimental-heat treatments of metals. Gas-fired furnaces are available for melting nonferrous metals and alloys. A semimuffle-type gas furnace for carburizing and a lead pot are also included.

Metallographic Laboratory.—Separate grinding and polishing equipment is provided for undergraduate and graduate instruction. Sixteen metallographic microscopes, three metallographic cameras, and macrographic equipment are available for instruction and research, together with ample darkroom facilities.

Physical Properties Laboratory.—Four rooms are devoted to this phase of metallurgy; one contains equipment for hardness testing and dimensional changes, another is equipped with tensile, impact, and fatigue machines, while the third and fourth rooms are used for the study of the properties of metals at elevated temperatures. Hardness-testing equipment includes two conventional Brinell machines, a Vickers Brinell, Shore scleroscope, and Rockwell and microcharacter instruments. Tensile-testing equipment includes a Southwark-Emery hydraulic testing machine of 600,000-pound capacity and a 50,000-pound Olsen machine. Impact-testing equipment includes an Olsen combination impact machine and a conventional Izod machine. For fatigue testing an Upton-Lewis machine and several machines of the R. R. Moore type are available. In the third and fourth rooms mentioned are thirty-two units for studying the creep characteristics of metals together with various special types of equipment. Each of these machines is equipped with separate temperature control.

Pyrometry Laboratory.—In the Pyrometry Laboratory the equipment includes several types of millivoltmeters, indicating and recording potentiometers, a transformation-point apparatus, optical and radiation pyrometers, various types of thermocouples, and ample facilities for calibrating and checking pyrometric apparatus. The equipment has been selected with the aim of supplying the student with information that will enable him to take charge of the installation and control of commercial pyrometric and temperature-control systems.

X-Ray Laboratory.—The X-Ray Laboratory has modern equipment both for radiography and for crystal-diffraction investigations. The radiographic installation is rated at a maximum of 280,000 volts and can thus produce highly penetrating x-rays. It is used for the inspection of metals, especially welds and castings, and also for certain types of grain-structure investigations.

A smaller x-ray installation is used for research in crystal structure, grain size, and inner strains, with special reference to engineering materials. Several special cameras for precision determination of lattice constants and a photographic densitometer are available.

Gas, Fuel, and Combustion Laboratories.—In this group are included the laboratories for undergraduate and general classwork in the analysis and calorimetry of industrial gases and fuels and the special equipment used for research purposes in these fields and in the combustion of fuels under different conditions.

The Gas and Fuel Laboratories are centered in a large room on the fourth floor of the north wing and contain the equipment required in the analysis of flue and fuel gases; calorimeters for gas, liquid, and solid fuels; and the standard equipment for testing fuels and lubricants.

The Combustion Laboratories have special facilities for research in the field of gaseous explosions, particularly the explosion of hydrocarbon-air mixtures in closed vessels. This equipment is supplemented by the special equipment in the petroleum and automotive laboratories.

The Furnace Laboratory contains furnaces for determining the properties of furnace materials, and the relationship of heat transfer and gas flow as applied to furnaces.

The Gas Engineering Laboratory contains furnaces for the manufacture of gas and for measuring and testing the finished products. This laboratory is largely devoted to the research work of the Michigan Gas Association and is concerned mainly with problems in the manufacture of gas.

Petroleum Laboratories.—In this group are included a number of small laboratories dealing with special research problems in the petroleum and allied fields, and a large room on the fourth floor in the north wing, which is thoroughly equipped with ammonia and brine refrigeration, as well as analytical fractionating equipment for assaying crude oil and other petroleum materials, and for conducting the general lines of research in the natural-gas and petroleum fields.

The Cracking-Research Laboratories include two special research units. One of these is a double-bomb, batch-cracking unit in which the density of the material may be determined while undergoing the cracking operations, and the effect of temperature, time, and pressure on the cracking of oils may be determined. The continuous unit consists of a radiant-heat tube still and the other necessary equipment for operating a pilot-cracking plant under conditions representative of commercial practice.

The Engine Laboratory includes an electric dynamometer and a C.F.R., A.S.T.M. test engine for testing and conducting research work on motor fuels.

Special laboratories and equipment for determining physical, thermal, and equilibrium properties of gases and oils are also available for special research in these fields, particularly as applied to the design of processing equipment and estimation of gas and crude-oil reserves.

The Technology Laboratories.—This group consists of a number of small laboratories, each equipped with facilities especially adaptable for study and research on the problems arising in the respective industries.

The Cement Laboratory is equipped with a small rotary kiln and other apparatus for burning Portland cement under controlled conditions and for testing the properties of cements.

The Ceramics Laboratories consist of a kiln room, preparation room, and laboratory. The kiln room is equipped with oil- and gas-fired recuperative kilns for high-temperature work, and for testing the burning properties of clays and refractory products. The preparation room includes crushing and grinding equipment, a dry pan for fine grinding of shales and hard clays, two mixers, a pugmill and extruding machine, glass-topped tables, and other equipment used in preparing clays for burning. The laboratory is supplied with a Fairbanks testing machine, volumeter, and means for analyzing and testing the raw and burned clay and foundry sands.

The Electrochemical Laboratory provides research facilities for electrochemical work. Direct current is available from a battery of

100 lead storage cells, a 5-kw. motor-generator set, and from the 110-volt line. Laboratory equipment includes a Wendt electrometric apparatus, conductivity bridges, and a complement of electrical instruments. Equipment for the study of electrothermal and high-temperature electrolytic processes are also available as part of the facilities of the metallurgical engineering laboratories.

The Precision Laboratory provides facilities for the accurate measurement of boiling points, solubilities, viscosities, specific heats, heats of reaction, and other important physicochemical properties of substances and solutions.

The Paint and Varnish Laboratory provides facilities for the study of the manufacture and application of paints, varnishes, nitrocellulose lacquers, enamels, and other finishing materials. In addition to regular laboratory facilities the equipment includes grinding apparatus, washed-air drying kiln, oven for baking japans and varnishes at high temperature, as well as spray-gun equipment for the application of various kinds of finishing materials. Quartz mercury- and carbon-arc vapor lamps furnish ultraviolet light, which is used as an accelerated weathering test for paint, varnish, and lacquer films. Additional facilities are also available in the general Chemical Engineering Laboratories.

The Pulp and Paper Laboratory is equipped to make and test sheets of paper. Equipment includes a digester and an autoclave for making pulp; pulp screen, ball mill, beater, sheet-making apparatus of the latest type, and paper-testing equipment. A constant temperature and humidity room houses the apparatus which requires these conditions.

General Laboratories.—Undergraduates whose work does not place them in one of the special laboratories have space assigned to them in one of the two large laboratories, which are equipped with the usual facilities of laboratory tables, water, compressed air, direct, alternating, and storage-battery current, analytical balances, and tables for study and computation of results.

Graduate students working on special problems have assigned to them individual graduate laboratories which are equipped with general laboratory facilities.

Visits of Inspection.—The educational value of visits of inspection is well recognized, and inspection trips are made regularly in connection with the various courses. The great industrial development of the neighboring cities of Detroit and Toledo, as well as that of other points in Michigan 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 acquire the viewpoint of the worker in an industrial organization. If he may also acquire professional knowledge, so much the better. The manufacturers of Michigan coöperate in this movement and, except in time of severe business depression, positions are usually available.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

Admission to Advanced Standing.—The general policy of the College of Engineering is stated in section 14. Prospective students of chemical and metallurgical engineering are urged to select German as their foreign language and to avoid undue specialization in chemistry. Courses in physical chemistry and chemical and metallurgical engineering should be illustrated with many problems applying general principles to the specific field. Courses in these subjects are not usually satisfactory unless they are designed especially for this group. Students in doubt of elections to be made in the first three years' work are cordially invited to correspond with the Department of Chemical and Metallurgical Engineering.

Student Branch, American Institute of Chemical Engineers. A student branch of this organization was established in 1922, and holds monthly meetings for discussion of topics of professional interest. It has a convenient and pleasant clubroom adjoining the seminar room in the East Engineering Building.

Reserve Officers' Training Corps.—The College of Engineering contains units of infantry, signal corps, and ordnance in the 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.

CURRICULUM IN CHEMICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Chemical Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 50.

Programs embodying certain required courses have been established for the four-year course in chemical engineering and the five-year course in chemical and industrial engineering. Both of these programs provide some elective courses. The only limitation placed on these elections is that these courses shall be so chosen as to make a logically arranged curriculum.

a) Preparatory Courses

	Hours
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E, 15E	9
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Economics 53, 173	6
Total	70

b) Secondary and Technical Courses

Chem. 45, Physical Chemistry	3
Chem. 47, Physical Chemistry	3
Chem. 57, Quantitative Analysis	4
Chem. 67E, Organic Chemistry	3
Chem. 69E, Organic Chemistry	5
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Mech. Eng. 2*a*, Elements of Machine Design	3
Mech. Eng. 3*c*, Heat Engines	4
Elec. Eng. 2*a*, Electric Apparatus and Circuits	4
Chem. Eng. 2, Fuels and Furnaces	3
Chem. Eng. 4, Technology of the Inorganic Industries	2
Chem. Eng. 5, Technology of the Organic Industries	3
Chem. Eng. 9*a* and 9*b*, Unit Operations	6
Chem. Eng. 12, Special Problems	5
Chem. Eng. 29, Unit Operations Laboratory	2
Met. Eng. 3, Structure and Properties of Metals	3
Total	60

Summary:

Preparatory Courses	70
Secondary and Technical Courses	60
Electives	10
Total	140

Students in chemical engineering who become candidates for degrees in both chemical engineering and mathematics are permitted to make the following substitutions:

1. They may substitute 3 hours of chemistry (beyond Chem. 5E) for Eng. Mech. 3.

2. They may select any two of the following three substitutions in the regular chemical engineering curriculum:

a) Substitute advanced mathematics for Mech. Eng. 2*a*, three hours.

b) Substitute advanced mathematics for Economics 173, three hours.

c) Substitute advanced mathematics, four hours, and Chem. 63, four hours, for Chem. 67E and 69E, eight hours.

3. In special cases other substitutions, approved by both the Chemical and Metallurgical Engineering and Mathematics Departments, may be made.

PROGRAM FOR FOUR-YEAR COURSE IN CHEMICAL ENGINEERING

FIRST YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Chem. 15E	4	Chem. 45	3
Draw. 3	2	Chem. 57	4
Eng. Mech. 1	3	Chem. Eng. 2	3
Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Mil. Science	0 or 1	Mil. Science	0 or 1
	18 or 19		19 or 20

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

SUMMER SESSION

The Summer Session may be utilized to decrease the work of some semester.

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Chem. 47	3	Chem. 67E	3
Eng. Mech. 2	4	Chem. Eng. 9*a*	3
Met. Eng. 3	3	Econ. 173	3
Mech. Eng. 3*c*	4	Elec. Eng. 2*a*	4
Chem. Eng. 4	2	Mech. Eng. 2*a*	3
English (Group III)	2	Elective	2
	18		18

FOURTH YEAR

Chem. 69E	5	Chem. Eng. 12	5
Chem. Eng. 5	3	Electives	12
Chem. Eng. 9*b*	3		
Chem. Eng. 29	2		
Econ. 53	3		
Elective	2		
	18		17

CURRICULUM IN METALLURGICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Metallurgical Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 50.

Programs embodying certain required courses have been established for the four-year course in metallurgical engineering and the five-year course in metallurgical and industrial engineering. Both of these programs provide some elective courses. The only limitation placed on these elections is that these courses shall be so chosen as to make a logically arranged curriculum.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E, 15E	9
Drawing 1, 2, 3	8
Metal Proc. 2, 9, and Chem. Eng. 1	7
Economics 53 and 54 or 173	6
	72

b) Secondary and Technical Courses

Chem. 45, Physical Chemistry	3
Chem. 47, Physical Chemistry	3
Chem. 57, Qualitative Analysis	4
Chem. 63, Organic Chemistry	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Mech. Eng. 2*a*, Elements of Machine Design	3
Mech. Eng. 3*c*, Heat Engines	4
Elec. Eng. 2*a*, Electric Apparatus and Circuits	4
Chem. Eng. 2, Fuels and Furnaces	3
Chem. Eng. 9*a* and 9*b*, Unit Operations	6
Met. Eng. 3*a*, Structures and Properties of Metals	4
Met. Eng. 6, Metallurgical Principles	3
Met. Eng. 8, Physical Metallurgy	2
Met. Eng. 12, Special Problems	5
Mineralogy 109	1
	56

Preparatory Courses	72
Secondary and Technical Courses	56
Electives, Restricted and Free	12
Total	140

Elective Courses

The twelve hours of electives are to be filled partly by restricted electives and partly by free electives.

Restricted Electives. The student must elect either Met. Eng. 141 or 142 and one course from Chem. Eng. 4, Chem. Eng. 29, Eng. Mech. 9, and Met. Eng. 44 or 144.

Free Electives. The remaining hours may be filled by courses offered in any department in the Engineering College or in any other College of the University subject to approval by the Head of the Department of Chemical and Metallurgical Engineering.

Students in metallurgical engineering who become candidates for degrees in both metallurgical engineering and mathematics are permitted to make the following substitutions:

1. They may substitute three hours of chemistry (beyond Chem. 5E) for Eng. Mech. 3.
2. They may substitute advanced mathematics for Mech. Eng. 2*a* and Economics 54 or 173.
3. In special cases other substitutions, on approval of both the Departments of Chemical and Metallurgical Engineering and of Mathematics, may be made.

PROGRAM FOR FOUR-YEAR COURSE IN METALLURGICAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3	4	Math. 4	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

Second Year

Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Chem. 15E	4	Chem. 45	3
Eng. Mech. 1	3	Chem. 57	4
Drawing 3	2	Electives	2
Mil. Science	0 or 1	Mil. Science	0 or 1
	18 or 19		18 or 19

Third Year

Eng. Mech. 2	4	Chem. Eng. 9*a*	3
Chem. 47	3	Mech. Eng. 2*a*	3
Chem. Eng. 2	3	Chem. 63	4
Met. Eng. 6	3	Met. Eng. 3*a*	4
Mineralogy 109	1	Met. Proc. 9	2
Mech. Eng. 3*c*	4	English (Group III)	2
	18		18

Summer Session

The Summer Session may be used to decrease the work of some semester.

* If modern language is elected, it may be classified here and the English postponed. See section 51.
† See note, section 56.
‡ Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each semester) is elected. Enrollment in military science is for a period of four semesters.

FOURTH YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Met. Eng. 8	2	Met. Eng. 12	5
Chem. Eng. 9*b*	3	Elec. Eng. 2*a*	4
Restricted or Free Electives	10	Restricted or Free Electives	6
Econ. 53	3	Econ. 54 or 173	3
	18		18

THE FIVE-YEAR CURRICULA IN CHEMICAL AND INDUSTRIAL ENGINEERING AND IN METALLURGICAL AND INDUSTRIAL ENGINEERING

Five-year curricula, including courses in chemical engineering and business administration, and in metallurgical engineering and business administration, have been authorized, leading to the degree of Bachelor of Science in Engineering (Chemical Engineering or Metallurgical Engineering) at the end of the fourth year, and to the degree of Master of Science (Industrial Engineering) at the end of the fifth year. The undergraduate programs contain the full program in chemical engineering or in metallurgical engineering with the substitution of Economics 53, 54, 171, and 172 for the economics specified in the usual four-year course. Business Administration 113 is to be added. This program does not permit any technical electives and requires 141 hours of credit for its completion.

Students in the fifth year will enroll in the Graduate School and at the completion of one year's work on an approved program will receive the M.S. degree in Industrial Engineering.

COURSES IN CHEMICAL AND METALLURGICAL ENGINEERING

The courses given in the Department of Chemical and Metallurgical Engineering are listed below under the headings "Chemical Engineering" and "Metallurgical Engineering." A large number of the courses though listed only under one heading are common to the requirements of graduate and undergraduate programs of both Chemical Engineering and Metallurgical Engineering.

CHEMICAL ENGINEERING

1. **Engineering Materials.** An elementary study of the manufacture and properties of the ferrous and nonferrous alloys, cements, clay products, protective coatings, fuels, and water softening. Two lectures and two recitations. *Prerequisites: Chem. 5 or an acceptable high-school course. Must be accompanied by Metal Proc. 2.* Three hours credit. Each semester.

2. **Fuels and Furnaces.** A study of the preparation, combustion, and utilization of fuels, including temperature measurement, analysis of gases and fuels, determination of heating values and furnace efficiencies, the computation of heat balances, maximum temper-

atures, and relative costs of heating. Three lectures or recitations and one four-hour laboratory period. *Prerequisites: Chem. Eng. 1. Must be preceded or accompanied by Phys. 45.* Three hours credit. Each semester.

4. **Chemical Technology of the Inorganic Industries.** A descriptive study of the processes and manufacturing methods used in the more important industries based on inorganic chemical technology. Two recitations. *Prerequisites: Chem. Eng. 2, Phys. 46, and Chem. 45.* Two hours credit. Each semester.

5. **Chemical Technology of the Organic Industries.** A descriptive study of the processes and manufacturing methods used in the more important industries based on organic chemical technology. Three lectures and two recitations. *Prerequisites: Chem. Eng. 4 and Chem. 67E; preceded or accompanied by Chem. 69E.* Three hours credit. Each semester.

9a. **Unit Operations.** An elementary discussion of the theory of the unit operations of chemical engineering and of typical equipment for carrying out these processes. Two lectures and two recitations. *Prerequisites: Chem. Eng. 4 and Mech. Eng. 3c (for metallurgical engineers Chem. Eng. 2, Phys. 46, and Chem. 45).* Three hours credit. Each semester.

9b. **Unit Operations.** A continuation of Course 9*a*. Two lectures and two recitations. *Prerequisite: Chem. Eng. 9a.* Three hours credit. Each semester.

10. **The Utilization of Fuels.** A course designed especially for mechanical engineering students, covering in a limited way the material offered in Chem. Eng. 2. Laboratory work. *Prerequisites: Chem. Eng. 1. Must be preceded or accompanied by Phys. 45, and accompanied by Mech. Eng. 7.* One hour credit. Each semester.

12. **Special Problems.** The purpose of this course is to train the student in methods of independent research. Each student is, after consultation, assigned a subject connected with some manufacturing process which he is to study intensively in both the library and laboratory. Wide latitude is allowed in the choice of a subject, and the student is, so far as possible, urged to select the one that interests him most. Laboratory work and reports. *Prerequisites: Chem. Eng. 4 and such other courses as are essential to a knowledge of the subject selected.* Five hours credit. Each semester.

13. **Design of Chemical Engineering Equipment.** A discussion of the construction and fabrication of chemical engineering equipment with especial reference to mechanical details of design. Lectures and recitations. *Prerequisites: Eng. Mech. 2 and Chem. Eng. 9a.* Two hours credit. Second semester.

20. **Summer Work in Factories.** Credit is given for a report on some phase of work in a factory. Application must be made for registration in this course and the nature of the problem must be approved before entering upon the work. One hour credit.

21. **Design Problem.** The American Institute of Chemical Engineers holds an annual competition for the solution of a problem open to all members of student chapters of the Institute. A credit of one hour will be granted to any student who submits a solution of this problem which is satisfactory to the local committee.

24. **Testing Petroleum Products.** Laboratory work. *Prerequisite: Chem. Eng. 2.* One hour credit. Second semester.

29. **Chemical Engineering Laboratory.** A laboratory study of the unit operations of chemical engineering, comprising a series of performance tests on various types of chemical engineering equipment. One recitation and one four-hour laboratory period. *Must be preceded or accompanied by Chem. Eng. 9b.* Two hours credit. Each semester.

102. **Heat and Material Balances.** Problems illustrating the application of the method of heat and material balances to chemical and manufacturing processes. Two recitations. *Prerequisite: Chem. Eng. 4.* Two hours credit. First semester.

105. **Chemical Engineering Thermodynamics.** A study of the principles of the three fundamental laws of energy as applied to chemical and metallurgical engineering problems. Two lectures and two recitations. *Open to graduates, and to seniors who receive special permission. Prerequisites: Chem. Eng. 2, Chem. 45, and Math. 38.* Three hours credit. First semester.

109. **Research Seminar.** Discussion of research of staff and graduate students. *Required of all applicants and candidates for the doctorate, and open to all graduate students.* No credit. Each semester.

110. **Special Problems.** A continuation of Course 12. Laboratory work. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

113. **Fluid Flow, Heat Flow, and Evaporation.** An advanced study of the fundamental theory of these processes and of the equipment for their operation. Lectures and recitations. *Prerequisites: Chem. Eng. 4 and 9a.* Two hours credit. Second semester.

115. **Drying, Distillation, Extraction, and Gas Absorption.** An advanced study of the fundamental theory of these processes and of the equipment for their operation. Lectures and recitations. *Prerequisites: Chem. Eng. 4 and 9b.* Two hours credit. Second semester.

116. **Evaporation.** Research work on the design of evaporators and on problems connected with handling of liquids on the commercial scale. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

117. **Distillation.** Research work on the theory, design, and performance of distillation equipment. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

118. **Crystallization.** Research work on the theory and practice of industrial crystallization. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

121. **Design of Chemical Machinery.** 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: Chem. Eng. 9b and a course in machine design.* Two hours credit. Each semester.

153. **Motor Fuels and Lubricants.** A study from the user's standpoint. *Open only to graduates, and to seniors who receive special permission.* One hour credit. Second semester.

155. **Petroleum Refining.** A study of processes and design of engineering equipment used in the manufacture of petroleum products and natural gasoline. Lectures and recitations. *Prerequisites: Chem. Eng. 5 and 9b.* Three hours credit. Second semester.

156. **Gas.** Research relating to the manufacture, properties, and uses of coal gas, water gas, oil gas, and producer gas. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

157. **Petroleum and Motor Fuels.** Research work on problems connected with the production and utilization of petroleum products. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

158. **Refractories.** Research work on the thermal and physical properties of refractory materials, combustion, and heat transfer at high temperatures. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

166. **Hydraulic Cements.** Research work on the properties of hydraulic cements as influenced by chemical composition and tem-

perature of burning; also studies of constancy of volume and permanence of concrete structures. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

167. **Advanced Electrochemistry.** Research relating to electrodeposition and electrochemical processes. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

171. **Explosives.** A study of the processes used in the manufacture of commercial and military explosives and pyrotechnic materials; their properties and uses. Lectures and recitations. *Prerequisite: Chem. Eng. 5.* Four hours credit. Second semester.

172. **Pulp and Paper.** A study of the processes used in the manufacture of pulp and paper; their properties and uses. Lectures and recitations. *Prerequisite: Chem. Eng. 9a.* Two hours credit. Second semester.

176. **Paint, Varnish, and Pyroxylin Lacquers.** Research relating to the manufacture, properties, and uses of paints, varnish, pyroxylin lacquers, and plastics. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

177. **Paper Manufacture.** Research work connected with the properties of paper pulp and paper-making materials. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

202. **Advanced Chemical Engineering Calculations.** A problem course illustrating the application of chemical engineering theory to industrial calculations. Problems involving economic balance in engineering design are emphasized. Conferences and group calculations. *Prerequisites: Chem. Eng. 105, 113, and 115.* Three hours credit. Second semester.

205. **Applied Thermodynamics.** An advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics and physical chemistry. A continuation of Course 105. Lectures and recitations. Two hours credit. Second semester.

212. **Seminar in Heat Transfer.** Conferences and problems in heat transfer. *Open to graduates, and to seniors who receive special permission.* Two hours credit. Second semester.

215. **Drying, Distillation, Extraction, and Gas Absorption.** An apparatus or plant is designed for each of these operations on the

basis of economic balances. *Prerequisites: Chem. Eng. 113, preceded or accompanied by Chem. Eng. 115, Met. Eng. 114, and a course in machine design.* Three hours credit. First semester.

254. **Petroleum Production Engineering.** The application of chemical engineering to gases and liquids under high pressure as encountered in the production of natural gases and crude oil; and in the estimation of reserves. *Prerequisites: Chem. Eng. 105 or 155.* Three hours credit. Second semester.

255. **Petroleum Refining Engineering.** The application of chemical engineering to the design of petroleum refineries. *Prerequisite: Chem. Eng. 155.* Two hours credit. First semester.

METALLURGICAL ENGINEERING

3. **Structure and Properties of Metals.** A microscopic study of the structure of metals as affected by composition and by thermal and mechanical treatment; the relation of these to the physical properties of metals; consideration of the factors that determine or limit the uses of metals and common alloys. Two lectures, one recitation, and one three-hour laboratory period. *Prerequisites: Chem. Eng. 1. Must be preceded or accompanied by Phys. 46.* Three hours credit. Each semester.

3a. **Structures and Properties of Metals.** Structures and properties of metals as affected by composition, mechanical and thermal treatment, and relation of properties to utilization of common metals and alloys. Lectures and recitations same as Met. Eng. 3, and two laboratory periods. For students in the Metallurgical Engineering program. *Prerequisites: Chem. Eng. 1. Must be preceded or accompanied by Phys. 46.* Four hours credit. Second semester.

6. **Metallurgical Principles.** An introduction to the principles and processes involved in the extraction of metals from their ores and the synthesis of alloys. This includes study of fuels and refractories as used in these processes and a consideration of slag constitution and measurement of high temperatures. Recitations and laboratory. *Prerequisites: Chem. Eng. 1 and Phys. 46.* Three hours credit. First semester.

8. **Physical Metallurgy.** Thermal and mechanical properties of metals as related to macro- and microstructure. Lecture, or quiz, and laboratory. *Prerequisite: Met. Eng. 3a or 3.* Two hours credit. First semester.

12. **Special Problems.** The purpose of this course is to train the student in methods of independent research. Each student is, after consultation, assigned a subject connected with some manufacturing process which he is to study intensively in both the library and laboratory. Wide latitude is allowed in the choice of a subject,

and the student is, so far as possible, urged to select one that interests him most. Laboratory work and reports. *Prerequisites: Met. Eng. 3a or 3 and such courses as are essential to knowledge of the subject selected.* Five hours credit. Each semester.

20. **Summer Work in Factories.** Credit is given for a report on some phase of work in a factory. Application must be made for registration in this course and the nature of the problem must be approved before entering upon the work. One hour credit.

44. **X-Ray Studies of Engineering Materials.** An introductory study of the principal methods of x-ray investigations of engineering materials. Lectures and recitations. *Prerequisites: Met. Eng. 3 and Phys. 46.* Two or three hours credit. First semester.

109. **Research Seminar.** Discussion of research of staff and graduate students. *Required of all applicants and candidates for the doctorate, and open to all graduate students.* No credit. Each semester.

110. **Special Problems.** A continuation of Course 12. Laboratory work. *Open to graduates and to seniors who receive special permission.* Three to five hours credit. Each semester.

114. **Crushing, Classification, Filtration, Calcination, and Conveying.** An advanced study of the fundamental theory of these processes and of the equipment for their operation. Lectures and recitations. *Prerequisites: Met. Eng. 3 or 3a and 9b.* Two hours credit. First semester.

141. **Metallurgy of Iron and Steel.** A critical study of the metallurgy of the ferrous metals; raw materials, the production of pig iron; the manufacture of steel, wrought iron, cast iron, and malleable iron. Two lectures and one recitation. *Prerequisites: Chem. Eng. 2, Met. Eng. 3 or 3a, and Met. Eng. 6.* Two hours credit. First semester.

142. **Nonferrous Metallurgy.** A course in the metallurgy of copper, zinc, lead, tin, nickel, and aluminum, covering extractive processes, fabrication, production, and properties of alloys. Two lectures and one recitation. *Prerequisites: Chem. Eng. 2, Met. Eng. 3 or 3a, and Met. Eng. 6.* Two hours credit. Second semester.

143. **Metallography of the Nonferrous Metals.** An advanced study of the microscopic structure of the common nonferrous metals and alloys, and of the effect of heat treatment, mechanical work, and composition on their structure and properties. One lecture and one laboratory period. *Prerequisites: Met. Eng. 3 or 3a and a course in physical chemistry.* Two hours credit. Second semester.

144. **X-Ray Studies of Engineering Materials.** Lectures and assigned work. *Prerequisites: advanced mathematics and physics as well as the necessary courses in metallurgical or chemical engineering.* Three hours credit. Second semester.

145. **Advanced Ferrous Metallurgy.** A study of the constitution of irons and steels and the effect on their properties of composition, heat treatment, and mechanical work. Lectures and recitations. *Prerequisites: Chem. Eng. 3 or 3a.* Two hours credit. Second semester.

146. **Advanced Ferrous Metallurgy.** Research work on the structures and properties of iron and steel. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

147. **Advanced Nonferrous Metallurgy.** Research work on structures and properties of nonferrous metals and alloys. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to five hours credit. Each semester.

148. **X-Ray Studies.** Research work in the application of x-rays to the structure and properties of materials. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Two to five hours credit. Each semester.

149. **Physical Metallurgy of Cast Ferrous Metals.** A study of the theory and mechanism underlying the solidification, structures, and properties of cast ferrous metals. Lectures and recitation. *Prerequisites: Met. Eng. 3 and a course in physical chemistry.* Two hours credit. Second semester.

151. **Furnace Design and Construction.** A study and application of the principles of furnace design; and the properties of refractory materials, and their use in furnace construction. One lecture, one recitation, and one laboratory period. *Prerequisites: Chem. Eng. 2 and 9a or Mech. Eng. 5.* Two hours credit. Second semester.

152. **Pyrometry and Furnace Control.** A study of the theory, construction, calibration, and use of commercial pyrometers; the methods of thermal analysis, and the various means of temperature control in furnaces. One recitation and one laboratory period. *Prerequisites: Chem. Eng. 2 and Phys. 46.* Two hours credit. Second semester.

154. **Metals for High-Temperature Application.** A study of the properties of metals at elevated temperatures and the theories involved in their preparation and application. Modern high-temperature steels will be considered. Two lectures and one quiz. *Open to*

graduates, and to seniors who receive special permission. Two hours credit. First semester.

241. **Physical Metallurgy.** An advanced study of the theory and principles fundamental to the mechanical and thermal treatment of metals and alloys. *Open only to graduates.* Two hours credit. First semester.

243. **Metals at Elevated Temperatures.** Reading and reports on principles and theories as related to utilization. *Open only to graduates.* Two hours credit. Second semester.

244. **Constitution of Metals and Alloys.** An advanced study of metallic structure based on properties of single crystals and aggregates. *Prerequisite: Met. Eng. 144.* Two hours credit. Second semester.

245. **Applied Thermodynamics.** Applied to metallurgical problems. Lectures and recitations. Two hours credit. First semester.

248. **Advanced X-Ray Studies.** Research work in the application of x-rays to the structure and properties of materials. Laboratory work and conferences. *Prerequisite: Met. Eng. 144.* Three to five hours credit. Each semester.

249. **High-Temperature Reactions.** Laboratory work and conferences. Laboratory technique at high temperatures including vacuum melting of metals, determination of gases in steels, special refractories, and equilibrium in chemical reactions. *Prerequisite: Chem. Eng. 105.* Three to five hours credit. Each semester.

Summer Session

Courses 3, 9*a*, 9*b*, 12, 29, 110, 116, 117, 146, 156, and 176 will probably be given during the Summer Session.

75. CIVIL ENGINEERING

Professors RIGGS,* GRAM, KING, HOAD, DECKER, WORLEY, CISSEL, MORRISON, WISLER, and SHERLOCK; Associate Professors EMMONS, W. C. SADLER, and HOUSEL; Assistant Professors ALT and MAUGH; Instructors BRATER and BOYD.

The department of Civil Engineering is organized into several divisions which correspond to the specialties of practicing civil engineers. These divisions have come about gradually through the requirements of actual practice, and it is inevitable, therefore, that there should be a great deal of overlapping in the various fields. In general, however, the competent civil engineer must have a broad understanding of the scientific principles common to general practice as well as a high degree of skill in applying these principles to problems in his own field of specialization.

* Honorary Professor of Civil Engineering.

While the training of the civil engineer is essentially technical, he does not always achieve his greatest usefulness as a technician. In fact, it is generally recognized that the habits of thought developed by the practicing civil engineer fit him admirably for administrative and executive positions. This is especially true in the constantly expanding transportation industry, in municipal and public affairs, and in many industrial and commercial fields where a background of technical training and experience in planning and executing important work is a valuable aid to the administrator.

The main divisions of civil engineering are as follows:

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

Hydraulic Engineering, which 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, which 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. The curriculum is designed to train students in the broader aspects of the profession as a foundation for executive positions. The Transportation Library contains over 100,000 items and offers unusual opportunity for research and advanced study.

Sanitary Engineering, which 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, which 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.

Public Health Engineering, which has to do more particularly with governmental supervision and control of all those activities of an engineering nature which are definitely related to public health.

The Department of Civil Engineering has endeavored through conferences with successful alumni and with prominent men in industry and public affairs, to arrange the details of the course of training so that graduates will be prepared not only for civil engineering practice but also for an active interest in social and public service.

The student is required to elect such courses in mathematics and in the general sciences as are necessary to a proper understanding of the technical and nontechnical courses which follow. He is also required to elect courses in mechanical, electrical, and chemical engineering, since narrow specialization by undergraduates is discouraged. It is felt that with this background, the graduate can augment his technical knowledge as circumstances require, either by graduate work in the University or by independent study while in practice.

As a part of his nontechnical work, the student is required to take a minimum number of hours in English and economics, supplemented by other elections. He is not only permitted but is distinctly encouraged to choose his nontechnical electives consistent with the general technical group which he adopts. The Department desires to give every possible opportunity for the development of individual capacities.

The Department does not guarantee employment to graduates, but the demand from employers usually exceeds the supply, so that graduates have little trouble in finding lucrative positions in which to obtain their early years of experience.

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. It also contains very complete files of Interstate Commerce Commission statistics, proceedings of the various engineering associations, the modern and current periodicals dealing with railways, highways, waterways, and other engineering subjects; state and national, railway, public utility, highway, and special commission reports; annual reports of railways and other transportation companies, pro-

ceedings of various transportation associations, and the latest books on the technical and economic phases of transportation.

Highway Laboratories.—Through a coöperative 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.

The Highway Laboratory is located in the basement of the north wing of the East Engineering Building. It has about 15,000 square feet of floor space divided between five main laboratories for the testing of cement, concrete, sand, gravel, rock, paving brick, and similar materials; asphalts, tars, oils, and bituminous mixtures; calcium chloride, metals and paints, culvert pipe; and soils. The laboratories also contain a large freezing chamber where temperatures as low as —40°F may be obtained, rooms for concrete curing equipment, sample storage, lockers, and showers.

The laboratories are constantly being improved as progress is made in the study of materials. The unit devoted to soils has received particular attention during the past few years and is well equipped for routine testing and research.

Hydraulic Experimental Equipment.—A flume in the West Engineering Building provides for inside laboratory experiments on the measurement of flowing water in quantities up to 12 cubic feet per second. The flume is 50 feet long, 2 feet wide, and 4 feet deep. Water is supplied by a 16-inch centrifugal pump driven by a 100-horsepower motor. Accurate measurement of discharge is provided by scales and weighing tanks with a total capacity of 100,000 pounds. A 90° V-notch weir calibrated by means of the weighing tanks is also available for measurement of flow. Space is available in the laboratory for investigation of special hydraulic problems.

Surveying Camp.—Course 3 in surveying, offered each summer at Camp Davis, is open to students who have completed Courses 1 and 2 in that subject. Camp Davis is located in the Jackson's Hole country, Wyoming, about 75 miles south of Yellowstone National Park. It is recommended that, wherever practicable, students in civil engineering avail themselves of the many unique advantages of the life and training at this camp.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 Science.—The attention of prospective students in civil engineering is called to the Reserve Officers' Training Corps. Those who consider taking military science are urged to enroll at the beginning of their course. For further details see section 66.

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 50.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English 6	2
Nontechnical Electives, see section 51	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2	6
Geology 11	4
Chem. Eng. 1 and Metal Proc. 2	5
Economics 53, 54	6
Total	68

b) *Secondary and Technical Courses*	
Surveying 1, 2	7
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Elec. Eng. 2*a*, Electrical Apparatus and Circuits	4
Mech. Eng. 3, Heat Engines	4
Civil Eng. 1, Structural Drafting	2
Civil Eng. 2*c*, Theory of Structures	3
Civil Eng. 3, Reinforced Concrete	3
Civil Eng. 5*a*, Elementary Design of Structures	3
Civil Eng. 10, Hydrology	3
Civil Eng. 12, Water Power Engineering	2
Civil Eng. 26, Specifications and Contracts	2
Civil Eng. 30, Water Works	3
Civil Eng. 32, Sewerage and Drainage	2
Civil Eng. 40, Highway Engineering	2
Civil Eng. 42*c*, Concrete Mixtures	1
Civil Eng. 50, Railroad Engineering	2
Total	57

c) *Electives* *Hours*

Major and Free 15

Summary:

Preparatory Courses 68
Secondary and Technical Courses 57
Electives 15

Total 140

ELECTIVES

a) *Major Electives* ..... 7 or 8

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 Head of the Civil Engineering Department.

Structural Engineering
Civil Eng. 5*b*, Design of Structures 3
Civil Eng. 4, Advanced Theory of Structures 2
Choice of either—
Civil Eng. 6, Applied Soil Mechanics 3
Civil Eng. 7*h*, Rigid Frame Structures 3

Hydraulic Engineering
Civil Eng. 16, Hydraulic Engineering Design 3
Civil Eng. 11, Hydraulics 2
Civil Eng. 14, Hydraulic Structures 3

Municipal and Sanitary Engineering
Civil Eng. 35, Sanitary Engineering Design 3
Civil Eng. 31, Water Purification 2
Choice of either—
Civil Eng. 33, Sewage Disposal 3
Civil Eng. 34, Municipal and Industrial Sanitation.. 3

Transportation Engineering (Highway)
Civil Eng. 54, Railway and Highway Location Design 3
Civil Eng. 41, Advanced Highway Engineering 2
Civil Eng. 45, Highway Traffic Control 2

Transportation Engineering (Railroad)
Civil Eng. 54, Railway and Highway Location Design 3
Civil Eng. 51, Economics of Railroad Construction and Operation 2
Civil Eng. 52, Railroad Maintenance 2

Hours

b) *Free Electives* ..... 8 or 7

The remaining elective hours may be filled by courses offered by any department in the University, subject to the approval of the Head of the Civil Engineering Department.

NOTE.—Students completing Surveying 3 (Summer Camp) or Military 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

FIRST YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Math. 36	4	Math. 37	4
Physics 45	5	Eng. Mech. 2	4
Surveying 1	3	Eng. Mech. 2*a*	1
Eng. Mech. 1	3	Surveying 2	4
Civil Eng. 1	2	Civil Eng. 40	2
		Elective	2
	17		17

SUMMER SESSION

Electives 8

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Electives	2	Civil Eng. 2*a*	3
Physics 46	5	Civil Eng. 3	3
Civil Eng. 2*c*	3	Economics 54	3
Economics 53	3	Eng. Mech. 3	3
Civil Eng. 42*c*	1	Civil Eng. 30	3
Eng. Mech. 4	3	Civil Eng. 50	2
	17		17

FOURTH YEAR

Geology 11	4	English 6	2
Civil Eng. 12	2	Mech. Eng. 3	4
Civil Eng. 10	3	Elec. Eng. 2*a*	4
Civil Eng. 32	2	Civil Eng. 26	2
Electives	5	Electives	4
	16		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 50.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English 6	2
Nontechnical Electives, see section 51	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2	6
Chem. Eng. 1 and Metal Proc. 2	5
Economics 53, 54, 173	9
Total	67

b) *Secondary and Technical Courses*	
Surveying 1	3
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory on Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Civil Eng. 1, Structural Drafting	2

	Hours
Civil Eng. 2*c*, Theory of Structures	3
Civil Eng. 3, Reinforced Concrete	3
Civil Eng. 5*a*, Elementary Design of Structures	3
Civil Eng. 26, Specifications and Contracts	2
Civil Eng. 27, Public Utility Problems	2
Civil Eng. 40, Highway Engineering	2
Civil Eng. 42*c*, Concrete Mixtures	1
Civil Eng. 50, Railroad Engineering	2
Civil Eng. 53, Terminal Design	3
Civil Eng. 57, Railroad Administration	3
Civil Eng. 58, Transportation	2
Mech. Eng. 3, Heat Engines	4
Elec. Eng. 2*a*, Electrical Apparatus and Circuits	4
Total	50

c) Group Options—one of the four groups listed below

Railroad	*Hours*	*Highway*	*Hours*
Civil Eng. 51	2	Civil Eng. 6	3
Civil Eng. 52	2	Civil Eng. 41	2
Civil Eng. 52*a*	2	Civil Eng. 42*a*	2
Civil Eng. 54	3	Civil Eng. 44	2
Elec. Eng. 8	2	Civil Eng. 45	2
Electives	12	Mech. Eng. 29	3
		Electives	9
	23		23

Aeronautical	*Hours*	*Marine*	*Hours*
Aero. Eng. 1	3	Naval Arch. 2	3
Aero. Eng. 3	2	Naval Arch. 4	3
Aero. Eng. 4	3	Naval Arch. 5	4
Math. 103	3	Mar. Eng. 9	3
Electives	12	Electives	10
	23		23

Summary:

Preparatory Courses	67
Secondary and Technical Courses	50
Group Options	23
Total	140

PROGRAM

FIRST YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
†English 1	3	†English 3	2
†English 2	1	†English (Group II)	2
Drawing 1	3	Drawing 2	3
‡Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	‡Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
§Physical Ed. or Mil. Science	0 or 1	§Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Surveying 1	3	Eng. Mech. 1	3
Economics 53	3	Economics 54	3
Civil Eng. 1	2	Civil Eng. 40 (Aero. & Marine)	2
		or	
		Electives (Rwy. & Hwy.)	2
	17		17

SUMMER SESSION (SECOND OR THIRD YEAR)

Eng. Mech. 2	4
Eng. Mech. 2*a*	1
Nontechnical electives	3
	8

† If modern language is elected, it may be classified here and the English postponed. See section 51.
‡ See note, section 56.
§ Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each each semester) is elected. Enrollment in military science is for a period of four semesters.

THIRD YEAR

First Semester

Railroad	*Hours*	*Highway*	*Hours*	*Aero.*	*Hours*	*Marine*	*Hours*
M.E. 3	4	M.E. 3	4	M.E. 3	4	M.E. 3	4
Ec. 173	3	Ec. 173	3	Ec. 173	3	Ec. 173	3
C.E. 50	2	C.E. 50	2	C.E. 50	2	C.E. 50	2
C.E. 2*c*	3	C.E. 2*c*	3	C.E. 2*c*	3	C.E. 2*c*	3
C.E. 42*c*	1	C.E. 42*c*	1	C.E. 42*c*	1	C.E. 42*c*	1
Nontech. Electives	3	Nontech. Electives	3	Aero. 1	3	N. A. 2	3
	16		16		16		16

Second Semester

C.E. 5*a*	3	C.E. 5*a*	3	C.E. 5*a*	3	C.E. 5*a*	3
C.E. 40	2	C.E. 40	2	Math. 103	3	E.M. 3	3
E.M. 3	3	E.M. 3	3	E.M. 3	3	C.E. 26	2
C.E. 26	2	C.E. 26	2	C.E. 26	2	C.E. 58	2
C.E. 58	2	C.E. 58	2	C.E. 58	2	N.A. 4	3
C.E. 51	2	C.E. 41	2	Aero. 3	2	Electives	4
C.E. 52	2	C.E. 42*a*	2	Electives	2		
	16		16		17		17

FOURTH YEAR

First Semester

C.E. 3	3	C.E. 3	3	C.E. 3	3	C.E. 3	3
C.E. 53	3	C.E. 53	3	C.E. 53	3	C.E. 53	3
C.E. 27	2	C.E. 27	2	C.E. 27	2	C.E. 27	2
C.E. 52*a*	2	C.E. 6	3	Aero. 4	3	N.A. 5	4
E.E. 8	2	C.E. 44	2	Engl. 6	2	Engl. 6	2
Electives	5	Electives	4	Electives	4	Electives	3
	17		17		17		17

Second Semester

E.E. 2*a*	4	E.E. 2*a*	4	E.E. 2*a*	4	E.E. 2*a*	4
Engl. 6	2	Engl. 6	2	C.E. 57	3	Mar.E. 9	3
C.E. 57	3	C.E. 57	3	Nontech. Electives	3	C.E. 57	3
C.E. 54	3	C.E. 45	2	Electives	6	Nontech. Electives	3
Electives	5	M.E. 29	3			Electives	3
		Electives	3				
	17		17		16		16

COURSES IN CIVIL ENGINEERING

The courses described below are identified by letters and course numbers. Thus, Civil Engineering, Course 2, is identified as Civil Eng. 2. Also Civil Eng. 65, etc.

Structural Group, Civil Eng. 1 to Civil Eng. 9.
Hydraulic Group, Civil Eng. 10 to Civil Eng. 19.
Sanitary and Municipal Group, Civil Eng. 30 to Civil Eng. 39.
Transportation Group, Civil Eng. 40 to Civil Eng. 58.
Graduate Group, Civil Eng. 60 to Civil Eng. 67.

1. **Structural Drafting.** Presenting and recording civil engineering data by graphical methods. Lectures, text, and laboratory. *Prerequisite: Drawing 2.* Two hours credit. Each semester.

2. **Theory of Structures.** Analysis of stresses in simple structures. Calculation of reactions, shear and bending moment due to fixed and moving loads. Design of simple wood, steel, and reinforced concrete beams and girders. Analysis of stresses in simple bridge and roof trusses. Lectures, text, and home problems. *Not open to Civil Engineering students. Prerequisite: Eng. Mech. 2.* Three hours credit. Each semester.

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. Each semester.

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

4. **Advanced Theory of Structures.** Analysis of stresses and deflection in special types of structures, cantilever trusses, draw spans, and arches. This is a continuation of Civil Eng. 2. Lectures, texts, problems. *Prerequisite: Civil Eng. 2c.* Two hours credit. Second semester.

5a. **Elementary Design of Structures.** Design work, covering theory of beams and plate girders, mill buildings, and elements of design of simple structures. Computations, drawing work. *Must be preceded or accompanied by Civil Eng. 2c.* Three hours credit. Each semester.

5b. **Design of Structures.** Design work covering general design of reinforced concrete and steel structures; foundations. Computations, drawing work. *Prerequisites: Civil Eng. 3 and 5a.* Three hours credit. Each semester.

6. **Applied Soil Mechanics.** A study of engineering problems which involve the use of soil as a material; theory of soil resistance; pressure distribution; determination of physical properties of soil, including bearing capacity; theory of plastic flow applied to foundations; design of substructures, pile foundations, and underground structures; earth-pressure theories and application to deep excavation; recent development in soil research. Lectures and references. *Prerequisite: Civil Eng. 3.* Three hours credit. Each semester.

7a. **Bridge Engineering.** Studies in the selection of the proper bridge structure for a given location; economics of bridge types; selection and construction of piers; determination of waterways; erection methods. *Must be preceded or accompanied by Civil Eng. 5b.* Two hours credit. First semester.

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. 5b.* Three hours credit. Second semester.

7c. **Bridge Design.** Advanced problems in the design of reinforced concrete and steel highway and railway bridges; lectures, computations, and drafting. *Prerequisite: Civil Eng. 7a.* Three hours credit. Second semester.

7e. **Wind Pressures.** Meteorology of air movements and origin of gusts; aerodynamics of engineering structures; laws of similarity of models; intensity and distribution of wind pressures on different types of structures. References, problems, seminar. *Prerequisite: Civil Eng. 2c.* Two hours credit. Second semester.

7h. **Rigid-Frame Structures.** Analysis of rigid frames by methods of successive approximations and slope deflections; application of methods to various types of buildings, bridges, and viaducts; consideration of special problems involved in the design of continuous frames. Lectures, references, problems. *Must be preceded or accompanied by Civil Eng. 5b.* Three hours credit. First semester.

7i. **Mechanical Methods of Stress Analysis.** The mechanical analysis of stresses in statically-indeterminate structures by means of models. The use of the Begg's apparatus in analyzing complicated structures will be given particular attention. Students will be required to make the models and the necessary observations and calculations. *Must be preceded or accompanied by Civil Eng. 7h.* One hour credit. Each semester.

7j. **Foundations and Underground Construction.** Design of substructures to meet various soil conditions; investigation of overloaded foundations; earth pressure in the deep underground; excavation problems; tunnel construction and design, critical diameter of

tunnels and shafts, subsidence and legal aspects of damage due to subsurface construction. *Prerequisite: Civil Eng. 6, and preceded or accompanied by Civil Eng. 42d.* Credit to be arranged. Each semester.

8. **Construction Methods and Equipment.** Deals with contractors' organizations, laws of management, plant selection, and layout; catalog studies of various types of equipment, their operating characteristics and care; standard methods of construction. Lectures, class discussion. Two hours credit. First semester.

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. Two hours credit. Second semester.

10. **Hydrology.** A study of natural streams; measurement of stream discharge; continuous discharge records; factors affecting precipitation; evaporation from land and water surface; relation of precipitation to stream flow; estimating stream flow; storage of water; floods. Two recitations and one three-hour laboratory period. *Open to seniors and graduates.* Three hours credit. Each semester.

11. **Hydraulics.** Principles of nonuniform flow applied to accelerating flow and to backwater; critical depth; hydraulic jump; waves of translation in open channels; application of principles of hydraulics to engineering practice. Lectures, problems. *Prerequisite: Eng. Mech. 4.* Two hours credit. Each semester.

12. **Water Power Engineering.** History of science; hydraulic and hydrological studies; power output of streams; hydraulics of turbines; selection of turbines, power-plant layout and equipment; economic considerations; engineering reports on water-power developments. Lectures, recitations, problems. *Must be preceded or accompanied by Civil Eng. 10. Open only to seniors and graduates.* Two hours credit. Each semester.

13. **Administration of Water Resources.** Progress made by India, Egypt, Italy, France, and Spain; development of common-law doctrines relating to waters, and their introduction into the United States; a few leading decisions; the abrogation of the common-law rule in the arid region; an engineering administration, based on principles, contrasted with court government under the common-law doctrine; examples of water administrations in western states. Lectures, assigned reading, reports. *Prerequisite: Eng. Mech. 4. Open to seniors and graduates.* Three hours credit. Each semester.

14. **Hydraulic Structures.** Dams, headgates, canals, flumes, pipes, tunnels, falls, breakwaters, wharves, jetties, and other structures; principles of irrigation, drainage, and harbor design; naviga-

ble rivers. Lectures with lantern slides showing important hydraulic structures; theses by students. *Prerequisite: Eng. Mech. 4.* Three hours credit. Second semester.

15. **Hydraulic Models.** A study of the use of hydraulic models for the advance determination of the performance of hydraulic structures; interpretation and reliability of results; principles of dimensional analysis and hydraulic similitude and applications to hydraulic problems. *Open to advanced seniors and graduate students.* Two hours credit.

16. **Hydraulic Engineering Design.** Description of hydraulic structures; hydraulic and structural computations; design of hydraulic structures; water-conveyance structures; dams; powerhouses; head gates; wasteways; regulating works. Lectures, computations, design. *Prerequisites: Civil Eng. 3, and preceded or accompanied by Civil Eng. 11.* Three hours credit. Second semester.

20. **Legal Aspects of Engineering Problems.** Agency, partnership, private and municipal corporations, rights in land, mechanics' liens, workmen's compensation, sales, patents and copyrights. Cases, lectures, discussion. *Open only to seniors and graduates.* Three hours credit. Each semester.

26. **Specifications, Contracts, and Engineering Relations.** Engineering relations; ethics; the engineer as a witness; contracts; bids and bidders; public lettings; methods of payment for contract and extra work; specifications. Lectures, reading, discussion. *Open to juniors, seniors, and graduates in engineering and in business administration.* Two hours credit. Each semester.

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. *Open to fourth- and fifth-year students.* Two hours credit. Each semester.

30. **Water Works.** A general study of municipal water supply. Quantity required and quality necessary for various purposes; public-health relationships; sources of supply; impounding reservoirs; wells, intakes; aqueducts and pipe lines; purification works; distribution; fire protection. Lectures, problems. *Prerequisite: Eng. Mech. 4. Open to seniors and graduates.* Three hours credit. Each semester.

31. **Water Purification.** Relates to engineering methods and devices for 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.*

30. Open to seniors and graduates. Two hours credit. Second semester.

32. **Sewerage and Drainage.** Functions and purposes of sewerage and drainage systems; health relationships; principles of design of sanitary, storm-water, and combined sewers; trunk sewers, intercepting sewers, inverted siphons, and other special structures; groundwater infiltration and its effects; sewer assessments; proper treatment and final disposal of sewage. Lectures, problems. *Prerequisite: Eng. Mech. 4. Open to seniors and graduates.* Two hours credit. Each semester.

33. **Sewage Disposal.** A broad survey of the engineering, public-health, legal and economic problems involved in the disposal of city sewage and industrial wastes. Sewage-treatment processes and devices; adaptation to climatic and other natural conditions; operation and maintenance; costs. Lectures, library reading, and visits to nearby disposal plants. *Prerequisite: Civil Eng. 32. Open to seniors and graduates.* Three hours credit. Second semester.

34. **Municipal and Industrial Sanitation.** The scientific foundations of public sanitation; the prevention of typhoid fever, malaria, and other diseases, and the betterment of living conditions through water purification, sewerage and drainage, and other major sanitary improvements involving community control of the environment; the collection, utilization, and disposal of garbage and other city wastes; street-cleaning methods, organization, and management; and industrial sanitation. Lectures, library reading. *Open to seniors and graduates.* Three hours credit. Each semester.

35. **Sanitary Engineering Design.** Computations and drawing-board design of pipe lines, large conduits, typical structures in reinforced concrete related to water supply, water purification, sewerage, and sewage disposal. Drawing room and visits to plants and work under construction. *Prerequisites: Civil Eng. 3, and accompanied or preceded by either Civil Eng. 31, 33, or 34.* Three hours credit. Each semester.

36. **Public Water Supply.** A course dealing with some of the broader aspects of public water supply, such as the conservation and protection of sources of supply, the characteristics of waters from different sources, accepted water-supply standards — both as to quality and quantity — health relationships, industrial water supply, purposes and results of water purification, legal rights and responsibilities of public water-supply departments, and water-works administration. Text, lectures, library reading. *Open to seniors and graduates.* Three hours credit. First semester.

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. *Open to seniors and graduates.* Two hours credit. Each semester.

40. **Highway Engineering.** Historical development; economics, administration, and legislation; preliminary investigations; design of road and street systems and the individual highway; drainage and foundations; highway materials; construction and maintenance of roads and pavements; street cleaning and snow removal; highway structures. Lectures, text. *Open to juniors, seniors, and graduates. Not restricted to engineering students.* Two hours credit. Each semester.

41. **Advanced Highway Engineering.** Location, subgrades and foundations, grading and drainage, highway surfaces; construction and maintenance procedures, equipment; comparison and selection of types as affected by physical and economic considerations. Lectures, text, review of current literature. *Prerequisite: Civil Eng. 40. Open to juniors, seniors, and graduates.* Two hours credit. Second semester.

42. **Civil Engineering Laboratory.** A group of laboratory courses, as listed below, for students desiring to study the physical properties of materials used in civil engineering construction.

42a. **Highway Materials Laboratory.** Physical properties of highway materials; testing of sand, gravel, rock, slag, cement, aggregates, cement-concrete, brick, wood block, stone block, and bituminous materials; proper method of reporting and interpreting results of tests. Lectures, text, laboratory. *Prerequisite or accompanying course: Civil Eng. 40. Open to juniors, seniors, and graduates.* Two hours credit. First semester.

42b. **Bituminous Materials Laboratory.** Properties of bituminous materials; testing of oils, asphalts, and tars; theory and design of bituminous paving mixtures; interpretation of results of tests; specifications. Lectures, text, laboratory. *Prerequisite: Civil Eng. 40. Open to juniors, seniors, and graduates.* Two hours credit. Second semester.

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. Each semester.

42d. **Soil Mechanics Laboratory.** A course to supplement Civil Eng. 6 and to acquaint the student with soil-testing technique. Laboratory soil tests; demonstrations and analysis of field tests; soil surveys and soil classification. *Must be preceded or accompanied by Civil Eng. 6.* One hour credit. Each semester.

43. Soils in Highway Engineering. Physical properties of soil as they affect the design and construction of highways. Soil surveys and highway design; subgrade soils; drainage, frost action, stabilization; mechanics of flexible surfaces; subgrade bearing capacity; stabilized soil mixtures and rational design of base and surface courses; fills and embankments and swamp construction. *Must be preceded or accompanied by Civil Eng. 6 and Civil Eng. 42d.* Two hours credit. First semester.

44. Highway Transport. History of highway-transport development; economics and fundamentals of different methods of transportation of passengers and commodities over highways; utilization of highway transport by railroads; legislation pertaining to operation of motor trucks, trailers, and motor busses as private and common carriers; traffic regulations; management of transportation companies; cost of operation of motor vehicles. *Open to seniors and graduates. Not restricted to engineering students.* Two hours credit. Each semester.

45. Highway Traffic Control. Causes of congestion; causes of accidents; physical changes to increase street capacity; regulation of moving traffic; regulation of parking; regulation of pedestrians; traffic signs and signals; municipal traffic codes; traffic bureaus; treatment of offenders. Lectures, text, field work, library reading. *Open to seniors and graduates. Not restricted to engineering students.* Two hours credit. Each semester.

46. Highway Administration. Development of highway administration and highway systems, local, county, state, and national; methods of financing roads and streets; functions and organization of highway departments. Lectures, text, library reading. *Open to seniors and graduates. Not restricted to engineering students.* Two hours credit. First semester.

47. Highway-Traffic Surveys. A study of traffic on city streets, in metropolitan regions, counties, states, and groups of states for purposes of traffic control or the formation of sound programs of highway improvement. The students conduct the various operations of a complete traffic survey. Lectures, assigned reading, and field work. *It is desirable that this course be preceded or accompanied by Civil Eng. 45. Open to seniors and graduates.* Two hours credit. Second semester.

50. Railroad Engineering. A general study of the railroad problem. Includes a consideration of surveys, alignment, earthwork, trestles, structures, tunnels, ballast, ties, rails, rolling stock, train resistance, block signals, train control, yards and terminals, operating expenses and organization. Lectures, text, problems. *Open to juniors and seniors, but not restricted to engineering students.* Two hours credit. Each semester.

51. Economics of Railroad Construction and Operation. Statistical analysis of operating expenses. A general study of curve, grade, and train resistances, ruling grades, rise and fall, and virtual profiles. Study of line changes, grade reductions, and elimination of grade crossings. Lectures, text, problems. *Open to juniors, seniors, and graduates.* Two hours credit. Each semester.

52. Railroad Maintenance. Maintenance of roadway, track, track appliances, switches and frogs, bridges, structures, culverts and drainage, signals and interlocking plants. Lectures, text, problems. *Open to juniors, seniors, and graduates.* Two hours credit. First semester.

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. Lectures, text, problems. *Open to juniors, seniors, and graduates.* Two hours credit. Second semester.

53. Terminal Design. Design of railroad, highway, waterway, and airport terminals, joint terminals, layout of the various types of yards, and traffic facilities. Opportunity is offered for specialized design of the following: port development, bus and truck terminals, airports, or general railroad terminals. Text, problems, drawing room. *Open to juniors, seniors, and graduates.* Three hours credit. Each semester.

54. Railway and Highway Location Design. Field and office practice of location and construction. Text, field work, and drawing room. *Open to juniors, seniors, and graduates.* Three hours credit. Each semester.

55. Advanced Terminal Design. Technical studies of metropolitan terminals, including details of car retarder, hump-yard computations, multiple-switch installations, and provisions for movement and transfer of passengers and freight. *Prerequisite: Civil Eng. 53.* Two hours credit. Each semester.

56. Advanced Railroad Location. The complete design of a railroad division, including paper location, selection of rolling stock, operating schedules, and appropriate facilities. *Prerequisite: Civil Eng. 54.* Three hours credit. Each semester.

57. Railroad Administration. Nature of the railroad organization; the various departmental and divisional functions; employee relationship, including labor, agreements on wages, working conditions and seniority; public relations; rates and service; intercarrier competition and traffic agreements. *Open to seniors and graduates. Not restricted to engineering students.* Three hours credit. Second semester.

58. **Transportation.** History of transportation; relation of highway, waterway, railway, and airway transportation. Lectures, library research, seminar. *Open to juniors, seniors, and graduates, but not restricted to engineering students.* Two hours credit. Each semester.

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 only.* Credit to be arranged. Each semester.

63. **Civil Engineering Research.** Assigned work in the fields of transportation, public utilities, or engineering relations and ethics. Exact nature of work to be determined by needs of individual students. To obtain credit a thesis must be prepared which would be acceptable for publication. *Open only to graduates.* Credit to be arranged. Each semester.

64. **Hydraulic Engineering Research.** Assigned work in hydraulic research; investigation of some problem or subject in hydraulics approved by the Professor of Hydraulic Engineering; a wide range of matter and method permissible. Reading, experiments, thesis. *Prerequisite: Civil Eng. 11. Open only to graduates.* Credit to be arranged. Each semester.

65. **Structural Engineering Research.** Assigned work on some problem in structural engineering, as approved by the Professor of Structural Engineering. A wide range of subject matter is available, including laboratory and library studies. An acceptable thesis is required. *Open to graduates.* Credit to be arranged. Each semester.

65a. **Seminar in Advanced Theory of Structures.** Study of special problems in theory of structures. *Open to qualified graduates.* Credit to be arranged. Each semester.

66. **Highway Engineering and Highway Transport Research.** Assigned work in the fields of highway engineering, highway transport, or highway-traffic control. Exact nature of work to be determined by needs of individual students. To obtain credit a thesis must be prepared which would be acceptable for publication. *Open only to graduates.* Credit to be arranged. Each semester.

67. **Railroad Engineering Research.** Assigned work in the field of railroad engineering. Exact nature of work to be determined by needs of individual students. To obtain credit a thesis must be

prepared which would be acceptable for publication. *Open only to graduates.* Credit to be arranged. Each semester.

Summer Session

Courses 2, 26, 27, 40, 45, 53, 63, 65, and 66, or similar courses, will be given during the Summer Session.

76. ELECTRICAL ENGINEERING

Professors BAILEY, HIGBIE, LOVELL, CANNON, and MOORE; Associate Professors ATTWOOD and STOUT; Assistant Professors BULL, DOW, GAULT, and HOLLAND.

Electrical engineers practice in a field of great breadth; any true subdivision of it is very difficult. The main divisions of practice, and work offered by the Department in relation thereto, are as follows:

Electrical Power Engineering has to do with the theoretical and practical phases of power generation, distribution, and utilization, together with the design and construction of the apparatus involved; among other specific applications it relates to electric railways, lighting, power plants, transmission, distribution, generators, motors, and the service of the public. The almost phenomenal growth of the electric public utilities and the corresponding use of electricity indicate the opportunities existing in this branch.

Electrical Communication deals with the transmission of signals, speech, music, and pictures by open wire lines, by cable, and by radio. The engineer practicing in this field utilizes greater extremes in magnitudes of time, distance, power, and efficiency than in any other branch of engineering. A well-balanced course in communication engineering must lay stress on general principles, whether electrical, mechanical, or economic. Premature specialization is to be avoided and a thorough groundwork in electrical engineering in its broadest sense to be obtained. This, followed by specialized courses in radio, telegraphy, and telephony taken in the senior year and, if possible, a graduate year, gives the student excellent preparation for the communication field and strengthens him for work in other fields by virtue of the broadened perspective.

Illumination Engineering is now an electrical activity because nearly all light sources are electrical. The illumination engineer deals with the many and varied special problems arising in relation to the production and utilization of light, economically and in accordance with correct principles of physics, physiology, psychology, art, and architecture.

The purpose of the work available to the undergraduate is to indicate the scope, present and prospective importance, and attractiveness of illumination as a field of professional activity, and to

establish firmly by thorough drill the principles upon which progress must be founded.

Electrical Engineering Design.—As every unit of apparatus produced must first be designed, design practice affects most phases of electrical engineering in one way or another. Design itself may mean designing the unit to be built, or may mean selecting units already made and assembling them in economic fashion to create a workable and efficient layout. Design involves the use of fundamental theory as modified by practical considerations of cost, properties of materials, and the selection of methods.

The courses of the design group are not in any sense intended to turn out finished designers. Rather, by using the background offered by design problems, they give an opportunity to clarify the student's knowledge of apparatus, and their training in diverse methods of attack is of value irrespective of the field of engineering the student may later enter.

To an increasing extent, nearly all electrical engineers are concerned with heat problems; the introductory work of Course 5, and the advanced work of Course 52, offer a training in heat transfer and temperature rise which is probably not duplicated in electrical engineering curricula.

Electrical Theory and Laboratory Technique constitute a division of work in the Department that is of growing importance in the field. The rapid development of electrical engineering and its relation to many applications of great variety have created a demand for workers with a more extensive training in fundamental electrical and physical theory and laboratory procedure.

Electronics deals with the individual and statistical behavior of electrons, ions, and atoms in various types of electric circuit elements. It treats these ultimate units as individual interacting material particles, subject to the usual laws of dynamics, subject to and modifying electric field forces, and capable of emitting and receiving radiant energy. It attempts to make useful to the electrical industry as much as possible of the knowledge obtained by physicists in investigations of atomic behavior and structure. This general avenue of approach permits rational analysis of the properties of materials used in electrical engineering, and aids in the development of useful new materials. The most widely recognized field of electronic study is the development, analysis, and application of peculiarly electronic equipment; such as electron tubes, electronic control apparatus generally, radio broadcast transmitters and receivers, photosensitive relays, mercury rectifiers, circuit-breakers and circuit-interrupting devices of all sorts, cathode-ray and x-ray equipment, gaseous-discharge light-sources, and electric-arc welding equipment.

Industrial Electrical Engineering includes the study of applications of electricity in industry, plant operation and management,

problems of personnel, production, and the business side of manufacturing.

Research.—The staff in Electrical Engineering is always very glad to offer its laboratory facilities and advice to graduate students who wish to work on research problems leading to one of the higher degrees. In keeping with this policy several fellowships are offered each year to graduate students.

Course 18 may be elected by graduate students pursuing research, while Course 9 serves the same purpose for undergraduates.

FACILITIES

The Electrical Engineering Laboratories include a dynamo laboratory, communication laboratories, a photometric laboratory, an electronics and high-voltage laboratory, a heat-transfer laboratory, and an electrical standards laboratory.

The Dynamo Laboratory is fully equipped with direct- and alternating-current apparatus of various types and sizes, representative of the leading American and foreign manufacturers.

In all of the electrical laboratory work, special emphasis is laid upon the development of the student's ability to analyze the phenomena which he observes in the operation of electrical machinery. To this end, and with the aim of developing the personal initiative of the student, a large number of moderate-sized machines have been provided in order to give each student intimate contact with the apparatus.

The laboratory is fully equipped with meters and instruments of various ranges, types, and makes. The equipment includes eight oscillographs with all accessories.

Distribution of power in the laboratories is controlled through a plug and socket system. The system gives great flexibility and requires that all connections be made by the student himself, but provides the means by which these operations may be quickly and easily performed.

The laboratory has on exhibit electrical apparatus of very early type which is of historic interest.

The Communication Laboratories are unusually well equipped for both practical and theoretical experimental study of communication by electrical means.

Oscillators covering both the audio- and radio-frequency ranges, vacuum-tube voltmeters and ammeters, and impedance bridges are provided for accurate measurements. Standards of inductance, capacity, and resistance are available.

For telephone work an artificial open-wire line, a loaded cable, and standard cable may be used for the study of the propagation of medium-frequency voltages and currents. A supply of telephone

instruments, sensitive meters, transformers, telegraph instruments including repeaters, and models of manual and automatic exchanges are provided for study.

The radio laboratory is well equipped with vacuum tubes for both receiving and transmitting purposes, high-voltage generators for power supply, standard wavemeters and capacities, thermoammeters and the usual types of auxiliary apparatus. Cathode-ray oscillographs are provided for the study of high-frequency currents. The Electrical Engineering Department also maintains an 800-watt short-wave transmitter which is available for operation and study.

The Photometric Laboratory, unexcelled and with few equals, is equipped for research as well as instruction in almost every phase of lighting. For precision work there are four ten-foot straight photometer bars, each in its own room and equipped with all accessories, such as lamp rotators, screens, electrical control and measuring devices, and sector discs. Photometer heads of the Lummer and Brodhun, equality, contrast, and flicker types are of Schmidt-Hoensch, or Leeds and Northrup manufacture, the best obtainable. There are at this writing twelve portable photometers of six different types for making surveys of interior lighting in real buildings and models of buildings, and exterior lighting. An imported Weber photometer is available for students competent to do research work; also photoelectric illumination meters for rapid measurements. Integrating spheres, 30 inches in diameter for small light sources and 80 inches for large sources, are arranged for convenient use, also as hemispheres. A single-mirror selector in conjunction with one of the Sharp-Millar photometers gives the equivalent of a long photometer bar for extended sources. A Keuffel and Esser color analyzer provides a form of spectrophotometer especially designed to facilitate measurements of the light-reflecting and light-transmitting properties of solids and liquids for any spectral color of light. A Taylor part-sphere, in conjunction with one of the Macbeth illuminometers, provides fairly precise means of measuring reflection factor of surfaces in place, without bringing them to the laboratory.

There is a historically complete as well as an up-to-date collection of light sources, for test as well as for record; including the latest forms of arc lamp and luminous tubes. Special equipment has been developed for our long series of published researches on line-sources and surface sources of light, which is constantly in use for work in course as well as for further investigations. A unique development of autographic photoelectric apparatus, employing especially designed amplifiers to multiply the currents from moving photoelectric cells so that they can actuate electric oscillographs, enable us to obtain a permanent record of a complete survey in the form of curves of illumination from any system of lighting installed in a scaled model, within a few minutes, so that great amounts of data in graphic form may be conveniently shown after preparations have been made.

A laboratory for photoelectric measurements is being developed. In addition to a large Case barium-oxide photoelectric cell and a Leeds and Northrup recording potentiometer designed to be used in combination for measurement of daylight and other illuminations of great magnitude, there is a fairly complete collection of other types of photoelectric cells available for use in Courses 73, 9, and 18.

Electronics and High Voltage Laboratory.—Electronic facilities are available for instruction and research in a variety of special fields. A 70,000-volt surge generator and a 60,000-volt cathode-ray oscillograph arranged for photographic recording of extremely fast surge voltages are available for insulation, spark-over, and corona tests; the same oscillograph is equipped for use in the investigation of a-c-arc reignition, dynamic-arc characteristics, other transient aspects of electric-arc behavior, and studies of the very short-time response of igniter-rod and grid-controlled rectifiers. Two smaller cathode-ray oscillographs are available for study and demonstration of repeating transients and high-frequency voltages and currents.

A varied assortment of electron tubes and photosensitive tubes and relays, with adequate laboratory-test facilities, permits instruction and research in tube characteristics and uses. Shop facilities permit assembly of electronic amplifiers, oscillators, and control assemblies as individual projects, and, together with a high-vacuum pumping system, permit design, construction, and testing of special tubes.

Mercury rectifiers with and without grid and igniter-rod control, in sizes suited for control circuits and for power supply, are used in laboratory classes and in research projects. Electronic devices such as stroboscopes, neon-glow lamps, etc., are used wherever advantageous for general laboratory service as well as for specific electronic instruction and research.

The Electrical Standards Laboratory is provided with standards of resistance, inductance and capacitance, standard cells, potentiometers, galvanometers, meters of the precision type, and ratio- and phase-angle testing equipment for current and potential instrument transformers, equipment for the generation of sine waves and for testing watt-hour meters and core loss in iron. Oscillographs of the mechanical and cathode-ray types are available for study of wave shapes.

Heat Transfer Laboratory.—The Department is unique in giving a considerable amount of heat-transfer training, of use to the designer of apparatus and in the very large and diversified field of electric heat applications. It is intended that a heat transfer laboratory will be developed and equipped by gradual stages. Meantime, the Department has the only Hydrocal in existence; this is a calculating machine of new type, able to demonstrate and solve transient situations in heat transfer and other types of diffusion. The Hydrocal

is used for demonstrations in undergraduate work; graduate students themselves operate it in Elec. Eng. 18 and Elec. Eng. 52.

Power Plant.—The University has a medium-sized, steam power plant of its own which is available for instructional purposes; also the University is well situated with regard to both hydraulic and steam-power plants of the Detroit Edison Company. Technical inspections of these plants are made in conjunction with the classroom work in appropriate courses.

Visits of Inspection.—See section 42.

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. In addition to the following required courses, elective courses in fields of particular interest are available to undergraduates and graduates.

Course 1 serves as an introduction to the engineering viewpoint of electricity and magnetism.

Courses 2, 3, and 4 form a basic group in the study of electrical circuits and machinery.

Course 5 is devoted to the fundamental electric, magnetic, and thermal considerations underlying the design of all electric apparatus.

Course 7 is an introduction to the principles of illumination and to the criteria by which its quality may be judged.

Course 11 is a study of the technical and economic principles underlying power generation and transmission.

Course 12 introduces the fundamentals of electronic theory, and includes a study of the simpler forms of vacuum tubes.

Course 17 is an advanced study of electrical circuits, including transients, nonsinusoidal wave forms, and long electrical lines.

The staff of the Department of Electrical Engineering, by constant study and revision of course content and teaching method, aims to offer such work as will react to the ultimate benefit of the student rather than to his immediate gain. Throughout, the teaching of theory and its modifications by practice, the development of analytic judgment, and the acquiring of a fundamental scientific background are emphasized. The acquisition of specific factual knowledge is left, except 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.

Close contact is maintained with the employing industries, both to enable the instructional staff to keep in touch with a fast-growing art and to facilitate the finding of employment for the graduates.

Graduate work is urged for every student who would benefit by taking more advanced work. The graduate courses offered are

being built up from year to year. The mathematical and physical nature of advanced electricity makes it profitable for some gifted students to spend much time in mathematics and physics; for the better students every encouragement is offered.

The individual initiative of exceptional seniors is encouraged by seminar, research, and special problem courses offered for the purpose.

Scholarships and fellowships are available at the University for assignment to students of outstanding ability and high scholastic standing. Any electrical student desiring to learn of the possibilities in this respect, or to make application, should consult the head of the Electrical Engineering Department. Application for a Graduate School fellowship must be made before March 1. See sections 44 to 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 student must begin, not later than his sophomore year, to plan the courses he desires to select for his elective work, both technical and nontechnical. This will be done in consultation with the head of the Electrical Engineering Department, and advisers appointed by him, and has as its purpose the coördination of all elective work into a consistent and unified program having the greatest value to the student. A consultation with the department head or the adviser will be held prior to the beginning of each semester, thus permitting the original program to be modified, if necessary, to realize more fully the student's objectives.

The Electrical Engineering Department does not have a rigid group-election system, but, rather, the needs and interests of each student are considered individually. The following groups are not mandatory in their present form, nor are they expected to cover all situations. They are given to show the courses available in the Electrical Engineering Department, and cognate courses in other departments. Elections may include other courses, also, provided that the program has a definite and unified purpose, and is approved by the department head.

It is, of course, impossible to incorporate any large part of any of these groups in the undergraduate program. The strong student who can profit by the instruction is urged to consider the advisability of at least one year of graduate work leading to the master's degree. In such a year he will have opportunity to take advanced work along the lines in which he expects to specialize. Such work

is usually impracticable in the undergraduate years, due to lack of time and adequate preparation.

Course 9 or Course 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. Course 9 is intended for undergraduates, and involves rather close faculty supervision. Course 18, intended for graduates, involves independent work with little supervision, and requires a report in the form of a thesis.

SUGGESTED ELECTIVE GROUPS

Electrical Power Engineering

Elec. Eng. 8, Electric Traction
Elec. Eng. 16, Electrical Rectification
Elec. Eng. 19, Study of Design—Power Plants
Elec. Eng. 20, Study of Design—Transmission and Distribution
Elec. Eng. 31, Symmetrical Components
Elec. Eng. 33, Industrial Electrical Engineering
Elec. Eng. 36, Electric Rates and Cost Analysis
Elec. Eng. 82, Theory of Gaseous-Conducting Electronic Apparatus
Mech. Eng. 5, Thermodynamics
Mech. Eng. 13, Steam Turbines
Mech. Eng. 16, Water Turbines
Civil Eng. 12, Water Power

Illumination

Elec. Eng. 15, Advanced Lighting
Elec. Eng. 70, Electrical Distribution, Wiring, and Control for Lighting
Elec. Eng. 71, Interior Illumination—Study of Design
Elec. Eng. 73, Photoelectric Cells
Elec. Eng. 74, Lighting Equipment
Elec. Eng. 82, Theory of Gaseous-Conducting Electronic Apparatus
Physics 186, Light
Physics 187, Geometrical Optics
Physics 188, Laboratory Work in Light
Fine Arts 101, History of Art
Psychology 37, Introductory Psychology
Psychology 160, Psychology of Vision
Dec. Design 4, Theory of Color
Arch. 15, History of Architecture

Electrical Engineering Design

Elec. Eng. 6, Advanced Theory of the Induction Motor
Elec. Eng. 25, 25*a*, Advanced Electricity and Magnetism
Elec. Eng. 27, Electric and Magnetic Properties of Materials
Elec. Eng. 52, Heat Problems in Electrical Design
Advanced Courses in Mathematics and Physics

Communication

Elec. Eng. 10, Advanced Theory of Electrical Circuits
Elec. Eng. 16, Electrical Rectification
Elec. Eng. 22, Radio Communication
Elec. Eng. 25, 25*a*, Advanced Electricity and Magnetism
Elec. Eng. 26, Heaviside Operators
Elec. Eng. 41, Telephone Communication
Elec. Eng. 81, Theory of High-Vacuum Electronic Devices
Physics 174, Sound
Physics 176, Laboratory Work in Sound

General Theory and Measurement

Elec. Eng. 10, Advanced Theory of Electrical Circuits
Elec. Eng. 25, 25*a*, Advanced Electricity and Magnetism
Elec. Eng. 26, Heaviside Operators
Elec. Eng. 27, Electric and Magnetic Properties of Materials
Elec. Eng. 28, Technical Electrical Measurements
Elec. Eng. 31, Symmetrical Components
Elec. Eng. 81, Theory of High-Vacuum Electronic Devices
Elec. Eng. 82, Theory of Gaseous-Conducting Electronic Apparatus

Electronics

Elec. Eng. 16, Electrical Rectification
Elec. Eng. 22, Radio Communication
Elec. Eng. 25, 25*a*, Advanced Electricity and Magnetism
Elec. Eng. 26, Heaviside Operators
Elec. Eng. 27, Electric and Magnetic Properties of Materials
Elec. Eng. 73, Photoelectric Cells and Their Applications
Elec. Eng. 81, Theory of High-Vacuum Electronic Devices
Elec. Eng. 82, Theory of Gaseous-Conducting Electronic Apparatus
Physics 166, High Frequency Measurements
Physics 196, Atomic and Molecular Structure
Physics 265, Conduction of Electricity through Gases

Industrial Electrical Engineering

Elec. Eng. 33, Industrial Electrical Engineering
Elec. Eng. 36, Electric Rates and Cost Analysis

Mech. Eng. 35, Factory Management
Mech. Eng. 36, Factory Management—Purchasing and Traffic
Ec. 171, Principles of Accounting I
Ec. 172, Principles of Accounting II
Bus. Ad. 102, Principles of Personnel
Bus. Ad. 113, Cost Accounting I
Bus. Ad. 161, Financial Principles I
Bus. Ad. 162, Financial Principles II

SPECIAL CURRICULA

In coöperation with the School of Business Administration, a five-year course leading to the degree of M.S. in Industrial Engineering is offered.

A five-year coöperative program in electrical engineering and industry is offered in coöperation with certain leading electrical industries. The student spends, in all, four semesters or sixteen months in one chosen industry. In this program, the required university work is the same as that for students choosing the regular program in electrical engineering. However, successful completion of the industrial part of the program entitles the student to eight credit hours which may be counted as eight hours of elective studies. The time spent in the University will be made up of those semester and summer session periods during which the student is not connected with the industry. The work in industry will be closely supervised by an officer of the University.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 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, as they are well qualified for it. Those who consider taking military science are urged to enroll at the beginning of their course. For further details see section 66.

CURRICULUM IN ELECTRICAL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Electrical Engineering) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 50.

a) Preparatory Courses — *Hours*

English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37, 39	18
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Economics 53, 54	6
Total	68

b) Secondary and Technical Courses

Physics 147, Electrical Measurements	4
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory in Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil Eng. 2, Theory of Structures	3
Mech. Eng. 2*a*, Elements of Machine Design	3
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 3*a*, Laboratory	1
Elec. Eng. 1, Prin. of Electricity and Magnetism	4
Elec. Eng. 2, D.C. Apparatus and Circuits	4
Elec. Eng. 3, A.C. Circuits	4
Elec. Eng. 4, A.C. Apparatus	4
Elec. Eng. 5, Design of Electrical Machinery	4
Elec. Eng. 7, Illumination and Photometry	2
Elec. Eng. 11, Power Plants, Transmission and Distribution	5
Elec. Eng. 12, Electronics and Electron Tubes	4
Elec. Eng. 17, Electromechanics	4
Total	64

Summary:

Preparatory Courses	68
Secondary and Technical Courses	64
Electives, from Suggested Groups	8
Total	140

PROGRAM

First Year

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E.	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

Second Year

Math. 36	4	Math. 37	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)		
	(18) or 17		(17) or 16

Summer Session

Elec. Eng. 3	4
Mech. Eng. 3	4
	8

Third Year

Elec. Eng. 1	4	Elec. Eng. 12	4
Elec. Eng. 7	2	Elec. Eng. 17	4
Math. 39	2	Eng. Mech. 2	4
Eng. Mech. 3	3	Eng. Mech. 2*a*	1
Eng. Mech. 4	3	Mech. Eng. 3*a*	1
Economics 53	3	Economics 54	3
	17		17

* If modern language is elected, it may be classified here and the English postponed. See section 51.
† See note, section 56.
‡ Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each semester) is elected as a substitute. Enrollment in military science is for a period of four semesters.

FOURTH YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Elec. Eng. 4	4	Elec. Eng. 5	4
Elec. Eng. 11	5	Physics 147	4
English (Group III)	2	Civil Eng. 2	3
Mech. Eng. 2*a*	3	Elective	5
Elective	3		
	17		16

FIVE-YEAR COURSE IN ELECTRICAL AND INDUSTRIAL ENGINEERING

In coöperation with the School of Business Administration, a program for electrical engineering students may be arranged for a fifth year leading to the degree of Master of Science in Industrial Engineering.

COOPERATIVE COURSE IN ELECTRICAL ENGINEERING AND INDUSTRY (FIVE YEARS)

The coöperative 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 8 credit hours (in place of University elective courses), giving him 140 hours required for the bachelor's degree. About five calendar years is 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 coöperating 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 coöperating student and industrial concern, this course may lead to permanent employment.

Coöperative relations will be established only with such industries as are able and willing to offer a definite program of work of educational value. No credit, therefore, will be given for industrial work except as arranged under the coöperative plan.

COURSES IN ELECTRICAL ENGINEERING

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; illustrations of the universality of the laws of physics as they occur in the fields of electricity, magnetism, gravitation, heat, light, etc. Three lectures and one three-hour computing period. *Prerequisites: Math. 37 and Phys. 46.* Four hours credit. Each semester.

2. **Direct-Current Apparatus and Circuits.** Torque, current, flux, e.m.f. and speed relations in self-regulation and control of motors and generators; electric- and magnetic-circuit calculations; power losses and efficiency of machines; commutation and armature reaction; parallel operation of generators; mechanical and electrical coupling of motors. Two lectures, one three-hour computing period, and one four-hour laboratory period. *Must be preceded or accompanied by Phys. 46.* Four hours credit. Each semester.

2a. **Direct- and Alternating-Current Apparatus and Circuits.** Characteristics 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. 37 and Phys. 46.* Four hours credit. Each semester.

3. **Alternating-Current Circuits.** Wave form of e.m.f.; relations of simple harmonic e.m.f.'s and currents; phase differences; active, reactive, and apparent power, power factor and reactive factor; resistance, inductance, and capacitance, singly and in any combination; polyphase circuits, balanced and unbalanced; power in polyphase systems; e.m.f.'s of armature windings—vector representation and calculation; transformers—construction, theory, operation, simple and complete vector diagrams, losses and constants, efficiency and regulation; instrument transformers; constant current transformers. Two lectures, one four-hour computing period, and one four-hour laboratory period. *Prerequisite: Elec. Eng. 2 or 2a.* Four hours credit. Each semester.

4. **Alternating-Current Machinery.** Principles of the synchronous machine, the induction machine, the synchronous converter, and the various types of single-phase motors. Lectures, recitations, computing period, and one four-hour laboratory period. *Prerequisite: Elec. Eng. 2a or 3.* Four hours credit. Each semester.

5. **Fundamentals of Electrical Design.** Design problems from various types of apparatus involving the electric and magnetic circuits; extensive treatment of field mapping; a large amount of

heat-transfer and temperature-rise work, using conduction, convection, and radiation, giving an introduction to heat in the form needed by the electrical engineer; particular emphasis given to tabular computation, step-by-step, trial-and-error, and graphical methods of solution. Two lectures and two four-hour computing periods. *Prerequisites: Elec. Eng. 1 and 3.* Four hours credit. Each semester.

6. **Advanced Theory of the Induction Motor.** Continuation of Course 4. Both polyphase and single-phase motors are studied. One lecture and one three-hour computing period. *Prerequisite: Elec. Eng. 4.* Two hours credit. Second semester.

7. **Illumination and Photometry.** Concepts, quantities, units, and relations employed in this science, such as the lumen, candlepower, foot-candle, lambert; theory and use of typical measuring devices—precision photometer and accessories, portable photometers, integrating spheres, reflectometers; calculation of illumination from point, line, and surface sources of light exhibiting typical space-distributions of light; light-flux output of any source having symmetrical distribution; calculations regarding light in an inclosure, utilization coefficient, point-by-point and flux-of-light method for designing illumination of an interior; laws of vision as they affect lighting; characteristics of lamps, reflectors, inclosing globes; glare and shadow; industrial, office, school, and residence lighting. Two lectures and one three-hour laboratory period. *Prerequisites: Phys. 46, and must be preceded or accompanied by Math. 37.* Two hours credit. Each semester.

7a. **Building Illumination.** Illustrations of causes of, and means to avoid, glare, improper shadows, poor distribution, unsteady light, and other faults; means for providing 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 semester. *Not open to electrical engineering students.* One hour credit. Each semester.

8. **Principles of Electric Traction.** Traffic studies, train schedules, speed-time and power curves, locomotive-train haulage, signal systems, cars and locomotives, control systems, traction systems, electrification of trunk lines. Recitations and problems. *Prerequisite: Elec. Eng. 3 or 2a.* Two hours credit. Second semester.

9. **Directed Research Problems.** Special problems are selected for laboratory or library investigation with the intent of developing initiative and resourcefulness. To a large degree the student's own desires will control the subjects investigated. The work differs from

that offered in Elec. Eng. 18 in that the instructor is in close touch with the work of the student. Elec. Eng. 9 may be elected by seniors who have suitable preparation. Elec. Eng. 18 is for graduates. *Prerequisite: Elec. Eng. 3.* Credit by arrangement. Each semester.

10. **Advanced Theory of Electrical Circuits.** Mathematical analysis of theoretical and practical problems; electrical filters; transmission of electric waves on lines having distributed capacitance, inductance, resistance, and leakage; mechanism of reflection at terminals; electromagnetic waves in space; Maxwell's equations. The course material is fundamental to further work in telephone, telegraph, and radio circuits. Lectures. *Prerequisite: Elec. Eng. 17.* Three hours credit. Each semester.

11. **Power Plants and Transmission Systems—Economics of Design.** Elementary principles of corporate finance, study of economic decay and tests for obsolescence; power-plant load curves as a basis for design; economic load division between units and plants, economic conductor-section and distribution systems; study of plant location; selection of oil-circuit breakers; economic use of power-limiting reactors, relays, synchronous condensers for power-factor control and phase modification; constant voltage transmission lines. Lectures, recitations, and problems. *Prerequisite: Elec. Eng. 2a or 3.* Five hours credit. Each semester.

12. **Electronics and Electron Tubes.** Potential distribution diagrams; analysis of electric fields in electron tubes; motions of electrons in electric, magnetic, and curved fields; cathode-ray devices; space-charge-limited currents. Kinetic theory of electric conduction and electron emission; work function. Electron-tube characteristics; simple amplifier circuits, gain, distortion, and coupling; survey of radio oscillators, detectors, modulators. Atoms and radiation; energy-level diagrams, ionizing processes and potentials; photoelectric currents and their uses. Theory and application of grid-controlled and igniter-rod rectifiers, illustrative of electric arc properties and of the application of kinetic theory to densely ionized regions; probes, positive ion sheaths, electron temperature, ion concentration. Three lectures and one three-hour laboratory period. *Prerequisites: Elec. Eng. 1, and preceded or accompanied by Elec. Eng. 3.* Four hours credit. Each semester.

15. **Advanced Lighting.** Selection by the student of a topic, with instructor's approval, for continued and intensive study, which is pursued until either all sources of information in English are exhausted or the time of the course is ended; short oral reports by each student to the class each week; written report and bibliography presented to instructor at end of course. *Prerequisites: Elec. Eng. 7, and preceded or accompanied by Elec. Eng. 3.* Two hours credit. Second semester.

16. **Electrical Rectification.** Equipment and circuits used for rectification; study of wave forms in circuits composed of resistance, inductance, capacity, and batteries; effective and average values; power measurements; Fourier analysis. Transformer connections, single phase and polyphase; transformer problems, saturation effects. Basic action in the principal types of rectifiers; gaseous ionization and electronic action as applied to rectifiers; applications. Lectures and recitations. *Prerequisites: Elec. Eng. 12, and preceded or accompanied by Elec. Eng. 17.* Two hours credit. Second semester.

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. Each semester.

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. Research. *Elected by permission of Head of Department.* Credit by arrangement. Each semester.

19. **Study of Design—Power Plants.** Study of modern power-station design and performance. Detailed study of electrical equipment, generators, switchboard, protective relays, circuit-breaker control and application, automatic operation. Special problems of interconnection, frequency control, stability, single-phase, short-circuit study through use of symmetrical components. *Prerequisites: Elec. Eng. 11 and 17.* Two hours credit. Second semester.

20. **Study of Design—Electric Transmission and Distribution Systems.** Electrical features of efficiency, regulation, control of voltage and power factor, inductive interference, corona and surges; mechanical problems of the design of supporting structures, sags and spans, etc. Lectures and recitations. *Prerequisites: Elec. Eng. 11 and 17.* Two hours credit. Second semester.

22. **Radio Communication.** Advanced work in resonant, coupled, and oscillatory circuits. Application of these circuits to radio problems. Audio- and radio-frequency amplification; transmitting and receiving circuits with especial attention to the use of vacuum tubes; antennae and principles of electromagnetic radiation; field measurements; frequency control. This course is so scheduled that it conflicts with Elec. Eng. 11. Students desiring to take Elec. Eng. 22 should arrange their schedules accordingly. Lectures and laboratory. *Prerequisites: Elec. Eng. 12 or Phys. 165; preceded or accompanied by Elec. Eng. 17.* Four hours credit. Second semester.

24. **Elements of Electrical Communication.** This course is designed for nonelectrical students who desire to obtain a general knowledge of the communication field. After a review of direct and alternating currents, the following subjects are considered: networks; uniform lines; loading; telephone repeaters; vacuum tubes; audio- and radio-frequency amplifiers; radio receiving and transmitting sets. Lectures and laboratory. *Prerequisite: Elec. Eng. 2a or equivalent. Not open to electrical students.* Three hours credit. Second semester.

25. **Electromagnetic Field Theory.** Advanced theory and problems in electric and magnetic fields, using elementary vector methods which are introduced as required. Problems in rectangular, cylindrical, and spherical coördinates, with and without space charge. Maxwell's equations, waves, and propagation of energy. *Prerequisites: Elec. Eng. 1 and 3.* Three hours credit. First semester.

25a. **Engineering Applications of Electromagnetic Field Theory.** Lorentz' equations, retarded potentials, radiation from antennae. Skin effect. Mass as a function of velocity; energy and mass; application to cathode-ray oscillograph, electron mechanics. Two-dimensional field studies, conformal transformations. Electrical surges, measurement of surge voltages and currents. Relations of field theory to modern physics. *Prerequisite: Elec. Eng. 25.* Three hours credit. Second semester.

26. **Heaviside Operators.** Advanced theory of electrical circuits as developed by the application of Heaviside operators. Methods of circuit solution for transients in circuits with lumped constants; circuits with distributed constants; long lines; cables. A study is made of the fundamental theorems upon which the method rests. Applications to engineering problems. Lectures and discussions. *Prerequisite: Elec. Eng. 17.* Two hours credit. Second semester.

27. **Electrical and Magnetic Properties of Materials.** Studies of the electric and magnetic properties of gaseous, liquid, and solid materials used in electrical engineering. The subject matter is treated from the engineering point of view, which is coördinated as far as possible with the modern physical viewpoint. Theory of electrical insulation, Debye dipole theory, absorption, conduction, losses, dependence of dielectric constant upon frequency and temperature, breakdown. Electrolytic and metallic conduction. Dia-, para-, and ferro-magnetic materials and theory. Electric cables, new electric and magnetic materials, permanent magnets, nonlinear circuits, batteries. Lectures and recitations. *Prerequisites: Elec. Eng. 12 and 25.* Three hours credit. Second semester.

28. **Technical Electrical Measurements.** Theory and practice in making measurements, particularly in alternating currents, to a precision and accuracy required by modern laboratories. Measurements of voltage, resistance, current, power, energy, etc. Ratio- and

phase-angle tests of current and potential instrument transformers. Indicating instruments, watt-hour meters, demand meters, relays, etc. Iron losses and their separation into hysteresis and eddy current losses. Opportunity is provided for working with a-c. bridges and oscillographs of various types, including the cathode-ray oscillograph. Individual reports on various measurement problems. One afternoon of laboratory. *Prerequisite: Elec. Eng. 3.* Two hours credit. Each semester.

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; reactances of synchronous machines, transformer reactances; reactances of transmission lines, using the method of geometric mean distances; metering of sequence quantities; application to inductive coördination study. Lectures, recitations, and problems. *Must be preceded or accompanied by Elec. Eng. 17.* Two hours credit. First semester.

33. **Industrial Electrical Engineering.** Industrial control and motor application with short review of motor performance. Detailed study of motor and control equipment suited to particular applications: electric hoists, electric braking, hydraulic pumps, machine tools, paper machines, electric elevators, ventilation. Electric furnace and other heat applications. Lectures and problems. *Prerequisite: Elec. Eng. 2a or to be preceded or accompanied by Elec. Eng. 4.* Three hours credit. First semester.

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; investigations of practical systems used in charging for electrical energy. Lectures. *Prerequisite: Elec. Eng. 11; open to seniors only.* One hour credit. Second semester.

41. **Telephone Communication.** Study of the characteristics of circuits, networks, and telephone apparatus at audio frequencies. Lecture and laboratory. *Must be preceded or accompanied by Elec. Eng. 10.* Two hours credit. Each semester.

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, such as comparison of hydrogen and air cooling; all work directed toward making heat transfer and temperature rise available to electrical engineers in design, application, and operation of apparatus in general. The student is familiarized with the operation of the Hydrocal, a new hydrodynamic-type calculating machine for solving transients in diffusion. *Prerequisite: permission of the instructor.* Two hours credit. Given when demand is sufficient, either semester or in summer session.

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. Plans and specifications, analyses, and tests. Lectures, problems, and surveys. *Prerequisites: Elec. Eng. 3 and Elec. Eng. 7.* Two hours credit. Second semester.

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. Methods and rules of design commonly used in spite of their insufficiency in unusual cases, because of their convenience, are subjected to close scrutiny. Higbie's book *Lighting Calculations,* used as textbook, is largely based on the preparations for this course. Consisting principally of lectures and problems, the course may include some field surveys or laboratory tests on scaled models, to check the calculations required.

On account of the great differences in fundamental lighting courses available in various colleges, the permission of the instructor to enter this course must be had in each individual case. Though it is intended primarily for graduates, especially qualified undergraduates may receive such permission. *Prerequisite: Elec. Eng. 7 or equivalent.* Two hours credit. First semester.

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

74. **Lighting Equipment.** Analysis of design and performance of lamps, reflectors, refractors, diffusers and other light-control media, and of complete luminaires, with reference especially to proper selection or design of assemblages to produce economically illuminations that are visually effective or esthetically desirable, for interiors or exteriors of buildings, for streets and display. Lectures and problems. *Prerequisites: Elec. Eng. 3 and Elec. Eng. 7.* Two hours credit. First semester.

81. **Theory of High-Vacuum Electronic Devices.** Analysis of electric fields, interelectrode capacitances, and amplification factors, in triodes, tetrodes, and pentodes. Mechanism of grid control of space-charge-limited current; uses of the various equivalent diodes; beam power-tube principles. Transit angle and equivalent circuits for ultra-high-frequency triode operation. Energy-level diagrams for electrons in metals; derivation of Dushman's equation for thermionic emission; thoriated and coated cathodes. Effects of initial electron velocities; equations for noise in amplifiers. Two lectures and one four-hour laboratory, computing, or seminar period. *Prerequisites:*

Elec. Eng. 12 or satisfactory first courses in electricity and magnetism and in electronics. Three hours credit. First semester.

82. Theory of Gaseous-Conducting Electronic Apparatus. Atomic energy states and spectral symbols; energy-level diagrams for sodium, neon, mercury, copper. Velocity distributions in gases; mean free paths, elastic and inelastic collisions, the Townsend coefficients. Vacuum and gas-filled phototube properties. Plasmas and plasma boundaries in electric arcs and glow discharges. Sheaths and probes in plasmas; plasma balance relationships. Initiation of vacuum arcs by grids, igniter rods, and outside bands; arc-back in mercury rectifiers, arc reignition in a-c. circuit-breakers. Theories of spark initiation and time lag. Two lectures and one four-hour laboratory, computing, or seminar period. *Prerequisites: Elec. Eng. 12 or satisfactory first courses in electricity and magnetism and in electronics, to be preceded or accompanied by Elec. Eng. 11 and Elec. Eng. 17.* Three hours credit. Second semester.

Summer Session

Courses *2a*, 3, 4, 17, and 18 are generally offered in the Summer Session. Courses 10, 11, 25, 26, 27, 31, 51 or 52, 71, and 81 or 82 may be given if there is sufficient demand. Those wishing to elect any of these courses should communicate with the instructor in charge of the particular course some time before the opening of the Summer Session.

77. ENGINEERING MECHANICS

Professors ERIKSEN, MENEFEE, VAN DEN BROEK, and ORMONDROYD; Associate Professors SWINTON and DODGE; Assistant Professors LIDDICOAT, HANSEN, OLMSTED, EVERETT, and WOJTASZAK.

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 two adjoining large rooms with entrance at Room 102, West Engineering Building. The equipment comprises a 50,000-pound, a 100,000-pound, and a 200,000-pound tension-compression machine, a 230,000-inch pound torsion machine with jaws for taking specimens 2⅞ inches in diameter, an Olsen impact machine, an Upton Lewis endurance tester, an electrically driven bar bender for bars up to 2½ inches in diameter, a Brinell hardness tester, a wire tester, a transverse bending machine for cast-iron arbitration bars and other short demonstration beams, a 9-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 telemeter strain gage, one Huggenberger extensometer, one Martens mirror strain gage, one electrical micrometer gage, one contact micrometer gage, several Berry gages, one vertical and one horizontal portable seismograph.

CURRICULUM IN ENGINEERING MECHANICS AND REQUIREMENTS FOR GRADUATION

The following curriculum leading to the degree of Bachelor of Science in Engineering (Engineering Mechanics) has been provided to meet the increasing demand from industry for graduates with the thorough theoretical grounding in mechanics and mathematics needed to cope with difficult engineering problems of research type.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
*Nontechnical Electives	6
Math. 3, 4, 36, 37, and 39	18
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Economics 53 and 54	6
Total	68

* See section 51.

b) *Secondary Courses*	*Hours*
Surveying 4	2
Eng. Mech. 1, 2, 2*a*, 3, 4	14
Elec. Eng. 2*a*	4
Civil Eng. 2	3
Mech. Eng. 3	4
Total	27

c) *Advanced Courses*	
Technical Group, in some specified technical engineering department, including an advanced design course; approximately	13
Eng. Mech. (advanced)	16
Math. 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 head 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. 36 and Phys. 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. *Prerequisites: Eng. Mech. 1, and preceded or accompanied by Math. 37.* 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, gyroscopy, and work and energy. Recitations, lectures, problems. *Prerequisites: Eng. Mech. 1 and Math. 37.* Three hours credit. Each semester.

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

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. 37.* Three hours credit. Each semester.

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. Letters, laboratory, reports. *Prerequisite: Eng. Mech. 2.* Two hours credit. Each semester.

7. **Research in Testing Materials.** *Prerequisite: Eng. Mech. 2.* Credit to be arranged. Each semester.

8. **Advanced Dynamics.** Advanced dynamics of rigid bodies in systems of engineering interest. La Grange's equations. *Prerequisite: Eng. Mech. 3.* Two hours credit. Second semester.

9. **Advanced Strength of Materials. Elastic Energy Theory (Least Work).** Elastic curves as influence lines. Analysis of redundant structures, trusses, frames, bents, curved beams (hair springs, arches). Lectures, problems. *Prerequisite: Eng. Mech. 2.* Three hours credit. Each semester.

10. **Research in Strength of Materials.** Special problems involving laboratory tests, and application of theory in engineering mechanics. Credit to be arranged. Each semester.

10a. **Research in Theory of Elasticity.** Special problems involving application of theory and experimental investigation. Credit to be arranged. Each semester.

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. Each semester.

12. **Vibration Problems in Engineering.** Vibration of systems with one degree of freedom. Balancing of rotating machines; calculation 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. First semester.

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. First semester.

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 on elastic foundation. Designed principally for graduate students. *Prerequisites: Eng. Mech. 1, 2, and 3, and Math. 105.* Two hours credit. Second semester.

14. **Stress Analysis in Machine Parts.** Stress concentration in tension and compression produced by fillets and holes. Photoelastic method of studying stress concentration. Stresses in shafts of variable cross-section. 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. Second semester.

15. **Theory of Thin Bars, Thin Plates, and Slabs.** With application to the solution of such problems as bending of beams on elastic foundation and track stresses; combined bending and tension on 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 highway and structural engineering. Designed principally for students interested in structural design. *Prerequisite: Eng. Mech. 2.* Three hours credit. First semester.

16. **Seminar in Engineering Mechanics.** Credit to be arranged. Each semester.

17. **Library Research Seminar.** Devoted to the history and development of modern engineering mechanics. *Prerequisites: Eng. Mech. 1 and 2.* One or two hours credit. Second semester.

18. **Ductility of Materials (Theory of Limit Design).** The theory of strength and resistance of structures predicated upon the ductility of materials and buckling strength of members. *Prerequisite: Eng. Mech. 2.* Two hours credit. Second semester.

20. **Mechanical Properties of Metals.** Attention is directed to the general principles rather than to a description of established, standardized methods of testing materials and manipulating apparatus. Tension and compression tests. Lüders' lines. Strain hardening. Residual stresses due to plastic flow of metals. Types of failures. Time effect and hysteresis. The fatigue of metals under cycles of stress. Causes of fatigue. Mechanical properties of metals at high temperatures. Various strength theories. Working stress. *Prerequisites: Eng. Mech. 2 and Math. 105.* One hour credit. Summer Session.

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 La Grange. *Prerequisites: Eng. Mech. 3 and Math. 105.* One hour credit. Summer Session.

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 to the design of columns. Stability of I-beams. Stability of thin plates under compression and shear. Applications in plate girder design. Stability of thin-walled structures. *Prerequisites: Eng. Mech. 1, 2, and 3, and Math. 105.* Two hours credit. Second semester.

26. **Plasticity.** Elastic and plastic deformation. The mechanism of plastic deformation. Strain hardening. Theory of strength. Plastic deformation in tension and compression. Plastic deformation in torsion and bending. Plastic flow in hollow cylinders. Plastic flow in rotating discs. Plane plastic flow. Creep at high temperature. *Prerequisites: Eng. Mech. 1, 2, and 3, and Math. 105.* Two hours credit. Second semester.

Summer Session

Courses 1, 2, 2*a*, 3, 4, 8, 9, 12, 13*a*, 14, 20, and 21, or similar courses, will be given during the Summer Session.

78. GEODESY AND SURVEYING

Professor JOHNSTON; Associate Professors CAREY and BOUCHARD; Assistant Professors MCFARLAN, YOUNG, and BLEEKMAN.

Geodesy and Surveying, broadly speaking, are the sciences which have to do with the making, recording, and reduction of observations and measurements for determining the relative positions of points on or near the earth's surface. Geodetic theory is applied when the work is influenced by the size and shape of the earth. The practice of plane surveying is confined to small areas.

Geodesy is employed in locating the natural and artificial features of large areas of the earth's surface both on land and at sea. Field data are obtained by a combination of astronomical and terrestrial measurements. These involve precise triangulation systems, level circuits, and topographic studies. The physical and mathematical sciences are relied upon, both in the making of observations and in the interpretation of data. Some of the data thus obtained are recorded in condensed form as maps, which are of great practical value in connection with military and commercial operations. While the main lines of geodetic work are in progress, much information from related fields of science is obtained. Geodetic measurements were made to determine the shape and size of the earth as early as 276 B.C. The science, as we know it today, owes much to Newton, Laplace, Legendre, Gauss, and other investigators of the past few centuries. The field is now sufficiently definite and stable to offer attractive opportunities to well-trained men.

Topographic Surveying.—Extensive topographic work is performed by the United States Coast and Geodetic Survey, the United States Geological Survey, and the Corps of Engineers of the Army. Modern city plans are preceded by topographic studies which often include large areas lying beyond the existing municipal limits. Geodetic principles are often applied here.

Boundary Surveying.—The location of boundaries, the placing of monuments, and the filing of permanent records, including notes, computations, maps, etc., is probably the most universal branch of surveying. Every property owner and every political division of the nation has a direct interest in the location of property lines. With the increase in population and in land values, this phase of surveying is becoming more important. The solution of many problems in this field requires a knowledge of geodesy and land law.

Legal and Administrative.—Many problems with which the surveyor is confronted make it necessary that he concern himself with the legal and administrative principles relating to boundary surveying, the registration of land titles, land laws, and riparian boundaries.

The Courses offered by the Department aim to give the student of geodesy and surveying a fundamental training that will enable him to enter any branch outlined above. In order that the Department may keep in touch with practice and aid graduates in securing employment, it maintains contact with organizations which specialize in surveying work.

The Department of Geodesy and Surveying, one of the oldest departments of the College of Engineering, became, by action of the Board of Regents in 1921, a professional department offering a curriculum leading to the degree of Bachelor of Science in Engineering (Geodesy and Surveying). The curriculum provides such training in pure and applied science as may be necessary to interest students in geodetic work, higher surveying, astronomy, and mathematics. Graduate work leading to the professional degree of Geodetic Engineer is done under the direction of the Graduate School. The Department is convinced that only by the mastery of fundamentals may students develop that proficiency which ultimately stimulates love of work. The Department, representing one of the oldest fields of science, accepts this basic idea as its guiding rule. The aim is to help the individual acquire a foundation upon which he can continue to build in the future, rather than to develop an immediately marketable efficiency. Students of geodesy and surveying are therefore urged to choose their elections in such a manner as to broaden and strengthen their foundations in science, pure and applied. They are also encouraged to become interested in the humanistic sciences and philosophy. Even those of the highest scientific attainment are obliged to deal with others, and they should always appreciate their responsibilities to society. The aid of the Department is always available to those students who are in doubt as to electives which would be most helpful to them.

Equipment for Surveying.—The equipment for surveying includes transits, levels, rods, tapes, etc. Special instruments are provided for triangulation and precise levels. Plane tables for topographic surveys, cameras for surveying and engineering photography, and a chronometer and sextants for use in astronomical work are available. The Department possesses barometers, hand levels, plotting instruments, and various kinds of small incidental equipment.

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.

There are but few districts east of the Missouri River where field work in surveying is not handicapped by growths of brush and trees or by buildings and other structures. In February, 1929, the University of Michigan purchased lands in Jackson's Hole, Wyoming, for a new camp for surveying work. The new location was occupied for the first time during the following summer. It is in the valley of the Hoback River, twenty miles south and east of the town of Jackson and seventy-five miles south of Yellowstone Park. An excellent road—U.S. 187—connecting the Lincoln Highway at Rock Springs, Wyoming, with the Yellowstone Park, passes within a mile of the camp site.

The Wyoming lands offer the following advantages: first, an almost unlimited area of open country; second, an adequate supply of water under gravity pressure; third, an ideal climate, with little cloudy weather, no oppressive heat, and cool nights; fourth, proximity to an improved highway which leads to the celebrated Jackson's Hole country, the Yellowstone Park, and to agricultural districts where mess supplies may be purchased; fifth, the beautiful mountains surrounding the valley of the Hoback River in which the camp is situated, which offer unlimited opportunities for exploration. The camp is within thirty-five miles of the celebrated Teton Mountains and seventy-five miles from the southern boundary of the Yellowstone Park.

All of the buildings at the camp have concrete floors and sheet steel superstructure. In addition to residence buildings, fourteen feet square, larger buildings for general use have been erected. Among these are a dining room and kitchen, a keeper's residence, instrument room, shop, and a garage. Each residence building is furnished with a stationary washbowl, a coal stove, bed and bedding, four chairs, and a table. The camp has electric lights, hot and cold showers, and a modern sanitary system.

In 1938 instruction begins on Monday, June 27. Students should reach the camp on the preceding Saturday. Instruction runs for five and one-half days per week for eight weeks. Field conditions are so satisfactory that all instruction may relate to surveys for a single important subject. The camp is open to students coming adequately prepared from any college of engineering. 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. Eight hours of credit are given those who complete the regular course, Surveying 3.

Students should be able to complete the camp work at a cost of about $150. The University fee is $45. The cost of board is approximately $55. This leaves a balance of practically $50, which should cover round-trip transportation costs from almost any part of the United States and leave a balance which would enable stu-

dents to visit the Yellowstone Park and other points of interest. The estimated cost of travel is made on the assumption that from three to four persons travel together in one car.

Further information may be obtained by writing to Professor C. T. Johnston, 209 West Engineering Building, Ann Arbor, Michigan. Camp Davis mail address is Jackson, Wyoming; freight and express, Victor, Idaho.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 Science.—The attention of prospective students in geodesy and surveying is called to the Reserve Officers Training Corps. Those who consider taking military science are urged to enroll at the beginning of their course. For further details see section 66.

CURRICULUM IN GEODESY AND SURVEYING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Geodesy and Surveying) are required to complete the curriculum detailed below. For the definition of an hour of credit see section 50.

		Hours
a)	*Preparatory Courses*	
	English 1, 2, 3, and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Nontechnical Electives	6
	Math. 3, 4, 36, 37, 39	18
	Physics 45, 46	10
	Chem. 5E	5
	Drawing 1, 2, 3	8
	Metal Proc. 2 and Chem. Eng. 1	5
	Total	62
b)	*Secondary and Technical Courses*	
	Eng. Mech. 1, 2, 2*a*, 3, 4	14
	Astronomy 31, 35	5
	Economics 53, 54	6
	Geology 11	4
	Elec. Eng. 2*a*	4
	Mech. Eng. 3	4
	Civil Eng. 2, 2*a*, 10	9
	Surveying 1, 2, 3, 5, 21	19
	Geodesy 1	3
	Total	68

Summary: *Hours*

Preparatory Courses	62
Secondary and Technical Courses	68
Electives	10
Total	140

PROGRAM

FIRST YEAR

FIRST SEMESTER COURSES	HOURS	SECOND SEMESTER COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Math. 36 (Calculus I)	4	Math. 37 (Calculus II)	4
Economics 53	3	Economics 54	3
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 1	3
Electives	2	Electives	2
	16		17

THIRD YEAR

Surveying 1	3	Surveying 2	4
Math. 39 (Diff. Equations)	2	Surveying 5	2
Eng. Mech. 2	4	Astronomy 35	2
Eng. Mech. 2*a*	1	Eng. Mech. 4	3
Eng. Mech. 3	3	Civil Eng. 2	3
Astronomy 31	3	Geology 11	4
	16		18

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

SUMMER SESSION

Surveying 3 8

FOURTH YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Surveying 21	2	Geodesy 1	3
Civil Eng. 2*a*	3	Mech. Eng. 3	4
Civil Eng. 10	3	Electives	9
English (Group III)	2		
Elec. Eng. 2*a*	4		
Electives	3		
	17		16

COURSES IN SURVEYING

1. **Surveying.** Fundamental theory and practice; note keeping; verniers; linear measurements; angle reading; traverse surveying; computing areas; straight line; circular curves; differential leveling; continuous leveling; profile; grade stakes; vertical curve. Lectures, text assignments, recitations, three four-hour periods of field practice. Required of students of geodesy and surveying and civil engineering. *Prerequisite: Math. 4.* Three hours credit. Each semester.

2. **Surveying.** Topographic field work; stadia; plane table; mapping from transit and plane table notes; theory of cross-sectioning and earthwork calculation; triangulation; adjustment, design, and care of instruments. Lectures, text assignments, recitations, field practice, drawing. Two recitations and two four-hour field or drawing periods. Required of students of geodesy and surveying and civil engineering. *Prerequisite: Surv. 1.* Four hours credit. Each semester.

3. **Surveying.** See Summer Session courses.

4. **Surveying.** Elementary theory and practice; use of instruments; reading verniers and angles; running straight lines; traverse survey; computing areas; leveling; profile; grade stakes; note keeping. Lectures, text assignments, one recitation, and one four-hour field period. Required of all students in aeronautical, marine, and mechanical engineering. *Prerequisite: Math. 4.* Two hours credit. Each semester.

5. **Least Squares.** Theory of least squares; adjustment and comparison of data; computation of triangulation systems; determination of empirical formulae. Lectures, text, problems, recitations. *Prerequisite: Math. 37.* Two hours credit. Each semester.

6. **Surveying.** See Summer Session courses.

7. **Municipal Surveying.** Surveys for street location, fixing grades, paving, sewers, property lines; subdivision planning and laying out; state laws relating to municipal surveys. Lectures, text, drawing, one recitation and one four-hour field period. *Prerequisite: Surv. 3.* Two hours credit. Each semester.

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

12. **Surveying.** Similar to Surveying 1 with drawing work added. Designed for forestry students. Lectures, text, recitations, field. Three four-hour field periods, and one one-hour recitation period. *Prerequisite: Math. 12.* Four hours credit. First semester.

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

21. **Photography. Basic Course.** Development of photography; cameras and equipment; the nature of light and lenses; exposure of the sensitive material; theory of development; organic developing agents; development of negatives; printing; enlarging and reducing; lantern slides; fixing and washing; defects in negatives; reduction and intensification. Lectures, reference work, one hour recitation and one four-hour laboratory period. *Prerequisites: elementary chemistry and physics.* Two hours credit. Each semester.

22. **Photography and Camera Surveying.** Camera surveying; mapping; principles of aerial photography; stereoscopy; principles of photoengraving; infrared photography; photomicrography; photomacrography; natural color photography; color work; toning of developed images; printing with salts of iron and platinum; orthochromatics; sensitometry. Lectures, reference work, one hour recitation, and one four-hour laboratory period. *Prerequisites: Surv. 21 and Surv. 2 or 13.* A section in advanced photography is offered for students having no training in surveying. Arrangements should be made with instructor for admission into this section. Two hours credit. Each semester.

23. **Map Projections and Sketching.** Map projections with special reference to the polyconic system; exercises in topographic mapping and sketching. Lectures, reference work, recitations, problems. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Three hours credit. First semester.

31. **History of Administrative Departments.** History and organization of national and state departments which conduct extensive surveys. Lectures, reference work. *Prerequisite: Surv. 3.*

Open to fourth- and fifth-year students only. Two hours credit. First semester.

32. **Land Law.** Legislation relating to registration of land titles and estates; acquiring of title to property; essential elements of deeds; application. Lectures, reference work. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Three hours credit. First semester.

33. **Land Law.** Law of boundaries; adverse possession; prescription and prescriptive rights; easements and rights of way. Lectures, reference work. *Prerequisite: Surv. 32. Open to fourth- and fifth-year students only.* Three hours credit. Second semester.

34. **Registration of Land Titles.** Legislation relating to the registration of land titles; Torrens Act of Australia and modifications as adapted to conditions of other countries. Lectures, reference work. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Three hours credit. Second semester.

35. **Boundary Surveys.** Boundary surveys from a legal standpoint; boundary surveys in this country and abroad; problems relating to the establishment of boundaries uncertain due to obliteration of monuments, errors in surveys, inaccurate descriptions in deeds, or to other causes. Lectures, reference work. *Prerequisite: Surv. 3 Open to fourth- and fifth-year students only.* Three hours credit. Second semester.

36. **Riparian Boundaries.** Uncertainty of riparian boundaries as now defined by court decision under the Common Law; method of definite determination of riparian boundaries. Lectures, reference work. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Three hours credit. Second semester.

COURSES IN GEODESY

1. **Geodesy.** Introductory course; history; elements of modern practice and its application to several branches of surveying. Lectures, text, recitations. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Three hours credit. Second semester.

2. **Geodesy.** Methods employed and field covered by the United States Coast and Geodetic Survey. Lectures, reference work. *Prerequisite: Geod. 1. Open to fourth- and fifth-year students only.* Two hours credit. Second semester.

Summer Session

3. **Surveying.** Adjustment of instruments; astronomical applications, time, azimuth, latitude, and longtitude; lines of communication, circular and easement curves, profiles, topography, grades, cross-sections; baseline measurement; triangulation; public land surveys; topography; project surveys; computation of field data; making of

maps and diagrams; preparation of permanent records of work performed; camp construction and maintenance and many things which relate to the welfare of those who live in the open. Field problems, office work, five and one-half days a week. *Prerequisites: Surv. 1 and 2, or 12 and 13.* See section 19 relating to fees. The prerequisite for Surveying 3, two hours credit in practical astronomy, may be met by electing two hours of Surveying 6 given at Camp Davis. Eight hours credit. Summer Camp.

4s. **Surveying.** Use of instruments, same as Surveying 4; given at Ann Arbor. Lectures, text, two recitations, and two four-hour field periods. *Prerequisite: Math. 4.* Two hours credit. Summer Session.

6. **Surveying.** Special advance work can be provided for those who have received credit in Surveying 3. Given only at Camp Davis. Credit, two to eight hours, depending upon the character of the work.

79. MATHEMATICS

Professors HILDEBRANDT, BRADSHAW, FIELD, and LOVE; Associate Professors AYRES, HOPKINS, and POOR; Assistant Professors CHURCHILL, ROUSE, DUSHNIK, and MILLER; Mr. KAZARINOFF, Dr. SHANKS, Dr. THRALL, Dr. KALES, and Mr. RAINVILLE.

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 the 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; the second, to differential and integral calculus. An introduction to differential equations is required in certain departments. Students who do not have credit in trigonometry are required to complete this subject 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 of 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 curricula. 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:

		Hours
a)	*Preparatory Courses*	
	English 1, 2, 3, and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Nontechnical Electives (preferably French or German)	8
	Math. 3, 4, 36, 37	16
	Physics 45, 46	10
	Chem. 5E	5
	Drawing 1, 2	6
	Met. Proc. 2 and Chem. 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. 2*a*	4
	Mech. Eng. 3	4
	Total	18
c)	*Advanced Courses*	
	Options in Mathematics including 103 or 105 and 106, and 151 or 153	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
	Total	62
Summary:		
	Preparatory Courses	60
	Secondary Courses	18
	Advanced Courses	62
	Total	140

Students in chemical engineering or in metallurgical engineering who become candidates for degrees in chemical engineering and mathematics or in metallurgical engineering and mathematics are permitted to make the following substitutions:

1. They may substitute three hours of chemistry (beyond Chem. 5E) for Eng. Mech. 3.

2. Students in chemical engineering may select any two of the following three substitutions. Metallurgical engineers may make only substitutions (*a*) and (*b*).

a) Substitute advanced mathematics for Mechanical Engineering 2*a*, three hours credit.

b) Substitute advanced mathematics for Economics 54 or 173, three hours credit.

c) Substitute advanced mathematics, four hours, and Chemistry 63, four hours, for Chemistry 67E and 69E, eight hours credit.

3. In special cases other substitutions, approved by both the Chemical and Metallurgical Engineering Department and the Mathematics Department, may be made.

COURSES IN MATHEMATICS

*3. **Algebra and Analytic Geometry.** Review of exponents, radicals, quadratic equations, systems of equations involving quadratics; theory of equations including Horner's method; determinants; complex numbers; curve tracing and locus problems in Cartesian and polar coördinates; straight line; circle. Four hours credit. Each semester.

4. **Plane and Solid Analytic Geometry.** Conic sections; change of axes; properties of conics involving tangents, diameters, asymptotes, parametric equations; surface tracing and locus problems in space; direction cosines; plane; straight line; quadric surfaces; space curves. Four hours credit. Each semester.

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

*8. **Trigonometry.** Radian measure; coördinate system; trigonometric ratios; trigonometric identities and equations; inverse functions; graphs; reduction and addition formulas; laws of sines, cosines, and tangents; theory and use of logarithms; orthogonal projections; solution of triangles. Two hours credit. Each semester.

* Students entering with credit in trigonometry will take Course 3. Students entering without trigonometry will take Course 7, except that those whose high-school records show unusual proficiency in mathematics may take Courses 3 and 8 instead. Permission to do this must be obtained from the Department of Mathematics at the time of classification.

9. **Solid Analytic Geometry.** Surface tracing and locus problems in space; direction cosines; plane; straight line; quadric surfaces; space curves. Two hours credit. Each semester.

36. **Calculus I.** Functions; limits; continuity; derivative; differentiation of algebraic functions; geometric applications; trigonometric, exponential, and logarithmic functions; differential; curvature; time rates; indeterminate forms; curve tracing; introduction to the indefinite integral. Four hours credit. Each semester.

37. **Calculus II.** Indefinite integral; 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. 36, or equivalent.* Four hours credit. Each semester.

39. **Differential Equations.** Simple types of ordinary equations of the first and second order; linear equations with constant coefficients; applications to geometry and mechanics. *Prerequisite: Math. 36.* 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. 39, 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. 37.* Two hours credit. First semester.

106. **Advanced Differential Equations.** Solutions 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 by the principle of areas; determination of weights of data obtained by different observers; graduation of weighted data; differential equations of chemical reactions of the first and of the second orders; graphical solution of differential equations. This is mostly a problem course planned for chemical engineers. Three hours credit. Each semester.

110. **Elementary Course in Complex Variables.** Operations on complex numbers; limit; convergence; continuity; derivative; conformal representation; integration; Cauchy theorems; power series; elementary functions; singularities; applications to engineering and mathematical physics. *Prerequisite: calculus.* Three hours credit. Second semester.

141. **Analytic Mechanics.** An introduction to theoretical mechanics and to vector methods in mechanics. No previous knowledge of vectors is assumed, the fundamental portions of vector analysis being developed as required in the study of the following topics in mechanics: rectilinear and curvilinear motion of a point; velocities and accelerations in the rigid body; relative motion; statics of a rigid body. Three hours credit. First semester.

142. **Analytic Mechanics.** Continuation of Math. 141. Continued study of theoretical mechanics by vector methods. The differential and integral vector operations developed and employed in the study of theory of attractive forces; free and constrained motion of a particle; free and constrained motion of a rigid body; general principles of mechanics. Three hours credit. Second semester.

145, 146. **Celestial Mechanics.** Rectilinear motion of a particle; gravitational theory of the sun's heat; central forces; potential and attraction of bodies; problem of two bodies. Problems of three and *n* bodies; geometric introduction to the lunar theory; general perturbations; introduction to periodic orbits. Two hours credit each. Throughout the year.

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's Series and Harmonic Analysis.** The development of Fourier's series, Legendre's coefficients, and Bessel's functions, and their applications to certain problems in mathematical physics. Three hours credit. Each semester.

153, 154. **Advanced Calculus, I and II (Longer Course).** Review of fundamental concepts; continuity; definite and improper integrals; vector analysis; partial differential equations; calculus of variations; functions of a complex variable; elliptic integrals; Fourier series; Bessel functions. *A student may not receive credit for both Math. 151 and 153, but 154 may follow 151.* Three hours credit each. First semester, Course 153; second semester, Course 154.

169. **Graphical Methods.** Graphical representation of functions; construction of graphical charts; graphical solution of equations; a study of the principles of differential and integral calculus by 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.

175. **Theory of the Potential.** 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 the Green function. Three hours credit. Second semester.

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

248. **Theory of Elasticity.** This is the general mathematical theory of elasticity. The course is designed to enable students to read A. E. H. Love on this subject. Three hours credit. Second semester.

249. **Methods in Partial Differential Equations.** The solution of boundary-value problems in the partial differential equations of engineering and physics by various methods, viz. the use of series of orthogonal functions, Green's functions, Fourier transformation and the method of Ritz. Other integral transformation methods, particularly the Laplace transformation and its connection with operational calculus. Three hours credit. Second semester.

Summer Session

Courses 3, 4, 8, 36, 37, 103, 151, 152, 169, 170, 176, and 249, or similar courses, will be offered in the Summer Session.

80. MECHANICAL ENGINEERING

Professors EMSWILER, BURSLEY, HAWLEY, LAY, SHERZER, KEELER, GORDY, and VINCENT; Associate Professors NICKELSEN, MICKLE, GOOD, MARIN, and LLOYD; Assistant Professors WATSON, KESSLER, CALHOON, and KOHLER; Instructors SPOONER and BOLT.

Mechanical Engineering is that branch of engineering which, broadly speaking, covers the fields of heat, power, design of machinery, industrial management, and manufacturing problems. Mechanical engineering may be divided into the following branches.

Steam Power Engineering deals with the theory, design, construction, and operation of the various forms of prime movers using steam as the motive power, and their applications in the modern power house. The problems of combustion of fuels, the application of power and steam in industrial plants, determination of power costs, and similar subjects, may be included under this heading. This branch is so closely allied with electric power engineering that a knowledge of both is essential to the practicing engineer in this field.

Internal Combustion Engineering covers the theory, design, construction, and operation of the various types of engines using gas, oil, or gasoline to generate the motive power; the different types

of gas producers, and the application of this form of engine to the generation of power for many purposes. Because of the present-day use of the automobile and airplane, and the development of the oil industry, the field has become very important in recent years.

Hydromechanical Engineering, one of the oldest branches of mechanical engineering, deals with the theory, design, construction, installation, testing, and operation of water wheels, water turbines, and centrifugal and reciprocating pumps.

Heating, Ventilating, and Refrigerating Engineering are included under one general heading because of the similarity in the type of problem involved. Broadly speaking, this group includes the theory, design, installation, testing, and operation of heating, ventilating, air-conditioning, and refrigerating plants. Among the specific applications would be the heating and ventilating requirements of buildings for various uses. Problems relating to compressed air are also considered in this group.

Automobile Engineering.—The University of Michigan has a strategic location at the center of the automobile industry in this country, and particular attention has been directed toward the development of courses in this branch of engineering. Work in this field covers the general principles of operation, theory and design of the automobile engine and other chassis units, and laboratory and road tests of the various component parts of the automobile or of the complete automobile itself.

Industrial Engineering deals with industrial plant operation and management, efficiency and safety methods, production, and the business side of manufacturing. This branch of engineering, while old in principle, has not been generally recognized until recent years, but now commands an important place in the engineering field.

Machine Design.—While design is included in practically all branches of mechanical engineering, and is therefore a necessary adjunct to those branches, there is also the general field for the man who wishes to follow machine design either as technical designer or as a manufacturer of machinery. The very general application of automatic machinery to manufacturing methods has established a definite need for good designers.

The Department of Mechanical Engineering of this University endeavors to give the student a thorough training in the fundamental principles of the basic mechanical engineering subjects. Most of the time of the first two years, and a part of the third year, is spent in a study of the foundation courses such as mathematics, economics, English, physics, chemistry, drawing, and mechanics. In the third and fourth years, required courses in heat engines, machine design, mechanical laboratory, thermodynamics, hydraulics, and power

plants supplement the foundation courses. The Department recognizes the fact that no student can properly expect to specialize in any branch of engineering in four years of college work. The fourth year, however, allows some opportunity, if desired, for selection of special courses in one or more of the mechanical engineering branches. Graduate work is encouraged, and a number of advanced courses are offered for those who plan to spend more than four years, or for graduate students from this and from other universities. It has been the policy of this department to keep in close touch with the actual needs of the graduate student, and as far as possible to give him the training that will fit him for the immediate future. Most of our graduates are absorbed immediately by the industries, and a friendly relation of mutual benefit is always maintained with these industries. Graduate mechanical engineers very rapidly rise to positions of responsibility in the industries, and a broad general course as well as a technical course is of great value to them in their advancement. For this reason students are urged to elect courses in several departments of the Engineering College, and also in the College of Literature, Science, and the Arts.

FACILITIES FOR INSTRUCTION

It is recognized by this department that the principal benefits to be derived from a college training are dependent more upon the character of the instruction than upon physical equipment. The importance of certain apparatus for purposes of illustration, demonstration, and testing is, however, apparent in some lines of work, and the department aims to include a sufficient amount of laboratory instruction to supplement properly the work of the classroom.

The Mechanical Engineering Laboratory is located in the West Engineering Building and has a floor space of approximately 13,000 square feet. It is devoted to experimental work in connection with the testing of engines, boilers, pumps, fans, air compressors, hydraulic machinery, and internal combustion engines. The very complete and modern Washington Street power plant which furnishes heat and power to the University buildings, is also available for inspection and special investigations by advanced students. (For description see section 41.) Occasionally tests are made of outside plants in the vicinity of Ann Arbor.

The laboratory, as a whole, comprises all the equipment utilized for illustration of the theory involved in mechanical engineering and for experimental work of both standard and research nature. The laboratory is well equipped with power machines of all kinds, which furnish the means of instruction in the principles of testing. Separate laboratory instruction is given along the lines of automotive work, and that part of the equipment applying especially to this division is segregated to form the automotive division of the laboratory.

For hydromechanical work the laboratory is equipped with a pair of 600-cubic-foot tanks on scales, a large Duplex pump, a Doble

tangential water wheel, two Rees Roturbo pumps, three single-stage centrifugal pumps, two electric dynamometers arranged for direct connection to centrifugal pumps, and all necessary accessories for testing.

The Automotive and Internal Combustion Engine Laboratory is located in the Engineering Annex. Its function is to familiarize the student with testing equipment and procedure and to allow him to determine for himself many of the facts and principles studied in the classroom. The operating equipment includes some twenty-five internal combustion engines, operating on the Otto or Diesel cycle, which are typical examples of those used in automobiles, trucks, tractors, railcars, airplanes, marine service, and Diesel power plants. These engines, as well as several trucks, cars, and chassis, are made available through the coöperation of the manufacturers and the Federal Government.

The test equipment includes six electric dynamometers with capacities varying from 30- to 300-horsepower, water and fan brakes, and several engine test stands of the reaction type. A chassis dynamometer with 6-foot drums is available for tests of a complete motor vehicle. The N.A.C.A. universal test engine provides opportunity for study of the engine cycle and combustion. A full complement of auxiliary instruments is available for laboratory or road tests of the complete transportation unit or any of its component parts.

In the display or museum section may be found typical examples of automotive equipment, from complete chassis down to the smallest parts. This apparatus, mounted and sectioned to show clearly its construction and operation, is used for class demonstration and service as a permanent exhibit open to the public.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 Science and Tactics.—Students who plan to take courses in military 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 he proposes to take his degree. For information regarding the work in Military Science and Tactics see section 66.

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 four-year curriculum.

For the definition of an hour of credit see section 50.

FOUR-YEAR CURRICULUM

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing and Descriptive Geometry 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Metal Proc. 3, Foundry	4
Metal Proc. 4, Machine Shop	4
Economics 53, 54	6
Total	74

b) *Secondary and Technical Courses*	
Surveying 4, Use of Instruments	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 2, Machine Design	4
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 4, Hydraulic Machinery	3
Mech. Eng. 5, Thermodynamics	3
Mech. Eng. 6, Machine Design and Mechanism	4
Mech. Eng. 7, Laboratory, First Course	2
Mech. Eng. 8, Laboratory, Second Course	3
Mech. Eng. 9, Power Plants	3
Civil Eng. 2, Theory of Structures	3
Elec. Eng. 2*a*, D.C. App. and Cir.	4
Chem. Eng. 10, Utilization of Fuels	1
Total	50

Summary:

Preparatory Courses	74
Secondary and Technical Courses	50
Electives, Restricted and Free	16
Total	140

SELECTION OF ELECTIVE COURSES

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

a) *Restricted Electives:*

The student, unless taking the five-year mechanical and industrial curriculum, must elect one 3-hour design course from the following list: Mech. Eng. 9*a*, 11*a*, 15*a*, 16*a*, 17*a*, 20*a*, 25*a*, 30*a*, 31*a*. Of this group, Mech. Eng. 15*a* must be preceded or accompanied by Mech. Eng. 15. Mech. Eng. 30*a* and 31*a* must be preceded by the corresponding classroom course and by Mech. Eng. 29.

Students who elect a design course other than Mech. Eng. 15*a*, 30*a*, or 31*a*, must also offer credit for graduation in some additional mechanical engineering course from the following list:

Mech. Eng. 11, 13, 15, 16, 17, 19, 20, 25, 30, 31, 35, 55.

A combination of Mech. Eng. 15, 24, 24*a*, or 15, 27, 27*a*, will also fulfill the above requirement.

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

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Economics 53	3	Economics 54	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

SUMMER SESSION

Elec. Eng. 2*a*	4
Metal Proc. 3	4
	8

THIRD YEAR

Eng. Mech. 3	3	Eng. Mech. 4	3
Mech. Eng. 2	4	Mech. Eng. 5	3
Mech. Eng. 3	4	Mech. Eng. 6	4
a) Mech. Eng. 7 and Chem. Eng. 10	3	*a*) Metal Proc. 4 or	4
or		*b*) Mech. Eng. 7 and Chem. Eng. 10	3
b) Metal Proc. 4	4		
Nontechnical Electives	3	Nontechnical Electives	3
	(17) or 18		(17) or 16

FOURTH YEAR

Mech. Eng. 4 and 8	6	Mech. Eng. 9	3
*Mech. Eng.	2 or 3	†Mech. Eng	3
English from Group III	2	Other Electives	7 or 9
Civil Eng. 2	3		
Surveying 4	2		
Electives	3		
	18 or 19		13 or 14

FIVE-YEAR CURRICULUM IN MECHANICAL AND INDUSTRIAL ENGINEERING

A five-year curriculum, including courses in economics and business administration in addition to courses in mechanical engineering, is planned as described below. The degree of Bachelor of Science in

* To be selected from Mech. Eng. 11, 13, 15, 16, 17, 19, 20, 24, 25, 27, 30, 31, 35, 55.

† To be selected from Mech. Eng. 9*a*, 11*a*, 15*a*, 16*a*, 17*a*, 20*a*, 24*a*, 25*a*, 27*a*, 30*a*, 31*a*.

Engineering (Mechanical Engineering) is given at the end of the fourth year. For the fifth year, registration must be made in the Graduate School; on the successful completion of this year, the degree of Master of Science (Industrial Engineering) is awarded. *Courses listed in the fifth year cannot be elected during the undergraduate years.*

Subjects—First Four Years	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	8
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing and Descriptive Geometry 1, 2, 3	8
Metal Proc. 2, 3, 4, 7	12
Eng. Mech. 1, 2, 2*a*, 3, 4	14
Mech. Eng. 2, 3, 5, 6, 7, 8, 9	23
Factory Management, Mech. Eng. 20, 35, 36	8
Chem. Eng. 1, 10	4
Elec. Eng. 2*a*	4
Civil Eng. 2	3
Economics 53, 54, 121, 171, 172	15
Total	140

Subjects—Fifth Year	
Economics 175	3
Mech. Eng. 40, 42	6
Bus. Ad. 113, 161, 162, 202	12
Electives	9
Total	30

Electives. Students pursuing this program are urged to elect English 6, Report Writing, during the fourth year. Attention is further invited to the following courses which are of especial significance to industrial engineering:

Electrical Engineering 7*a* (Building Illumination) .....1 hour
Mechanical Engineering 25 (Heating and Ventilation)....2 hours

These courses may be elected during the fifth year.

PROGRAM IN MECHANICAL AND INDUSTRIAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

Second Year

Math. 36	4	Math. 37	4
Drawing 3	2	Physics 46	5
Economics 53	3	Economics 54	3
Physics 45	5	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Mil. Science	0 or 1	Mil. Science	0 or 1
	17 or 18		17 or 18

Summer Session

Metal Proc. 3	4
Mech. Eng. 2	4
	8

Third Year

Mech. Eng. 3	4	Mech. Eng. 5	3
Eng. Mech. 3	3	Mech. Eng. 8	3
Economics 171	3	Economics 172	3
Mech. Eng. 7	2	Mech. Eng. 6	4
Chem. Eng. 10	1	Eng. Mech. 4	3
Met. Proc. 4	4		
	17		16

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

† See note, section 56.

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

FOURTH YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Mech. Eng. 35	3	Metal Proc. 7	2
Mech. Eng. 9	3	Mech. Eng. 36	3
Elec. Eng. 2*a*	4	English	2
Economics 121	3	Mech. Eng. 20	2
*Nontechnical electives	4	*Nontechnical electives	4
		Civil Eng. 2	3
	17		16

FIFTH YEAR

Economics 175	3	Bus. Ad. 162	3
Bus. Ad. 161	3	Bus. Ad. 202	3
Mech. Eng. 40	3	Mech. Eng. 42	3
Bus. Ad. 113	3	Electives	6
Electives	3		
	15		15

COURSES IN MECHANICAL ENGINEERING

2. **Machine Design.** Application of theory of strength and resistance of materials to machine elements, including shafts, journals, bearings, keys, cotters, spur gearing, springs, thin-pressure vessels, fastenings, and the energy of flywheels Two recitations and two three-hour design periods a week. *Prerequisites: Drawing 3 and Eng. Mech. 2.* Four hours credit. Each semester.

2a. **Elements of Machine Design.** The application of the theories of strength and rigidity to machine elements, and a study of the transmission of power by them. This course covers keys and cotters, screw fastenings, power screws, shafts, rigid and flexible couplings, journals and bearings, gears, belts, clutches, brakes, and flywheels. Three one-hour recitations a week. *Prerequisite: Eng. Mech. 2. Not open to any student required to take Mech. Eng. 6 or any advance-design courses in the Department of Mechanical Engineering.* Three hours credit. Each semester.

3. **Heat Engines.** Elementary thermodynamics, fuels and combustion, and the principles involved in the application of heat to the

* For nontechnical electives, see section 51.

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 46, and Math. 36.* Four hours credit. Each semester.

3a. **Mechanical Engineering Laboratory.** An elective course for students who are not required to take Mech. Eng. 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. 3.* One hour credit. Each semester.

3c. **Heat Engines.** (For students in chemical engineering.) This course is similar in content to Course 3, but omits fuels and combustion, includes work on refrigeration and refrigerants, and stresses thermodynamics. *Prerequisites: Phys. 45 and 46, Math 36, and Chem. Eng. 2.* Four hours credit. Each semester.

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.

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

6. **Machine Design and Mechanism.** Design of machine parts, considering static and dynamic forces, critical speeds and the theory of elasticity. Studies and layouts of cams and followers, linkages, wrapping connectors, gear trains, clutches, and other mechanisms. Analytical and graphical problems. Two recitations and two three-hour design periods a week. *Prerequisite: Mech. Eng. 2.* Four hours credit. Each semester.

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. 3, and accompanied by Chem. Eng. 10.* Two hours credit. Each semester.

8. **Mechanical Engineering Laboratory.** Second Course. Experimental study of a steam turbine, Diesel engine, fan, steam

injector, air compressor, refrigerating plant, Unaflow steam engine, centrifugal pump, and impulse water turbine. Laboratory, computations, and a few reports; two periods of four and one-half hours each a week. *Prerequisites: Mech. Eng. 7, and preceded or accompanied by Mech. Eng. 5. Three hours credit.* Each semester.

9. **Power Plants.** A study of the engineering, operation, and economics of power plants. Lectures, recitations, and problems. *Prerequisite: preceded by Mech. Eng. 3. Open to senior and graduate students.* Three hours credit. Each semester.

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 the power house, and includes setting and piping plans for all the principal machines to be installed. Computations and drawing; two four-hour periods a week. *Prerequisites: Mech. Eng. 9 and Eng. Mech. 4.* Three hours credit. Second semester.

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; feedwater treatment; problems of design. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 3.* Three hours credit. First semester.

11a. **Design of Steam Generating Equipment.** This course covers the design of boilers of different types, including calculations and drawing of important details. Drawing, problems; two four-hour periods a week. *Prerequisite: Mech. Eng. 2. Not open to students below the senior year.* Three hours credit. Second semester.

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. About 20 per cent of the time is devoted to a study of the general principles of governing. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 5.* Three hours credit. First semester.

14. **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. *Prerequisite: preceded or accompanied by Mech. Eng. 3.* Three hours credit. Each semester.

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. *Prerequi-*

sites: Eng. Mech. 3, and preceded by Mech. Eng. 5. Three hours credit. Each semester.

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. 2 and Mech. Eng. 15.* Three hours credit. Each semester.

16. **Water Turbines.** A course covering 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. *Prerequisites: preceded or accompanied by Mech. Eng. 4.* Three hours credit. First semester.

16a. **Design of Water Turbines.** This course 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. 2.* Three hours credit. Second semester.

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. 4.* Three hours credit. Second semester.

17a. **Design of Pumping Machinery.** This course 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. 4 and 6. Preferably accompanied by Mech. Eng. 17.* Three hours credit. Second semester.

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. Second semester.

19. **Refrigeration and Air Conditioning.** A study of the theory, design, and construction of refrigerating equipment; characteristics of various refrigerants; the application of refrigeration to cold storage, ice-making, and air conditioning; the fundamental principles of air conditioning; air-conditioning equipment. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 5.* Three hours credit. Second semester.

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 in-

volved in the use of mechanical handling equipment and also to the effect on labor. Lectures, recitations, problems, reports, and plant inspection. *Prerequisite: Mech. Eng. 2.* Two hours credit. Each semester.

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. 2. Not open to students below senior year.* Three hours credit. First semester.

21a. **Design of Machine Tools.** A complete layout of a modern machine tool is made, and the type and form of material for each part is determined. Bearings, lubrication, clutches, motor mountings, controls, etc., are studied. Computations for strength and rigidity are based on the maximum power and cutting force anticipated. Complete power transmission for speeds and feeds are designed. Final manufacturing drawings include dimensions, tolerances, and allowances. Two four-hour periods a week. *Prerequisite: Mech. Eng. 6.* Three hours credit. Second semester.

22. **Research in the Mechanical Laboratory.** Opportunity for advanced experimental study along any line of work in which student may be specializing; consists of investigations for securing data on more difficult problems of mechanical engineering; student is left largely to own resources in planning and carrying out work. Laboratory. *Prerequisite: Mech. Eng. 8.* Two or three hours credit. Each semester.

23. **Hydraulic Machinery.** Opportunity for advanced experimental study along any line of work in which student may be specializing; consists of investigations for securing data on more difficult problems of hydromechanical engineering; student left largely to own resources in planning and carrying out work. Laboratory. *Prerequisite: Mech. Eng. 4.* Two or three hours credit. Each semester.

24. **Design of Diesel Engines.** The student studies current practice in oil engines and makes preliminary calculations for the principal dimensions of the type of Diesel engine which he chooses to design. He sketches the principal parts, determines the gas pressure and inertia forces, and the resultant bearing loads. Lectures, drawing. Two three-hour periods a week. *Preceded or accompanied by Mech. Eng. 15.* Two hours credit. First semester.

24a. **Design of Diesel Engines.** Continuation of Mech. Eng. 24. 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. *Prerequisite: Mech. Eng. 2 and Mech. Eng. 24.* Two hours credit. Second semester.

25. **Heating and Ventilation.** 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. 3.* Two hours credit. First semester.

25a. **Design of Heating and Ventilating Systems.** The student is given the usual data furnished the heating and ventilating engineer. He then makes a layout of piping, ducts, auxiliary apparatus with computations for the size of principal equipment. Two four-hour periods a week. *Prerequisite: Mech. Eng. 3.* Three hours credit. Second semester.

26. **Aircraft Power Plants—Experimental Tests.** An experimental study of aircraft engines and their operation. Practice in the use of test apparatus and in test methods. Determination by test of the characteristic performance of engines of both the carbureted and the compression ignition type, together with the effect of such factors as speed, spark timing, mixture ratio, compression ratio, and the use of various fuels. *Prerequisites: Mech. Eng. 7 and Mech. Eng. 14.* Three hours credit. Each semester.

27. **Design of Aircraft Engines.** The student studies current practice in aircraft engines and makes preliminary calculations for the principal dimensions of the type of aircraft engines which he chooses to design. He sketches the principle parts, determines the gas pressure and inertia forces and the resultant bearing loads. Lectures, drawing. Two three-hour periods a week. *Preceded or accompanied by Mech. Eng. 15.* Two hours credit. First semester.

27a. **Design of Aircraft Engines.** Continuation of Mech. Eng. 27. 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. *Prerequisite: Mech. Eng. 2 and Mech. Eng. 27.* Two hours credit. Second semester.

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, operation and control. Lectures, recitations, laboratory demonstrations. *Not open to students below junior year.* Three hours credit. Each semester.

30. **Automobile and Truck Engines.** The student selects the type of car or truck; makes expectancy curves for engine performance; then computes the dimensions and sketches principal parts. Lectures, problems, drawing. Two four-hour periods a week. *Prerequisites: Mech. Eng. 6 and 29.* Three hours credit. First semester.

30a. **Design of Automobile and Motor Truck Engines.** Continuation of Course 30. Lectures, assembly drawing and details. Two

four-hour periods a week. *Prerequisite: Mech. Eng. 30.* Three hours credit. Second semester.

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. 6 and 29.* Three hours credit. First semester.

31a. Design of Automobile and Motor Truck Chassis. Continuation of Course 31. Lectures, assembly drawings, and details. *Prerequisite: Mech. Eng. 31.* Three hours credit. Second semester.

32. Automotive Laboratory. An experimental study of automobile and aircraft engine construction, horsepower, fuel economy, thermal efficiency, mechanical efficiency, heat balance, indicator cards, carburetion, compression ratio, and electrical systems. Road tests of car performance include speed range, acceleration, braking, and fuel mileage. Laboratory, reports. Two periods of four and one-half hours each week. *Prerequisites: Mech. Eng. 7 and 29 or 15.* Three hours credit. Each semester.

33. Advanced Automobile Testing and Research. An opportunity for advanced experimental and research work. The student is left largely to his own resources in planning apparatus and in carrying out the work. Laboratory, reports. *Prerequisite: Mech. Eng. 32.* Two or three hours credit. Each semester.

34. Advanced Automobile Design and Research. Special problems in the design of some automobile or truck unit. Drawing. *Prerequisites: Mech. Eng. 30 and 31.* Credit and hours to be arranged. Each semester.

35. Factory Management. This course deals with management problems and methods involved in the operation of manufacturing institutions. The topics considered are: 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 freshmen and sophomores.* Three hours credit. Each semester.

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 coöperating manufacturing plant constitute the work of the course. *Prerequisite: Mech. Eng. 35.* Three hours credit. Second semester.

37. Special Topics on the Internal Combustion Engine. This course affords the student an opportunity of investigating certain

features of the theory, design, and construction of internal combustion engines according to his interests. Reading, reports. *Prerequisite: Mech. Eng. 15.* Two hours credit. Each semester.

38. **Internal Combustion Engineering.** Research work on Diesel or other types of internal combustion engines. Laboratory. *Prerequisites: Mech. Eng. 15 and 8 or 32.* Credit and hours to be arranged. Each semester.

39. **Internal Combustion Engineering.** Research design of parts or units requiring special study. *Prerequisite: Mech. Eng. 15a, 24a, or 27a.* Credit and hours to be arranged. Each semester.

40. **Factory Management—Field Work.** The principles of production developed in Mech. Eng. 35 and 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. First semester.

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. Each semester.

42. **Factory Management—Purchasing.** This course consists of a comprehensive treatment of the principles involved in purchasing. The following topics are considered: inventory management, selection of sources, price analysis, standards and specifications, organization of a purchasing department, government regulations and buying policies applied to specific materials. Some attention will be devoted to the economics of freight transportation. Lectures, recitations, and term report. *Prerequisite: Mech. Eng. 35.* Three hours credit. Second semester.

44. **Automotive Electrical Equipment.** A study of storage batteries, ignition, starting and lighting equipment for gasoline automobiles; storage battery equipment, charging apparatus, motors and control equipment for electrically propelled vehicles. Lectures, recitations, laboratory. *Prerequisites: Phys. 46 and Mech. Eng. 29.* Three hours credit. First semester.

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

50. **Balancing, Critical Speeds, and Gyroscopic Action.** Fundamental equations of dynamics. Static and dynamic balance. Balancing of rotating and reciprocating masses, including connecting rods.

Balancing machines. Vibrations and damping. Critical speeds. Gyroscopic torque, steady and variable. Equations of motion with moving axes. Applications of gyroscopic action. Lectures, recitations, and laboratory demonstrations. *Prerequisite: Eng. Mech. 3.* Two hours credit. Each semester.

55. 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. 5 and 8.* Three hours credit. Second semester.

Summer Session

Courses 2, 3, 6, 7, and 8, or similar courses, are generally given during the Summer Session.

81. NAVAL ARCHITECTURE AND MARINE ENGINEERING

Professors SADLER and BRAGG; Associate Professor BAIER; Assistant Professor ADAMS.

The work in this Department has for its object the training of men in connection with the design and construction of ships and their machinery, and also of those who may wish to enter the field of water transportation. The three main divisions are as follows:

Naval Architecture, which embraces all questions relating to the design and construction of ships, and includes such topics as form, strength, resistance, propulsion, and stability; and methods of solving the general problem of ship design.

Marine Engineering, which includes those subjects which deal more particularly with the design and construction of the various types of machinery, such as steam reciprocating, turbine and oil engines, boilers of different types, and auxiliaries.

Water Transportation, which deals more specifically with those problems which enter into the selection of types of vessels suitable for various trades and conditions of operation, and which in addition to a general knowledge of the design and construction of vessels, also includes certain studies in economics, finance, and trade.

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 which may give him a more specific training in the particular line of work which he may wish to follow, in any group.

The Department of Marine Engineering in planning out 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 are also 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 Marine Laboratory, 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 enable its graduates to obtain positions in the various lines mentioned above.

Marine Engineering Laboratory.—On the first floor of the West Engineering Building the east wing contains the experimental tank. This tank is 300 feet long, 22 feet wide, with a depth of water of 10 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 8 to 12 feet, and are made of paraffin-wax and wood. If made of wax a clay mold is first made approximately to the shape desired, and a core inserted. The paraffin is then poured into the mold, and, after cooling, the rough model is taken to the model cutting machine. This machine consists essentially of two moving tables or platforms, upon one of which is placed the model and upon the other the drawing which it is desired to reproduce. The model moves under a pair of rotating cutters, which are made to follow the lines of the drawing. After cutting, it is brought to its final shape by hand, then carefully weighed, and sufficient ballast added to bring it to any desired draft and displacement.

The tank is spanned by a traveling truck which is driven by a motor and can be run at different speeds. Upon this truck are mounted the dynamometers for measuring the resistance of the models of various forms at different speeds.

Combined Courses have been arranged with Albion, Battle Creek, and Olivet Colleges. For detailed information see section 15.

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 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 are urged to enroll at the beginning of their course. For further details see section 66.

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 50.

a) Preparatory Courses	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Nontechnical Electives	6
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Economics 53, 54	6
Total	66

b) Secondary and Technical Courses	
Surveying 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
Eng. Mech. 4, Fluid Mechanics	3
Mech. Eng. 2, Elements of Machine Design	4
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 4, Hydraulic Machinery	3
Mech. Eng. 7, Mechanical Laboratory	2
Elec. Eng. *2a,* Electric Apparatus and Circuits	4
Naval Arch. 2, Ship Calculations	3
Naval Arch. 4, Resistance and Propulsion of Ships	3
Naval Arch. 5, Structural Drawing	4
Mar. Eng. 9, Marine Machinery	3
*Civil Eng. 2, Theory of Structures	3
Total	49

* Students electing Group C, Water Transportation, for their group options, will substitute an elective in place of Civil Eng. 2.

Summary:	*Hours*
Preparatory Courses	66
Secondary and Technical Courses	49
Group Options	25
Total	140

Group Options.—Three groups of studies may be followed in this department, viz.:

Group A, which is arranged for those who wish to devote the principal part of their studies to the design and construction of ships.

Group B, for those who wish to specialize more in the design of propelling machinery and other machinery connected with ships.

Group C, for those who wish to fit themselves for water transportation work.

A. NAVAL ARCHITECTURE	*Hours*
Naval Arch. 3, Stability, etc.	3
Naval Arch. 6, Ship Drawing and Design	3
Naval Arch. 7, Ship Drawing and Design	3
Naval Arch. 12, Experimental Tank Work	2
Naval Arch. 13, Ship and Engine Specifications and Cost Estimating	2
Electives	12
Total	25

B. MARINE ENGINEERING	
Mech. Eng. 5, Thermodynamics	3
Mech. Eng. 8, Mechanical Laboratory	3
Mech. Eng. 13, Steam Turbines	3
Mech. Eng. 15, Gas Engines	3
Mar. Eng. 10, Boiler Design; or Mar. Eng. 11, Engine Design	3
Electives	10
Total	25

C. WATER TRANSPORTATION	
Economics 130, Transportation	3
Economics 173, Accounting	3
Naval Arch. 13, Specifications	2
Civil Eng. 55, Transportation	2
Electives	15
Total	25

In this group students will substitute an elective for Civil Eng. 2 in the regular schedule.

PROGRAM

First Year

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

Second Year

Math. 36 (Calculus I)	4	Math. 37 (Calculus II)	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Nontechnical Elective	3	Nontechnical Elective	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

Summer Session

Elective	4
Elec. Eng. 2*a*	4
	8

Third Year

Eng. Mech. 4	3	Eng. Mech. 3	3
Mech. Eng. 3	4	Naval Arch. 2	3
Mech. Eng. 4	3	Naval Arch. 6 or Mech. Eng. 5	3
Surveying 4	2	Mech. Eng. 2	4
Naval Arch. 5	4	Mech. Eng. 7	2
Electives	2	Electives	3
	18		18

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

FOURTH YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Civil Eng. 2	3	Naval Arch. 7 or Mech. Eng. 8	3
Naval Arch. 3 or Mech. Eng. 13	3	Naval Arch. 4	3
Marine Eng. 9	3	Naval Arch. 13 or Marine Eng. 10 or 11	2 (3)
Naval Arch. 12 or Mech. Eng. 15	2 (3)	English Group III	3
Economics 53	3	Economics 54	3
Electives—Option A	3		
Electives—Option B	(1)		
Option A	17	Option A	13
Option B	16	Option B	14

COURSES IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

1. **Ships and Shipbuilding.** (Primarily for students not in the Department of Naval Architecture and Marine Engineering.) A brief summary of the types of ships, their structure, outfit, machinery, form, and construction. Lectures and recitations. Two hours credit. First semester.

2. **Ship Calculations.** The following are the topics discussed: methods of determining areas, volumes, centers of gravity of ship-shaped bodies, displacement, centers of buoyancy, metacenters, and trim; statical stability, launching, and water-tight subdivision. Lectures and recitations. Three hours credit. Second semester.

3. **Stability of Ships and Preliminary Design.** This course includes investigations of the statical and dynamical stability of ships, a discussion of rolling, pitching, and seagoing qualities of ships; a study of rudders and turning, freeboard, tonnage, and strength analysis. The latter part of the course is devoted to estimates and calculations involved in the design of ships. *Prerequisite: Naval Arch. 2.* Three hours credit. First semester.

4. **Resistance and Propulsion.** 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; methods of conducting trial trips, etc., are discussed. *Prerequisite: Naval Arch. 2.* Three hours credit. Second semester.

5. **Structural Drawing and Design.** This course comprises a discussion of the principal features of construction of all types of ships; classification societies' rules; and preparation of some of the principal working structural plans such as bulkheads, deck plating, and stern frame. Practice is also given in fairing the lines for a small vessel. Lectures, recitations, and drawing room. Four hours credit. Each semester.

5T. Structural Drawing. (Primarily for students not in the Department of Naval Architecture and Marine Engineering.) This is a short course similar to the drawing room work given in Course 5. Lines for a small vessel are faired and one structural plan is prepared. One hour credit. Each semester.

6. Ship Drawing and Design I. The lines of a vessel of an average type are drawn and all the calculations are made which are necessary for plotting curves of form, launching curves, and flooding curves. *To be accompanied or preceded by Naval Arch. 2.* Three hours credit. Each semester.

7. Ship Drawing and Design II. In this course the student is given the general features of a vessel and prepares a complete design of the same, including all the general plans and calculations. *Prerequisites: Naval Arch. 3 and 6.* Three hours credit. Each semester.

8. Navigation. Given in Detroit by the Extension Service. Two hours credit.

9. Marine Machinery. It is the purpose of this course to familiarize the student with the different types of machinery used for propelling vessels. A study is made of 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. The preliminary calculations are made for a triple-expansion reciprocating engine and the sizes of the main parts are worked out. A brief study is made also of condensers and air pumps. Lectures, recitations. *Prerequisites: Mech. Eng. 3 and Eng. Mech. 1.* Three hours credit. First semester.

10. Marine Boiler Drawing and Design. In this course a Scotch marine boiler of general type is designed. Three hours credit. Each semester.

11. Marine Engine Drawing and Design. The complete general plans of a triple- or quadruple-expansion engine are prepared, together with all calculations for the same. *Prerequisite: Mar. Eng. 9.* Three hours credit. Each semester.

12. Naval Architecture. Laboratory work in Experimental Tank. Two three-hour laboratory periods. Two hours credit. Each semester.

13. Naval Architecture. Specifications, contracts, and cost estimating. Two hours credit. Second semester.

15. Naval Architecture. Advanced reading and seminar. Credit to be arranged.

16. Naval Architecture. Advanced drawing and design. Credit to be arranged.

17. Marine Engineering. Advanced reading and seminar. Credit to be arranged.

18. Marine Engineering. Advanced drawing and design. Credit to be arranged.

82. PHYSICS

Professors RANDALL, WILLIAMS, COLBY, SMITH, SAWYER, GOUDSMIT, BARKER, and DENNISON; Associate Professors LINDSAY, MEYER, DUFFENDACK, CORK, SLEATOR, and LAPORTE; Assistant Professor FIRESTONE.

The instruction in general physics is given in a thorough course with the use of trigonometry extending throughout the year. The first semester presents mechanics, sound, and heat; the second electricity and light. The subjects are amply illustrated with appropriate experiments accompanying the lectures. Two hours a week are devoted to laboratory work. The numerous courses, both experimental and theoretical, which the Department offers, are open for additional work in physics.

WEST PHYSICS BUILDING.—The elementary work in general physics is carried on in the West Physics Building. The first floor contains the laboratories for electricity and light, a recitation room, the storage battery room, and the instrument shop. On the second floor are the large lecture room for demonstrations in general physics, a smaller lecture room, one laboratory for mechanics, consultation rooms, and apparatus rooms. The third floor contains two general laboratories and four recitation rooms.

EAST PHYSICS BUILDING.—Advanced work and research in physics have been removed to the first unit of the East Physics Building, the second unit of which, when built, will contain the large lecture rooms, laboratories, class, and consultation rooms for the elementary courses. The new laboratory has two wings 144 feet and 132 feet in length and each 60 feet wide. It is of reinforced concrete construction with specially deadened floors. There are four stories, a basement, and a first and second subbasement, all seven floors connected by an elevator.

Laboratories are provided for courses in heat and high temperature measurements, sound, light and applied optics, radioactivity, electrical measurements, and vacuum tubes, all supplied with adjacent apparatus, research, and consultation rooms. For research and industrial work in sound there is a two-story structure extending

through the first and second basements entirely separate from the walls of the surrounding building. X-ray research has ample quarters in the first and second basements. Two large rooms and several smaller ones are devoted to nuclear research. For this work high potential generators are housed in a two-story room with special subbasement. Spectroscopy both in the photographic and infrared regions has a series of laboratories. In addition, there are single- and multiple-unit research rooms available for any purpose. All rooms are provided with numerous storage battery connections and both the 110 v. a-c. and 220 v. d-c., as well as water, gas, and compressed air. Two storage batteries contain altogether about 300 cells, and switchboards make possible a universal distribution of power. In addition, there are two instrument shops, a wood shop, a glass-blowing room, and general apparatus rooms. The building also contains necessary offices, four rooms for lectures and classes in advanced courses, a library, and a faculty room.

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 all students interested, both as to the possibilities of the new profession and the particular work best suited to each individual.

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 50.

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, Group II, Group III	10
Modern Language (preferably German or French)	8
Mathematics 3, 4, 36, 37, 39	18
Physics 45, 46, 147, 165, 196	19
Chemistry 5E, 45*	8
Drawing 1	3
Chemical Engineering 1 and Metal Processing 2	5
Total	71

* Students in this curriculum may elect Chem. 45 without having had Chem. 15E.

b) *Secondary and Technical Courses*	*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
Total	15

c) *Options and Electives*	
Options in Physics	14
Options in Chemistry	8
Options in Mathematics	3
Options in Engineering	10
Electives from Economics, Geography, History, Philosophy, Political Science, Sociology	6
Free Electives	13
Total	54

Summary:

Preparatory Courses	71
Secondary and Technical Courses	15
Options and Electives	54
Total	140

COURSES IN PHYSICS

Description of Courses.—For all courses beyond 100, except Physics 130 which requires 45 only, Physics 45 and 46 are prerequisites. The individual courses may have particular prerequisites besides. Physics 45 and 46 are required of all engineering students. Calculus is a prerequisite for courses numbered above 130.

45. Mechanics, Sound, and Heat. At least half the semester is devoted to elementary mechanics; the remainder of the time to sound and heat; all with experimental illustrations. Two lectures, three recitations, and one two-hour laboratory period a week. *No student is admitted to the class who has not had a preparatory course in physics. A knowledge of plane trigonometry is indispensable.* Five hours credit. Each semester.

46. Electricity and Light. A continuation of Course 45. It takes up the fundamental phenomena and laws of electricity and light with ample class illustrations. Physics 45 and 46 are required of all engineering students. *Must be preceded by Phys. 45 and by Chem. 5E, or an equivalent.* Two lectures, three recitations, and one two-hour laboratory period a week. Five hours credit. Each semester.

105. **Modern Physics.** This course includes descriptions and discussions of many of those fundamental experiments which have established the present viewpoint in physics. Among the topics treated are the nature of light, the quantum theory of its emission and absorption, radioactivity, electron phenomena, elementary theory of specific heats, etc. The treatment is nonmathematical. Only students not specializing in physics may receive graduate credit. *Prerequisite: Phys. 36 or Phys. 46.* Two hours credit. First semester.

130. **Architectural Acoustics.** Practical control of reverberation, sound transmission through walls, and vibration insulation, as applied to the acoustics of buildings. *Primarily for architects. Prerequisite: Course 45.* One hour credit. Second semester.

147. **Electrical Measurements.** The course includes the modern methods of measuring current, resistance, electromotive force, capacity, inductance, and hysteresis of iron, and the calibration of the instruments employed. This course is in the curriculum in electrical engineering. *Preceded or accompanied by Elec. Eng. 3.* Two lectures and one four-hour laboratory period a week. Four hours credit. Each semester.

154. **Electrical Measurements.** Alternating and transient currents. Measurement of inductance and capacitance by audio-frequency currents and vacuum-tube amplifiers. Alternating-current bridge circuits. Application of the bridge to various problems. Hysteresis curves and losses for different kinds of steel. A Rosa-curve tracer is used to trace the wave form of alternating currents and voltages. *Prerequisite: Phys. 147.* Four hours credit. Second semester.

156. **Radioactivity.** Natural and artificial radioactivity. Elementary particles. Structure of atomic nuclei. Some knowledge of atomic structure is essential; *Course 196 taken at the same time satisfies this requirement.* Two hours credit. Second semester.

158. **Radioactivity Laboratory.** The distinguishing properties of alpha rays, beta rays, and gamma rays. The penetrating power of radiations in various substances and the half-life periods and chemical properties of several materials. *Must be preceded or accompanied by Course 156.* One hour credit. Second semester.

165. **Electron Tubes.** A study of the characteristics of electron tubes and their functions as detectors, amplifiers, and generators. *A knowledge of alternating-current theory is necessary.* Two hours credit. First semester.

166. **High-Frequency Electrical Measurements.** A laboratory course dealing with radio-frequency problems. *Prerequisite: Course 165.* Two hours credit. Second semester.

171. **Mechanics of Solids.** Statics and dynamics. Relative motion, central forces, force functions, the equations of d'Alembert, Poisson, Laplace, and Lagrange. Vectors are employed in certain problems. Three hours credit. First semester.

172. **Mechanics of Fluids.** Statics and elementary dynamics. Center of pressure, stability, viscosity, capillarity, and the equations of motion of a fluid. *Prerequisite: Course 171 or equivalent.* Two hours credit. Second semester.

175. **Sound.** Mathematical study of mechanical vibrating systems; complex numbers in wave and vibration problems; plane and spherical sound waves. Two hours credit. First semester.

177. **Laboratory Work in Sound.** Use of vacuum tube oscillators and amplifiers in the measurement of sound intensity and the calibration of acoustical instruments. Two hours credit. First semester.

181. **Heat.** Fundamental principles. Expansion, specific heats and temperature, change of state and van der Waals' equation, elementary kinetic theory, and the absolute scale of temperature. Two hours credit. First semester.

182. **Measurements of High Temperature.** The present methods of high-temperature measurement. The calibration and use of indicators, recorders, and pyrometers, and laboratory methods of producing high temperatures. Two hours credit. Second semester.

183. **Laboratory Work in Heat.** To follow or accompany Course 181. Modern methods of measuring thermal quantities. The gas thermometer, thermopile, interferometer measurement of thermal expansion, measurement of specific heats, heats of fusion and of vaporization, thermal conductivities, etc. Two hours credit. First semester.

186. **Light.** Theory of interference, diffraction, polarization, double refraction, etc. Two hours credit. Second semester.

187. **Geometrical Optics.** Fundamental methods and principles of geometrical optics and the design of optical instruments. Thick lens optics, the ideal optical instrument, the aberration theory of Abbé, the characteristics of optical instruments. Exercises in the design of simple instruments, and discussions of the various types of optical glass. Three hours credit. First semester.

188. **Laboratory Work in Light.** To accompany or follow Course 186. Experiments on interference, diffraction, polarization, double refraction, etc. 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. A limited amount of laboratory work may be included. Three hours credit. Second semester.

195. **Series Spectra.** An introduction to the subject of series in spectra. Two hours credit. First semester.

196. **Atomic and Molecular Structure.** The determination and description of characteristic energy levels, and the classification of electrons. Three hours credit. Second semester.

203, 204. **Molecular Physics.** Introduction to the theories of matter and radiation. Intended primarily for students in Chemical Engineering. *Course 203 is a prerequisite for Course 204.* Three hours credit each. First semester, Course 203; second semester, Course 204.

205, 206. **Electricity and Magnetism.** A fundamental treatment of electromagnetic theory. Electrostatic and electromagnetic phenomena on the basis of Maxwell's equations. Theory of electromagnetic waves and radiation from a Hertzian oscillator. The connection with the special relativity theory. *Prerequisite: Course 154. Course 205 is a prerequisite for Course 206.* Three hours credit each. First semester, Course 205; second semester, Course 206.

207, 208. **Theoretical Mechanics.** The Lagrange equations of motion. Principles available for the integration of the equations with numerous applications to particle and to rigid body motion. Principle of least action, Hamilton's Principle. Transformation of the canonical coördinates. The Hamilton-Jacobi equation. Poisson brackets. *Prerequisite: an adequate knowledge of differential equations. Course 207 is a prerequisite for Course 208.* An introductory course in mechanics is desirable. Three hours credit each. First semester, Course 207; second semester, Course 208.

209. **Thermodynamics.** The two laws and their foundation. Gas equilibria and dilute solutions. The phase rule of Gibbs. Theory of binary mixtures after van der Waals. *Prerequisite: Course 181.* Three hours credit. First 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. Non-ideal gases and the theory of the solid body. The theory of radiation. Fluctuation phenomena. *Prerequisite: Course 209.* Three hours credit. Second semester.

211, 212. **Quantum Theory and Atomic Structure.** The Bohr formulation of the quantization of multiple periodic systems and its application to atomic spectra (optical and x-ray) and molecular spectra. Heisenberg's uncertainty principle and matrix mechanics.

De Broglie waves and the Schrödinger wave equation. Application to physical problems. *Prerequisite: Course 196. Course 211 is a prerequisite for Course 212.* Three hours credit each. First semester, Course 211; second semester, Course 212.

[213, 214. **Introduction to Theoretical Physics.** The partial differential equations of mathematical physics. Omitted in 1937–38.]

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, Course 215; second semester, Course 216.

265. **Conduction of Electricity Through Gases.** Electron theory of conduction through gases: electric spark, glow discharge, electric arc. Origin of spectra: ionizing and radiating potentials, energy levels in line and band spectra. Three hours credit. First semester.

Summer Session

Physics 45, 46, 105, 145, 165, 181, 183, 186, 188, 196, 205*s*, 207, 247*s*, 250*s*, 265*s*, or similar courses, will be offered in the Summer Session.

Part VI

COMBINED CURRICULA

Since these curricula lead to fields other than engineering they were not listed for accreditment with the Engineers' Council for Professional Development.

83. ENGINEERING-BUSINESS ADMINISTRATION COMBINED CURRICULUM

The College of Engineering and the School of Business Administration offer a five-year combined course to meet the needs of those students who desire dual preparation in the fields of engineering and business administration. Such preparation seems appropriate because of the complicated economic organization of today and the close practical relationship between business activities and technology. From the point of view of the community there is a growing need of enlightened control by business men of the productive powers developed by engineers and scientists, and it is believed that students who have a balanced training in economics and technology will be able to render valuable services in developing such control. More specifically, such a combination is desirable for those who look forward to engaging in contracting, factory management, industrial personnel management, the marketing of industrial equipment, the management of public utilities, or other businesses in which the scientific and technical aspects are prominent.

The combined course covers the general training in engineering essential for this purpose, together with a complete and well-rounded training in business administration. The course in business administration comprises two years, and ordinarily a bachelor's degree is required for admission to it. Under the combined curriculum, however, a student is registered in the School of Business Administration after the completion of the three-year prescribed curriculum in the Engineering College, with a minimum average grade of 2.5. Upon the satisfactory completion of the first year of the business administration curriculum, the student will be recommended for the degree of Bachelor of Science in Engineering (Business Administration). Upon the satisfactory completion of the second year in the business administration program, the degree of Master of Business Administration will be granted.

Students should note that application for admission to the School of Business Administration must be made before April 20, and that the College of Engineering requires a higher average grade for its

recommendation for transfer to the School of Business Administration on the combined course than it requires for graduation in the four-year curricula.

The following schedule for the first three years has been approved by the two faculties as the general requirement for the Engineering-Business Administration combined course.

Minor substitutions in the following list of courses may be made by students whose major interests are in chemical and metallurgical, civil, electrical, aeronautical, or marine engineering. These substitutions must be approved by the Committee on Combined Courses. For the definition of an hour of credit see section 50, and for the grading system see section 35.

CURRICULUM IN ENGINEERING-BUSINESS ADMINISTRATION

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Total	54

b) *Secondary and Technical Courses*	
Surveying 4	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 2*a*, Strength and Elasticity Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil Eng. 2, Theory of Structures	3
Elec. Eng. 2*a*, Electric Apparatus and Circuits	4
Mech. Eng. 2*a*, Elements of Machine Design	3
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 5, Thermodynamics	3
Economics 53, 54, General Economics	6
Economics 171, 172, Accounting	6
Total	45

c) Electives to be selected from the following group:

Economics, Engineering, English, History, Military Science up to 4 hours, Modern Language, Philosophy, Political Science, Psychology, and Sociology	12

Summary:

	Hours
Preparatory Courses	54
Secondary and Technical Courses	45
Selected Electives	12
Total for three years in Engineering	111

PROGRAM

FIRST YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Economics 53	3	Economics 54	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

SUMMER SESSION

Elec. Eng. 2*a*	4
Mech. Eng. 3	4
	8

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

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

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Eng. Mech. 3	3	Economics 172	3
Eng. Mech. 4	3	Surveying 4	2
Mech. Eng. 5	3	Mech. Eng. 2*a*	3
Economics 171	3	Civil Eng. 2	3
*Electives	6	English (Group III)	2
		*Electives	6
	18		19

84. ENGINEERING-FORESTRY (WOOD TECHNOLOGY) COMBINED CURRICULUM

The College of Engineering and the School of Forestry and Conservation offer a five-year combined curriculum to meet the needs of students who plan to enter one of the wood-using industries and who desire a broader engineering foundation for their work in wood technology than can be obtained in two years of preparatory work.

This program recognizes the fact that intelligent utilization of wood requires not only a thorough knowledge of its structure, properties, and uses, but also of the machinery and processes involved in its manufacture and treatment.

The combined curriculum aims to turn out well-rounded professional men with sufficient training in both engineering and wood technology to qualify them for effective service as technicians, executives, or investigators in the lumber or other wood-using industries, or in some specific aspect of wood utilization, such as kiln-drying, preservative treatment, or timber testing. The present lack of technical men in the wood-using industries, which rank third or fourth in importance among the major groups of manufacturing industries in the country, leaves ample room for the employment of individuals with a training of this sort, which is not now generally available.

The student in the combined course is registered in the College of Engineering for three years on the completion of which, with a minimum average grade of 2.5, he is recommended for transfer to the School of Forestry and Conservation. On the satisfactory completion of the first year in that School, the student will be recommended for the degree of Bachelor of Science in Engineering (Forestry-Wood Technology).

Students should note that application for admission to the School of Forestry and Conservation must be made before April 20, and that the College of Engineering requires a higher average grade for the combined curriculum than for graduation in the regular four-year curricula.

* Elective courses must be selected from the following group: Economics, Engineering, English, History, Military Science up to 4 hours, Modern Language, Philosophy, Political Science, Psychology, Sociology.

On the satisfactory completion of his second year in the School of Forestry and Conservation, and the meeting of that School's specific requirements for graduation, he will be recommended for the degree of Master of Forestry (Wood Technology).

The following schedule, which is based on the four-year program in mechanical engineering, has been approved by the two faculties as the general requirement for the first three years of the combined curriculum. Minor modifications or substitutes may be made subject to the approval of the committee in charge.

Students who, during their first three years, follow a program in some other branch of engineering, for example, civil engineering, will be permitted to take advantage of the combined curriculum, provided (*a*) that during their third year in the College of Engineering they make such substitutions in the regular program as may be approved by the head of the department concerned and by the committee in charge, and (*b*) that during their first year in the School of Forestry and Conservation they take such supplementary courses in engineering as are similarly approved. For the definition of an hour of credit see section 50, and for the grading system see section 35.

CURRICULUM IN ENGINEERING-FORESTRY

		Hours
a)	*Preparatory Courses*	
	English 1, 2, 3, and a course from Group II	8
	English, junior-senior, a course from Group III	2
	Math. 3, 4, 36, 37	16
	Physics 45, 46	10
	Chemistry 5E	5
	Drawing 1, 2, 3	8
	Metal Proc. 1, 4	6
	Metal Proc. 2 and Chem. Eng. 1	5
	Total	60
b)	*Secondary and Technical Courses*	
	Surveying 4	2
	Eng. Mech. 1, Statics	3
	Eng. Mech. 2, Strength and Elasticity of Materials	4
	Eng. Mech. 2*a*, Strength and Elasticity Laboratory	1
	Eng. Mech. 3, Dynamics	3
	Eng. Mech. 4, Fluid Mechanics	3
	Elec. Eng. 2*a*, Electric Apparatus and Circuits	4
	Mech. Eng. 2, Elements of Machine Design	4
	Mech. Eng. 3, Heat Engines	4
	Mech. Eng. 5, Thermodynamics	3
	Mech. Eng. 7, Laboratory	2
	Chem. Eng. 10, Utilization of Fuels	1
	Chemistry 63, Organic Chemistry	4
	Economics 53, 54	6
	Botany 1	4
	Total	48

Summary: *Hours*

Preparatory Courses 60
Secondary and Technical Courses 48

Total for three years in Engineering 108

PROGRAM, COLLEGE OF ENGINEERING

FIRST YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Solid Anal. Geom.)	4
English 1	3	English 3	2
English 2	1	English (Group II)	2
Drawing 1	3	Drawing 2	3
*Chem. 5E or Chem. Eng. 1 and Metal Proc. 2 ..	5	*Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E ...	5
Assembly	0	Assembly	0
†Physical Ed. or Mil. Science	0 or 1	†Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

SECOND YEAR

Math. 36 (Calculus)	4	Math. 37 (Calculus)	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2 (Strength and Elasticity of Materials	4
Eng. Mech. 1 (Statics) ..	3	Eng. Mech. 2*a* (Strength and Elasticity of Materials)	1
Economics 53	3	Economics 54	3
Mil. Science .....(1)		Mil. Science .....(1)	
	(18) or 17		(18) or 17

SUMMER SESSION

Elec. Eng. 2*a* (D.C. and A.C. Apparatus and Circuits .. 4
Metal Proc. 4 (Machine Shop) 4

8

* See note, section 56.
† Physical education throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each semester) is elected as a substitute. Enrollment in military science is for a period of four semesters.

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Eng. Mech. 3 (Dynamics)	3	Eng. Mech. 4 (Fluid Mechanics)	3
Mech. Eng. 2 (Elements of Machine Design)	4	Mech. Eng. 5 (Thermodynamics	3
Mech. Eng. 3 (Heat Engines)	4	Chemistry 63	4
Mech. Eng. 7 (Mech. Eng. Lab.) and Chem. Eng. 10 (Utilization of Fuels)	3	Surveying 4	2
Metal Proc. 1 (Wood-working)	2	Botany 1	4
		English (Group III)	2
	16		18

PROGRAM, SCHOOL OF FORESTRY AND CONSERVATION

FIRST YEAR

Civ. Eng. 2 (Theory of Structures)	3	Mech. Eng. 35 (Factory Management)	3
For. 31 (Introduction to Forestry)	3	Econ. 173 (Elements of Accounting)	3
For. 101 (Dendrology)	3	For. 128 (Wood Pathology)	4
For. 163 (Anatomy and Properties of Wood)	4	For. 154 (Logging and Wood Utilization)	4
For. 191 (Forest Policy)	2	For. 166 (Timber Mechanics)	2
	15		16

SECOND YEAR

For. 131 (Wood Prod. Insects)	3	For. 168 (Chemical Utilization of Woods)	3
For. 159 (Wood-Using Industries)	2	For. 170 (Lumber Grading and Specifications)	3
For. 165 (Conditioning and Preservative Treatment of Wood)	4	For. 172 (Plywood and Laminated Construction)	3
For. 181 (Elements of Forest Management)	3	For. 176 (Forest Economics)	3
Forestry Problem	3	Forestry Problem	3
	15		15

85. ENGINEERING-LAW COMBINED CURRICULUM

The College of Engineering and the Law School of the University offer a six-year combined course to meet the needs of those members of the bar whose practice is in fields for which an engineering foundation is desirable.

Such fields include patent law, for which a knowledge of mechanical and electrical devices and of processes is important, and law as affecting the operation and the business of public-service, manufacturing, and other corporations.

There is, moreover, an increasing tendency for graduates in law to engage in the management of corporations. The combined course should therefore be of value to many also who are not actively engaged in the practice of law.

It is believed that many of the studies in an engineering curriculum, such as mathematics, physics, chemistry, and engineering mechanics, in which the faculty of analysis is trained, are very helpful as preparation for the study of law.

The student in the combined course is registered in the College of Engineering for three years and then in the Law School for a like period. On the completion of the three-year curriculum in the College of Engineering with a minimum average grade of 2.5, the student is recommended for transfer to the Law School. On the satisfactory completion of the first year of the law curriculum, the student will be recommended for the degree of Bachelor of Science in Engineering (Law).

The following schedule for the first three years has been approved by the two faculties as the general requirement for the Engineering-Law Combined Course. Minor modifications or substitutions in the purely engineering courses may be made, subject to the permission of the committee in charge. Students should note that application for admission to the Law School must be made before April 20, and that the College of Engineering requires a higher average grade for its recommendation for transfer to the Law School on the combined course than it requires for graduation in the four-year curricula. For the definition of an hour of credit see section 50, and for the grading system see section 35.

CURRICULUM IN ENGINEERING–LAW

a) *Preparatory Courses*	*Hours*
English 1, 2, 3, and a course from Group II	8
English, junior-senior, a course from Group III	2
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chemistry 5E	5
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Total	54

b) *Secondary and Technical Courses*	*Hours*
Surveying 4	2
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. *2a,* Strength and Elasticity Laboratory	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Fluid Mechanics	3
Civil Eng. 2, Theory of Structures	3
Elec. Eng. *2a,* Electric Apparatus and Circuits	4
Mech. Eng. *2a,* Elements of Machine Design	3
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 5, Thermodynamics	3
Economics 53, 54, General Economics	6
Political Science 107, 108, American Government	6
Total	45
c) Electives to be selected from the following group: Accounting, Astronomy, Chemistry, Economics, Technical Engineering, English, Geology, History, Mathematics, Modern Language, Physics, Political Science, Psychology	12
Summary:	
Preparatory Courses	54
Secondary and Technical Courses	45
Selected Electives	12
Total for three years in Engineering	111

PROGRAM

FIRST YEAR

FIRST SEMESTER COURSES	HOURS	SECOND SEMESTER COURSES	HOURS
Math. 3 (Alg. and Anal. Geom.)	4	Math. 4 (Pl. and Sol. Anal. Geom.)	4
*English 1	3	*English 3	2
*English 2	1	*English (Group II)	2
Drawing 1	3	Drawing 2	3
†Chem. 5E or Chem. Eng. 1 and Metal Proc. 2	5	†Chem. Eng. 1 and Metal Proc. 2 or Chem. 5E	5
Assembly	0	Assembly	0
‡Physical Ed. or Mil. Science	0 or 1	‡Physical Ed. or Mil. Science	0 or 1
	16 or 17		16 or 17

* If modern language is elected, it may be classified here and the English postponed. See section 51.

† See note, section 56.

‡ Physical education twice a week throughout the year (without credit in hours) is required of all first-year students, unless military science (one hour credit each semester) is elected as a substitute. Enrollment in military science is for a period of four semesters. Such credit cannot be used as a selected elective in the above program.

SECOND YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Math. 36	4	Math. 37	4
Physics 45	5	Physics 46	5
Drawing 3	2	Eng. Mech. 2	4
Eng. Mech. 1	3	Eng. Mech. 2*a*	1
Economics 53	3	Economics 54	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

SUMMER SESSION

Elec. Eng. 2*a*	4
Mech. Eng. 3	4
	8

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Eng. Mech. 3	3	*Political Science 108	3
Eng. Mech. 4	3	Surveying 4	2
Mech. Eng. 5	3	Mech. Eng. 2*a*	3
*Political Science 107	3	Civil Eng. 2	3
†Electives	6	English (Group III)	2
		†Electives	6
	18		19

* Courses in history, when approved, may be substituted for political science.
† Elective courses must be selected from the following group: Accounting, Astronomy, Chemistry, Economics, Technical Engineering, English, Geology, History, Mathematics, Modern Language, Physics, Political Science, Psychology.

COLLEGE OF ENGINEERING

SUMMARY OF STUDENTS

1936–1937

	1st Year	2d Year	3d Year	4th Year	5th Year	Specials	Total
Civil Engineering	...	31	38	49	...	3	121
Mechanical Engineering	...	122	123	118	...	...	363
Electrical Engineering	...	46	65	52	...	...	163
Chemical Engineering	...	102	122	66	...	...	290
Marine Engineering	...	28	17	15	...	1	61
Aeronautical Engineering	...	65	79	55	...	1	200
Geodesy and Surveying	...	...	3	2	...	...	5
Engineering Mechanics	...	...	2	2	...	...	4
Mathematics	...	2	7	17	...	...	26
Physics	...	9	7	7	...	...	23
Mechanical & Industrial	...	1	7	10	2	...	20
Chemical & Industrial	...	3	1	1	...	...	5
Engineering Law	...	10	11	5	...	...	26
Transportation	...	4	6	13	...	...	23
Business Administration	...	18	26	6	...	...	50
Astronomy	...	...	1	...	...	...	1
Forestry	...	...	1	...	...	...	1
Metallurgy	...	13	27	13	...	...	53
General Special	...	...	...	...	...	2	2
Unclassified, 1st year	420	...	...	...	...	...	420
Grand Total	420	454	543	431	2	7	1857
Counted twice	...	18	53	28	...	...	99
Net Total in Engineering	420	436	490	403	2	7	1758

Undergraduates, College of Engineering	1758
Students in Engineering enrolled in Summer Session of 1936	307
Students in Engineering enrolled in the Graduate School	219
Students enrolled in Engineering* Extension Courses	258
Net total number of students in Engineering	2277

* 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.

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UNIVERSITY OF MICHIGAN OFFICIAL PUBLICATION

The University of Michigan Official Publication is the title given to the series of administrative bulletins published by the University. This series includes the following:

For Prospective Students

The prospective student should have, in addition to a copy of the Bulletin of General Information, a copy of one or more of the announcements or bulletins listed under this head. These will be sent, without charge, on request to the Registrar of the University.

Bulletin of General Information

Announcements:

College of Literature, Science, and the Arts
College of Engineering
Medical School
Law School
College of Pharmacy
School of Dentistry
College of Architecture
School of Education
School of Business Administration
School of Forestry and Conservation
University Hospital School of Nursing
School of Music
Horace H. Rackham School of Graduate Studies
Summer Session
Extension Service

Bulletins describing the work of various departments and curricula.

Other Bulletins

The President's Report
Reports and communications of University officers

For Bulletin of General Information and Announcements address Mr. Ira M. Smith, Registrar of the University.

For general information concerning the University, address Mr. Shirley W. Smith, Vice-President and Secretary of the University, Ann Arbor, Michigan.