UNIVERSITY OF MICHIGAN
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College of Engineering

Announcement
1934-1935
and
1935-1936

ANN ARBOR, MICHIGAN
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UNIVERSITY OF MICHIGAN

College of Engineering

Announcement

1934-1935

and

1935-1936

Save this Announcement and bring it with you. It will be needed for reference throughout the year.

THE CAMPUS FROM THE AIR

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JANUARY

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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, 1934–35

1934

September 17–21, Monday–Friday.....Examinations for admission
September 18–22, Tuesday–Saturday.....Orientation Period
September 21 and 22, Friday and Saturday.....
.....Classification of all Engineering students
September 24, Monday, morning.....FIRST SEMESTER BEGINS
November 29, Thursday.....Thanksgiving Day, holiday
December 21, Friday evening.....Holiday vacation begins

1935

January 7, Monday, morning.....Classes resume
January 26, Saturday.....Semester examinations begin
February 6–8, Wednesday–Friday.....Examinations for admission
February 8 and 9, Friday and Saturday.....
.....Classification of all Engineering students
February 8, Friday, evening.....FIRST SEMESTER CLOSES*
February 11, Monday, morning.....SECOND SEMESTER BEGINS*
February 22, Friday.....Washington's Birthday, holiday
April 5, Friday, evening.....Spring vacation begins
April 15, Monday, morning.....Classes resume
May 30, Thursday.....Memorial Day, holiday
June 1, Saturday.....Semester examinations begin
June 17, Monday.....COMMENCEMENT

Summer Session, 1935

June 18, Tuesday—August 29, Thursday.....In the Law School
June 24, Monday—August 2 and 16, Friday..In the Medical School
June 24, Monday—August 16, Friday.....In all other divisions

Academic Year, 1935–36

September 23–27, Monday–Friday.....Examinations for admission
September 24–28, Tuesday–Saturday.....Orientation Period
September 27 and 28, Friday and Saturday.....
.....Classification of all Engineering students
September 30, Monday, morning.....FIRST SEMESTER BEGINS
November 28, Thursday.....Thanksgiving Day, holiday
December 20, Friday, evening.....Holiday vacation begins

1936

January 6, Monday, morning.....Classes resume
February 12–14, Wednesday–Friday.....Examinations for admission
February 14 and 15, Friday and Saturday.....
.....Classification of all Engineering students
February 14, Friday, evening .....FIRST SEMESTER CLOSES*
February 17, Monday, morning.....SECOND SEMESTER BEGINS*
February 22, Saturday.....Washington's Birthday, holiday
April 10, Friday, evening.....Spring vacation begins
April 20, Monday, morning.....Classes resume
May 30, Saturday.....Memorial Day, holiday
June 6, Saturday.....Semester examinations begin
June 22, Monday.....COMMENCEMENT

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

WEST ENGINEERING BUILDING

Part I

OFFICERS AND FACULTY

BOARD OF REGENTS

Elected Members

Hon. ESTHER M. CRAM, Flint.....Dec. 31, 1935
Hon. EDMUND C. SHIELDS, Lansing.....Dec. 31, 1935
Hon. JAMES O. MURFIN, Detroit.....Dec. 31, 1937
Hon. RICHARD R. SMITH, Grand Rapids.....Dec. 31, 1937
Hon. JUNIUS E. BEAL, Ann Arbor.....Dec. 31, 1939
Hon. RALPH STONE, Detroit.....Dec. 31, 1939
Hon. FRANKLIN M. COOK, Hillsdale.....Dec. 31, 1941
Hon. CHARLES F. HEMANS, Detroit.....Dec. 31, 1941

Members ex Officio (Without Vote)

Hon. PAUL H. VOELKER, Lansing, *State Superintendent of Public Instruction*
ALEXANDER GRANT RUTHVEN, *President of the University*

Officers

ALEXANDER GRANT RUTHVEN, *President*
SHIRLEY W. SMITH, *Vice-President and Secretary*

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ALFRED HENRY LOVELL, M.S.E., *Assistant Dean and Secretary, College of Engineering* 3000 Geddes Road
CAMILLA BLANCHE GREEN, *Assistant Secretary, College of Engineering* 910 Dewey Avenue
IRA MELVILLE SMITH, LL.B., *Registrar* 4 Geddes Heights
ALBERT EASTON WHITE, Sc.D., *Director, Department of Engineering Research* 2110 Dorset Road

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WILLIAM HENRY BUTTS, Ph.D., *Professor Emeritus of Mathematics* 407 East Kingsley

MEMBERS OF THE FACULTY AND OTHER OFFICERS*

Professors and Associate Professors

HENRY CLAY ANDERSON, B.M.E., *Professor of Mechanical Engineering, and Head of the Department of Mechanical Engineering* 1610 Washtenaw Avenue

STEPHEN STANLEY ATTWOOD, M.S., *Associate Professor of Electrical Engineering* 1411 Wells Street

WILLIAM LEAKE AYRES, Ph.D., *Associate Professor of Mathematics* 1204 Henry Street

WALTER LUCIUS BADGER, M.S., *Professor of Chemical Engineering* 917 Church Street

BENJAMIN FRANKLIN BAILEY, Ph.D., *Professor of Electrical Engineering, and Head of the Department of Electrical Engineering* 1019 Baldwin Avenue

EDWIN MYRON BAKER, B.S., *Professor of Chemical Engineering* 1603 Morton Avenue

ERNEST FRANKLIN BARKER, Ph.D., *Professor of Physics* 18 Ridgeway

FLOYD EARL BARTELL, Ph.D., *Professor of General and Physical Chemistry* 1919 Scottwood Avenue

SAMUEL LAWRENCE BIGELOW, Ph.D., *Professor of General and Physical Chemistry* 1520 Hill Street

WILLIAM WARNER BISHOP, A.M., Litt.D., LL.D., *Librarian* 733 Oakland Avenue

ORLAN WILLIAM BOSTON, M.S.E., M.E., *Professor of Metal Processing, and Director of the Department of Metal Processing* 2021 Vinewood Boulevard

†HARRY BOUCHARD, B.C.E., *Associate Professor of Geodesy and Surveying* 1111 Woodlawn Avenue

EDWARD MILTON BRAGG, S.B., *Professor of Naval Architecture and Marine Engineering, and Head of the Department of Naval Architecture and Marine Engineering* 1056 Ferdon Road

JOHN CROWE BRIER, M.S., *Professor of Chemical Engineering* 2301 Vinewood Boulevard

GEO. GRANGER BROWN, Ph.D., Ch.E., *Professor of Chemical Engineering* 1910 Hill Street

JOSEPH ALDRICH BURSLEY, B.S.(M.E.), *Professor of Mechanical Engineering, and Dean of Students* 2107 Hill Street

HARRY LINN CAMPBELL, M.S., *Associate Professor of Metal Processing* 909 Church Street

JOSEPH HENDERSON CANNON, B.S.(E.E.), *Professor of Electrical Engineering* 1803 Hill Street

CLIFTON O'NEAL CAREY, C.E., *Associate Professor of Geodesy and Surveying* Geddes Road

*In this list are included the names of certain instructors in other Colleges offering courses of interest to students in engineering.
†Absent on leave, first semester, 1934–35.

ERMINE COWLES CASE, Ph.D., *Professor of Historical Geology and Paleontology, and Chairman of the Department of Geology* 619 East University Avenue

*JAMES HARLAN CISSEL, B.S.(C.E.), *Professor of Structural Engineering* 1411 White Street

WALTER FRANCIS COLBY, Ph.D., *Professor of Physics* 801 Berkshire Road

JAMES MURLE CORK, Ph.D., *Associate Professor of Physics* 2034 Day Street

HEBER DOUST CURTIS, Ph.D., *Professor of Astronomy, Chairman of the Department of Astronomy, and Director of the Observatory* 1308 East Ann Street

CARL E. W. LEONARD DAHLSTRÖM, Ph.D., *Associate Professor of English* 1304 Horman Court

ARTHUR JAMES DECKER, B.S.(C.E.), *Professor of Sanitary Engineering* 2014 Geddes Avenue

DAVID MATHIAS DENNISON, Ph.D., *Associate Professor of Physics* 704 Pauline Boulevard

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ORA STANLEY DUFFENDACK, Ph.D., *Associate Professor of Physics* 2107 Devonshire Road

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PETER FIELD, Ph.D., *Professor of Mathematics* 904 Olivia Avenue

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MOSES GOMBERG, Sc.D., *Professor of Organic Chemistry, and Chairman of the Department of Chemistry* 712 Onondaga Street

*Absent on leave, 1934–35.
†Died July 26, 1934.

CHARLES WINFRED GOOD, B.S.E.(M.E.), *Associate Professor of Mechanical Engineering, and Assistant to the Director of the Department of Engineering Research* 622 South Seventh Street

CHARLES BURTON GORDY, A.M., Ph.D., *Associate Professor of Mechanical Engineering* 1929 Lorraine Place

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ALLEN FIRMAN SHERZER, B.M.E., *Professor of Mechanical Engineering* 1213 Ferdon Road

WILLIAM GABB SMEATON, A.B., *Professor of General and Physical Chemistry* 1941 Geddes Avenue

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NEIL HOOKER WILLIAMS, Ph.D., *Professor of Physics* 1020 Olivia Avenue

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WILLIAM PLATT WOOD, M.S.E., *Professor of Metallurgical Engineering* Ann Arbor Hills

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Assistant Professors

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GLENN LESLIE ALT, B.S.(C.E.), *Assistant Professor of Civil Engineering* 918 Sybil Street

LEIGH CHARLES ANDERSON, Ph.D., *Assistant Professor of Organic Chemistry* 1109 Packard Street

WERNER EMANUEL BACHMANN, Ph.D., *Assistant Professor of Organic Chemistry* 1208 Olivia Avenue

LOUIS ARTHUR BAIER, B.Mar.E., *Assistant Professor of Naval Architecture* 408 South Fifth Avenue

RALPH LEROY BELKNAP, Sc.D., *Assistant Professor of Geology* 116 North State Street

GEORGE MOYER BLEEKMAN, M.S.E., *Assistant Professor of Geodesy and Surveying* 1507 Morton Avenue

ROBERT D. BRACKETT, A.M., *Assistant Professor of English* 1301 Horman Court

PAUL NARCISS BUKOVSKY, M.S., *Assistant Professor of Mechanism and Engineering Drawing* 924 Sylvan Street
HEMPSTEAD STRATTON BULL, M.S., *Assistant Professor of Electrical Engineering* Ann Arbor Hills
CARL EDWIN BURKLUND, Ph.D., *Assistant Professor of English* Marlboro Drive
FLOYD NEWTON CALHOON, M.S., *Assistant Professor of Mechanical Engineering* 1047 Olivia Avenue
ROBERT JOHN CARNEY, Ph.D., *Assistant Professor of Analytical Chemistry, and Director of Chemistry Store* 519 Lawrence Street
LEE OWEN CASE, Ph.D., *Assistant Professor of General and Physical Chemistry* 1406 Henry Street
RUEL VANCE CHURCHILL, Ph.D., *Assistant Professor of Mathematics* 1459 Rosewood Street
ALBERT LORING CLARK, JR., B.S.E.(M.E.), *Assistant Professor of Mechanism and Engineering Drawing* 14 Ridgeway
ROBERT CARL COLE, A.M., *Assistant Professor of Mechanism and Engineering Drawing* 507 Walnut Street
RICHARD R. COURSEY, First Lieutenant, U.S.A., *Assistant Professor of Military Science and Tactics* 929 Church Street
RUSSELL ALGER DODGE, M.S.E., *Assistant Professor of Engineering Mechanics* 1233 Baldwin Avenue
WILLIAM GOULD DOW, M.S.E., *Assistant Professor of Electrical Engineering* 1418 Golden Avenue
WILLIAM HENRY EGLY, A.M., *Assistant Professor of English* 1208 Cambridge Court
MAURICE BARKLEY EICHELBERGER, B.S., *Assistant Professor of Mechanism and Engineering Drawing* 906 Rose Avenue
WALTER B. FARISS, Captain, U.S.A., *Assistant Professor of Military Science and Tactics* 1615 Wells Street
ALFRED LYNN FERGUSON, Ph.D., *Assistant Professor of General and Physical Chemistry* 721 Church Street
FLOYD ALBURN FIRESTONE, Ph.D., *Assistant Professor of Physics* 1424 Morton 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
ROCKWELL E. HARDY, Captain, U.S.A., *Assistant Professor of Military Science and Tactics*
DEAN ESTES HOBART, B.S., *Assistant Professor of Mechanism and Engineering Drawing* 1314 Minerva Road
JAMES HALLETT HODGES, Ph.D., *Assistant Professor of General and Physical Chemistry* 1334 Sheehan Avenue
LEWIS NELSON HOLLAND, M.S., *Assistant Professor of Electrical Engineering* 1205 Brooklyn Avenue
WILLIAM STUART HOUSEL, M.S.E., *Assistant Professor of Civil Engineering* 1119 Spring Street

ARNE ARTHUR JAKKULA, M.S.(C.E.), Ph.D., *Assistant Professor of Civil Engineering* 1615 South Boulevard
CLARENCE FRANK KESSLER, M.S.E., *Assistant Professor of Mechanical Engineering* 1756 Broadway
HENRY LEBRECHT KOHLER, M.E., *Assistant Professor of Mechanical Engineering* 1401 Henry Street
RICHARD THOMAS LIDDICOAT, B.S.E.(C.E.), M.S., *Assistant Professor of Engineering Mechanics* 1602 Morton Avenue
HAROLD RHYS LLOYD, M.A., *Assistant Professor of Mechanical Engineering* 1105 Berkshire Road
ROY KENNETH MCALPINE, Ph.D., *Assistant Professor of Analytical Chemistry* 926 Sylvan Street
DONALD WILLIAM MCCREADY, Ph.D., *Assistant Professor of Chemical Engineering* R.R. 2, Ann Arbor
HAROLD JAMES MCFARLAN, B.S.E.(C.E.), *Assistant Professor of Geodesy and Surveying* Long Shore Drive
LAWRENCE CARNAHAN MAUGH, M.S.(C.E.), *Assistant Professor of Civil Engineering* 313 Virginia Avenue
ALLAN DOUGLAS MAXWELL, Ph.D., *Assistant Professor of Astronomy* 1127 East Ann Street
CLIFFORD CYRILLE MELOCHE, Ph.D., *Assistant Professor of Analytical Chemistry* 525 Linden Street
CHARLES THOMAS OLMSTED, B.S.(C.E.), *Assistant Professor of Engineering Mechanics* Barton Hills
PHILIP ORLAND POTTS, B.M.E., *Assistant Professor of Mechanism and Engineering Drawing* 824 Granger Avenue
LEWIS STEPHEN RAMSDELL, Ph.D., *Assistant Professor of Mineralogy* Packard Road
LOUIS JOSEPH ROUSE, Ph.D., *Assistant Professor of Mathematics* 1137 Michigan Avenue
CHESTER BAKER SLAWSON, Ph.D., *Assistant Professor of Mineralogy* 715 Granger Avenue
WILLIAM WARNER SLEATOR, Ph.D., *Assistant Professor of Physics* 2503 Geddes Avenue
WILLIAM ALLEN SPINDLER, B.S.E.(Ch.E.), M.S., *Assistant Professor of Metal Processing* 518 East William Street
MELVILLE BIGHAM STOUT, M.S., *Assistant Professor of Electrical Engineering* 1417 Morton Avenue
LARS THOMASSEN, Ch.E., Ph.D., *Assistant Professor of Chemical Engineering* 2115 Woodside
MILTON JOHN THOMPSON, Sc.D., *Assistant Professor of Aeronautical Engineering* 1511 Morton Avenue
MORTON G. WALLINGTON, Lieutenant, U.S.A., *Assistant Professor of Military Science and Tactics* 1129 Ferdon Road
IVAN HENRY WALTON, A.M., *Assistant Professor of English* 1506 Golden Street
HARRY JAMES WATSON, B.M.E., *Assistant Professor of Mechanical Engineering* 1510 Morton Avenue

PHILIP FRANCIS WEATHERILL, Ph.D., *Assistant Professor of General and Physical Chemistry* 1113 Ferdon Road
EDWARD YOUNG, B.S.E.(C.E.), *Assistant Professor of Geodesy and Surveying* 1600 Montclair Place

Engineering Research

ERNEST JAMES ABBOTT, Ph.D., *Research Physicist* 1102 Forest Avenue
JOHN CHIPMAN, Ph.D., *Research Engineer* 1411 Granger Avenue
CLAUDE LESTER CLARK, Ph.D., *Research Engineer* 1415 Brooklyn Avenue
LEONARD ARNOLD DELP, M.S.Chem., *Research Associate* 429 Hilltop
ALFRED W. FLEER, B.S.E.(Ch.E.), *Michigan Gas Association Fellow in Gas Engineering* 1127 East Ann Street
PAUL HAROLD GEIGER, Ph.D., *Research Physicist* 1715 Hermitage Road
CHARLES WINFRED GOOD, B.S.E.(M.E.), *Assistant to the Director* 622 South Seventh Street
DONALD WILLIAM MURPHY, Sc.D., *Research Associate* 715 Forest Avenue
JOSEPH RALEIGH NELSON, A.M., *Editor of Publications* 1515 Granger Avenue
RICHARD SCHNEIDEWIND, Ph.D., *Research Engineer* 1402 Washington Heights
MARLAND BLICK SMALL, A.B., *Assistant to the Director* 711 Packard Street
ROBERT WORTH SMITH, M.S., *Research Associate* 1014 Cornwell Place
JAMES HARRY TAYLOR, M.S.E., *Detroit Edison Company Fellow in Metallurgy* 1315 Washtenaw Avenue
HARVARD BURTON VINCENT, Ph.D., *Research Physicist* 607 Sunset Road
JAMES HERBERT WALKER, B.M.E., *Honorary Research Engineer* 2000 Second Avenue, Detroit
ALBERT EASTON WHITE, Sc.D., *Director of the Department of Engineering Research* 2110 Dorset Road
RALPH A. WOLFE, Ph.D., *Research Physicist* 1709 Hermitage Road
EVERETT E. WYNKOOP, M.S.E., *Chemical Engineering Fellow in Boiler Feedwater Studies* 312 Maynard Street

Instructors

EDWIN A. BOYD, *Instructor in Highway Engineering* 832 Brookwood Place
BEN DUSHNIK, Ph.D., *Instructor in Mathematics* 809 East Kingsley Street
FRANKLIN LELAND EVERETT, M.S.E., Ph.D., *Instructor in Engineering Mechanics* 1305 Gardner Street
WILLIAM WAYNE GILBERT, M.S., *Instructor in Metal Processing* 1309 Washtenaw Avenue

JOHN GRENNAN, *Instructor in Foundry Practice*
719 South Seventh Street
LEO KIRSCHBAUM, A.M., *Instructor in English*
337 East Jefferson Street
CHARLES EDWARD KRAUS, B.S.E.(M.E.), *Instructor in Metal Processing*
1309 Washtenaw Avenue
HAZEL MARIE LOSH, Ph.D., *Instructor and Research Assistant in Astronomy*
910 East Huron Street
EDWIN WILKINSON MILLER, Ph.D., *Instructor in Mathematics*
1418 Washington Heights
ARTHUR FRANKLIN PARKER, *Instructor in Machine Shop Practice*
1441 White Street
ROBERT METHVEN PETRIE, A.M., Ph.D., *Instructor in Astronomy*
1308 East Ann Street
BURDELL LEONARD SPRINGER, M.S., *Instructor in Aeronautical Engineering*
1309 Washtenaw Avenue
WILLIAM TELFER, *Instructor in the Working, Treating, and Welding of Steel*
R.R. 2, Washtenaw Road
DONOVAN HAROLD YOUNG, M.S.E., *Instructor in Engineering Mechanics*
814 East Huron Street

STANDING COMMITTEE

Dean H. C. SADLER, Assistant Dean A. H. LOVELL, Professors H. C. ANDERSON, B. F. BAILEY, E. M. BRAGG, E. L. ERIKSEN, P. FIELD, L. M. GRAM, C. T. JOHNSTON, H. W. MILLER, E. A. STALKER, A. E. WHITE, and A. H. WHITE

COMMITTEES OF THE COLLEGE OF ENGINEERING

Committee on Classification:
Professors A. J. DECKER, H. H. HIGBIE, C. E. LOVE, J. C. BRIER, and H. J. GOULDING, and Assistant Professor C. F. KESSLER.

Committee on Delinquent Students:
Professors H. W. KING, R. H. SHERLOCK, and C. B. GORDY

Committee on Discipline:
Professor A. MARIN, Assistant Dean A. H. LOVELL, and Professor R. H. SHERLOCK

Committee on English for Foreign Students:
Professors J. R. NELSON, H. W. KING, and H. H. HIGBIE, and Assistant Professor C. E. BURKLUND

Committee on Extension of Time:
Professors C. O. WISLER and J. M. NICKELSEN, and Assistant Professor R. A. DODGE

Committee on Scholarships and Loans:
Professors H. W. MILLER, J. C. BRIER, and PETER FIELD, and Dean H. C. SADLER, *ex officio*

Committee on Substitution:
Professors B. F. BAILEY, E. M. BRAGG, J. H. CISSEL, and A. O. LEE

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 Graduate School, each of which publishes a separate annual announcement. The various Faculties include over eight hundred and twenty-eight officers of instruction. During the past year, 13,257 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 Christian Association and the Ann Arbor churches minister to the spiritual, religious, and social needs of the student body; the pastors and assistant ministers have largely 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 in aeronautical, chemical, civil (including transportation), electrical, and mechanical engineering, geodesy and surveying, naval architecture and marine engineering, astronomy, engineering mechanics, mathematics, and physics.

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 University of Michigan is very fortunate in having unusual facilities for the study of transportation, including a special transportation library containing 100,000 items, and departments offering instruction in aeronautical, automobile, marine, railway, highway, and electrical engineering—including the design and construction of vehicles of transportation and of electric communication (telephone, telegraph, and radio)—and in economics, business administration, and other subjects of importance to the student of transportation. The curriculum in transportation has as a foundation the courses common to the present professional curricula.

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 Sciences, 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.

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 in an additional Summer Session. In these programs the student will complete his selected teaching major, 25 to 35 hours of credit, and a teaching minor in his regular engineering course. He will elect the required 17 hours of credit in Education so that 9 hours may be accepted by the head of his technical department as electives, in his junior and senior years, the remaining 8 hours to be completed after graduation in Engineering.

For students expecting to teach academic subjects in secondary schools, one of the following teaching majors, to be approved by the Committee in Charge, will be required:

a) Applied Mathematics
b) Applied Physics
c) Applied Chemistry
d) Engineering Mechanics
e) Mechanical Drawing

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.

* For grading system, see section 35.

The Electrical Engineering Department offers 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 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 in long lines 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. Further detailed information is furnished to each freshman on acceptance of his application.

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 following Commencement.

Every student in the College of Engineering, in order to finish his program in four years, is expected 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 regis-

tration 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, Chairman of the Committee on English for Foreign Students. Such students shall satisfy the Committee 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 Committee 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 Committee on English, 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 Committee on English 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 Committee thinks necessary, and may be allowed to visit

such classes as may in the judgment of the Committee 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 without deficiencies* must present fifteen high-school units, including the following:

GROUP I—TEN UNITS

For admission to the College of Engineering, all of the following must be presented:

English	3 units
Mathematics (Algebra, through quadratics; Geometry—Plane and Solid	3 units
Physics	1 unit
History	1 unit
Greek, Latin, German, French, or Spanish—one of these	2 units

GROUP II—ONE AND ONE-HALF OR TWO UNITS

One and one-half or two units also in any one of the following combinations must be presented. The first combination is urgently advised. See note (*d*).

Trigonometry	½
Chemistry	1
or	
Chemistry	1
Foreign Language (additional)	1
or	
Trigonometry	½
Foreign Language (additional)	1
or	
Foreign Language (additional)	2
or	
Trigonometry	½
Botany, Zoology, or History (additional)	1
or	
Foreign Language (additional)	1
Botany, Zoology, or History (additional)	1
or	
Other combinations of the above subjects	2

*PROVISIONAL ADMISSION.—In general, an applicant for admission either on certificate or by examination who lacks not more than one and one-half of the units prescribed as shown in Groups I and II of section 10, 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.

GROUP III—THREE AND ONE-HALF OR THREE UNITS

The remaining three or three and one-half units may be presented in any subjects for which credit toward graduation is given by the accredited school and which are taught in a manner approved by the University. See section 11 with regard to the maximum number of credits allowed for vocational work.

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 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.

e) **Science.**—In order that a half unit in science may be accepted, it must be supplemented by a second half unit in science. For this purpose the only groupings permitted are the following:

(1) Botany and Zoology
(2) Zoology (or Botany) and Physiology
(3) Physiography and Geology
(4) Physiography and Physiology

11. **Vocational Units.**—No more than three of the fifteen units required for admission will be accepted in vocational subjects and no more than two units in any one of them.

In Drawing and Manual Training, a unit means the equivalent of at least three hundred and sixty periods, not less than forty-five minutes each.

All applicants must send prospectuses of the courses of study or letters from instructors describing the work done when credit is asked in the vocational subjects,—Manual Training, Drawing, Agriculture, and Commercial Branches. 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 in vocational studies.

DRAWING.—*Freehand Drawing,* one-half or one unit allowed. The student should show that he can represent correctly, in outline and in light and shade, geometric and simple natural or decorative form. Accuracy of proportion and perspective is essential. Pencil, charcoal, or brush may be used.

Design, one-half unit allowed. In this work a student should demonstrate some knowledge of the principles of design and the ability to apply them. The exercises should consist of compositions of straight and free curved lines and simple shapes and their use in the design of simple objects, such as book covers, etc. The exercises may be in black and white, various values, or in colors, and may consist in part of objects executed in wood or metal, and the like.

Mechanical Drawing, one-half or one unit allowed. This work should cover:

a) Exercises giving evidence of skill in the use of instruments and knowledge of materials used. The exercises should consist mainly of the accurate geometrical construction of the more important plane curves, with simple problems involving tangents and normals to the same.

b) Graded exercises in the orthographic projections of simple geometrical forms and working drawings of some of the more elementary constructions in wood and metal, all fully dimensioned, in which the conventional signs are properly used.

MANUAL TRAINING.—Not more than two units will be accepted. The work accepted may be:

Bench work, wood turning, cabinet making, and pattern making in the wood-working laboratory.

Manufacturing of wrought iron and steel, effects on structure due to working, heat treating and equipment, case hardening, welding and brazing, protective coatings, etc.

COMMERCIAL BRANCHES.—Not more than a total of two units will be accepted in commercial branches, to be selected from the following list:

Advanced Arithmetic, one-half unit. Credit will be allowed for arithmetic only if taken after at least one semester of algebra.

Double Entry Bookkeeping, one-half or one unit. If credit to the extent of a full unit is sought, the student should devote at least ten periods of not less than forty-five minutes each in class each week for one academic year. The applicant should have a working knowledge of single-entry and double-entry bookkeeping in the usual lines of business. He should understand the use of the various books, such as the journal, cash book, sales book, invoice book, ledger, and special column journals and cash books. He should know how to prepare profit and loss statements and balance

sheets, and to explain the meaning of the terms involved in both kinds of statements.

Commercial Geography, one-half unit. The amount and character of work accepted in this subject is indicated by the scope of the best textbooks on the subject.

Industrial History, one-half or one unit. The scope of this work is indicated by such texts as Cheyney or Cunningham in English industrial history, or Wright, Coman, or Bogart in American history.

Elementary Economics, one-half unit. The applicant should have a knowledge of the leading facts and principles in Economics, including such subjects as division of labor, the factors of production, the law of diminishing returns, demand and supply, value and prices, and international trade. One of the better elementary texts in use will serve as a basis. This should be supplemented with discussions and problems.

AGRICULTURE.—One or two units. Recitations and laboratory work in the various divisions of agriculture, including farm crops and horticulture, animal and dairy husbandry, soil physics, soil fertility, and farm mechanics. The study should be preceded by a course in Botany.

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.

The principals of approved schools are urged to send direct to the Registrar, immediately at the close of the first semester of the senior year, upon the blank furnished by the University, the application of each prospective graduate intending to enter the freshman class at the beginning of the ensuing year. The applicant will be given a tentative report concerning his eligibility for admission, which will be confirmed when the principal's supplementary report of the final semester's work has been received by the Registrar. If the applicant's credentials are satisfactory, he

*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.

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.

It is recommended that graduates from preparatory schools enter at once. If they do not, they must present evidence that they are, at the time of admission, prepared to do the work of the College. They must show especially satisfactory preparation in mathematics and in English. This preparation may be shown by a certificate of work done or by attendance at the Summer Session of the University of Michigan with a satisfactory record of eight hours of work, a part of which must be in mathematics.

As a general rule no advanced credit will be given for work done in the usual high-school course. However, college credit may be given for languages presented in excess of the fifteen units required for admission, if the courses are deemed equivalent to similar courses in the University. Such credit will be adjusted after admission.

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. Eleven and one-half or twelve units are prescribed as shown in Groups I and II of section 10. The three and one-half or three units remaining may be presented in any of the other subjects mentioned under admission requirements in section 10. In general, applicants will not be admitted with deficiencies in more than one and one-half units of the prescribed units.*

No one is admitted partially by examination and partially on certificate. School credits are not accepted in lieu of the examinations given by the University.

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.

As a rule he should have completed the required work in English, mathematics, physics, chemistry, and the nontechnical subjects, and in drawing and engineering mechanics if his institution offers adequate instruction in them.

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.

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; other entering students will be considered as sophomores until they have been in residence one semester and have satisfied the requirement for recognition as upperclassmen, for which see section 32.

a) Graduates of the University and of approved colleges are admitted without examination to advanced standing as candidates for a degree in Engineering.

*A student enrolled in the College of Literature, Science, and the Arts, who desires to elect, in the College of Engineering, any course which is not printed in the Literary Announcement, must obtain the written permission of the Assistant Dean of the Literary College.

They should present to the Assistant Dean an official certificate of their graduation—not their diploma—and an official copy of the record of the studies they have completed, showing the subjects studied, the number of weeks devoted to each, and the number of class periods a week.

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 in an approved college may be admitted to advanced standing without examination, except such as may be necessary to determine what credits he is entitled to receive.

An applicant must present a letter of honorable dismissal from college, an official copy of his college record, and an official record of his preparatory studies, similar to those required of students admitted on certificate. See section 12.

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

16. All advanced credits are adjusted by the Assistant Dean of the College of Engineering; and, until a transcript of record at another institution or other like information is furnished, no one is authorized to say what credit may be given for work done elsewhere or what class a student may enter after having attended another college for a specified time.

The requirements for admission must be complied with before any advanced credit is given.

Advanced credit is given only upon examination or upon an official transcript covering the work done, and showing the scholarship or proficiency attained.

Advanced credit is given only for work equivalent to courses offered in the University of Michigan.

Applicants for admission in engineering 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 of Engineering 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 Announcements of the Graduate School.

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.

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 matriculation fee and the semester fee must be paid in advance, and no student can enter upon his work until after such payment.*

To cover expenses students are urged to provide themselves with money orders or Travelers Cheques. For the convenience of students, the Cashier's Office will cash or accept in payment of tuition or other University fees money orders or Travelers Cheques. Personal checks will not be cashed, but will be accepted for the exact amount of fees.

Matriculation Fee.—Every student before entering any College or School of the University is required to pay a matriculation fee. This fee, which for citizens of Michigan is $10, and for those who come from any other state or country, $25, is paid but once, and entitles the student to the privileges of permanent membership in the University.

Semester Fees.—In addition to the matriculation fee every student has to pay a semester fee. For Michigan students, the semester fee in the College of Engineering is $57 for each semester; for non-Michigan students, $70 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 Fee. 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 and may elect not more than a total of ten hours in one academic year, and not more than six hours in any one semester, upon the payment of a semester fee of $25 for each semester of work taken. Such students, if entering the University for the first time, must also pay the usual matriculation fee, as well as the Health Service fee of $7.50 for each semester unless exempted under regulations governing the Health Service. They may also obtain the privileges of outdoor physical education and the Michigan Union

or Michigan League upon payment of the appropriate incidental fees *at the time of registration.*

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 are required to pay a late registration fee of $1.00 per day up to a maximum of $6.00 for registration six days after the last regular day.

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.

Graduation Fee.—The fee for graduation is $10, and the by-laws of the Board of Regents prescribe that no person shall be recommended for a degree until he has paid all dues, including the graduation fee. To receive a degree at Commencement the candidate must be present in person and must have paid the graduation fee at least twenty-five days prior to Commencement Day. Others who have satisfied all the requirements for graduation, including the payment of the graduation fee. will receive their degrees at a subsequent meeting of the Board of Regents.

Laboratory Fees.—Laboratory fees are abolished, but students in laboratory courses must make a cash deposit to pay for materials used and for breakage.

Camp Fee.—Extra fees, in addition to the regular tuition for the Summer Session, are required of students who take Course 3 in Surveying (at Camp Davis). See section 78.

Indebtedness to the University.—No student will be admitted to examinations at the close of any semester or summer session until all debts to the University (except student loans not yet due) are paid.

Other Expenses.—Fletcher Hall, a dormitory accommodating approximately 60 men, is 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 Fletcher Hall 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. By practice of strict economy it may be possible to keep these expenses close to $500 for the year. Many students are enabled to complete their course by withdrawing for a year or two to earn money to carry them through the remaining years.

Drawing instruments and equipment cost from $30 to $40, and, if well selected, will be serviceable for many years. They 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 is withdrawing, and (*b*) surrender to the Cashier of the University of the student's receipt, the athletic coupon or book, together with tickets issued to such student for future athletic events, and the Michigan Union or Michigan League annual membership card. In case of loss of the student receipt, $5.00 will be deducted from the refund as a penalty. It 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. No refund of matriculation fee will be made except in case of withdrawal within the first two weeks after registration.

4. A student who withdraws not more than two weeks after his registration will be entitled to a refund of his entire semester fee, together with the matriculation fee.

5. 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.

6. 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.

7. 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.

8. A student who transfers from full-time to part-time status will receive a refund in accordance with regulations 4, 5, and 6 above and will be required to pay the entire part-time semester fee.

9. 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.

10. Refunds for Summer Session or 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 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 do justice to his college work.

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. The Faculty recommends to such students that they should not attempt to carry the full amount of work outlined. Much more efficient work can be accomplished by taking a longer time to cover the curriculum. Each student doing outside work should notify his classifier of such fact at the time of classification.

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 forty-nine sleeping rooms for the alumni and guests of members accommodating sixty-eight persons.

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 and holders of fellowships or scholarships that do not include the privileges of the Michigan Union who elect to pay an additional amount of $5.00 per semester.

c) Those enrolled for full-time work in Ann Arbor during the Summer Session.

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

The Women's 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 and holders of fellowships or scholarships that do not include the privileges of the Michigan Union who elect to pay an additional amount of $5.00 per semester.

c) Those enrolled for full-time work in Ann Arbor during the Summer Session.

Payment of the League fee 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. These activities are supported by a portion of the semester fee. 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 FOR PHYSICAL EDUCATION

26. 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.

All men entering the University for the first time are given a thorough medical and physical examination before university fees are paid. At this time also a measurement of various parts of the body is taken and plotted on an anthropometric chart. A comparison with the average measurements can be made in this way, and any existing abnormalities corrected. A second measurement is taken after class work is finished, in order to note what changes have taken place. Abnormal posture conditions are corrected, and special exercises for strengthening weak parts are given. Realizing the fact that most college men have inferior chest development, the character of the class work is arranged to overcome this condition. Both athletic and gymnastic work is given, however, in order to produce variety and enthusiasm for exercise. Men qualifying for freshman football, cross-country running, hockey, track, basketball, swimming, boxing, fencing, and wrestling teams are given credit in physical education, while these sports are in progress, after which they are transferred to the regular gymnasium classes. Arrangements for the exchange of this work must be made with the Director of the Gymnasium; otherwise no credit will be given.

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, shower baths, and a swimming tank which, with instruction in swimming, is open to all women registered in the University. The field house for women on Palmer Field provides bowling alleys, indoor golf school, indoor archery range, rifle range, lockers, and showers.

The facilities of the Gymnasium, including physical examination and instruction, are free for all students, the only charge being a rental of $2.00 a year for a locker. For men, attendance twice a week is required of all first-year students in the College of Engineering. Classes begin Monday of the third week of the first semester. Students electing military science are excused from the work in physical education. During the year six hygiene lectures are given in connection with the physical training practice. All freshmen including those electing military science are required to attend these lectures.

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 new 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.

ASSEMBLY AND MENTOR SYSTEM

27. 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.

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.

HONOR SYSTEM

28. The students of the College of Engineering have adopted the following system: all examinations and written quizzes in the College are held under the Honor System, the object of which is to create a 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. Only in special cases, and then only for good and valid reasons, will permission to drop a course be given after this time.

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

Upperclassmen are not required to obtain excuses for irregularities of attendance from the Assistant Dean, but should explain them to their instructors.

*For the definition of upperclassmen see section 32.

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.

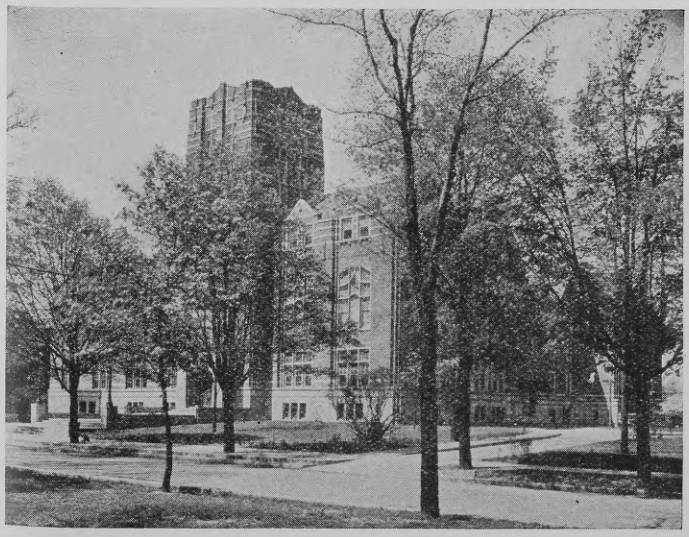
At the time of completing a course students must obtain from the Secretary a blank form for presentation to the instructor. The blank when filled out must be deposited by the student with the Secretary at once.

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 in order to raise his grade average.



MICHIGAN UNION

d) No student whose general average grade is below 2.0 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 Delinquent Students, students placed on probation may be removed from probation, and students placed on the home list may be continued on probation.

j) Students having an average grade of less than 3.0 may not elect extra hours; students having an average of 3.0 or more may elect extra hours, the number of extra hours which such students may elect to be determined by the classifier.

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, 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 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 875,000 volumes, of which many are of importance to engineers. The periodicals regularly received number 4,740.

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. Over one-half of the collection consists of 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 8,000 books and 160 periodicals of particular interest to students in Chemical 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.

THE WILLIAM L. CLEMENTS LIBRARY of American History, completed in 1923, the gift of Hon. William L. Clements, B.S., '82, houses the invaluable collection gathered by him and given to the University. The collection of books, manuscripts, and maps relating to the discovery of the western continent, its settlement, and later history is especially rich in rare books, pamphlets, and manuscripts dealing with our early colonial history and the period of the American Revolution. It numbers 26,300 volumes.

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 fourteen boilers totaling 8,200 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 turbo-alternator 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 hydro-electric 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.

The classes in hydraulics have been given the opportunity to assist in the tests of new power plants, and forty seniors spent four days on the tests of one of the largest plants in the State. The managements of the companies operating these plants are all in hearty sympathy and accord with the College of Engineering and afford the students every opportunity for inspection of the plants.

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. The coöperation of railways with the work of the department extends not only to giving students access to the properties but to giving freely to the University plans of all standard and special structures, for illustrative material, as well as courses of lectures by officers of the companies.

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 an inspection trip is made under the direction of the automobile department. These trips, while primarily for engineering students, are open to any who are interested.

The classes in Chemical 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, the American Society of Civil Engineers, and the Society of Industrial 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, and differs from other student chapters in that its membership is limited in numbers and is confined to senior and junior students whose scholarship is above the college average.

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.

Society of Industrial Engineers.—This is a student branch of the national society of the same name. Membership is open to all engineering students interested primarily in the science of efficient industrial management and production. The branch holds monthly meetings throughout the school year, at which industrial executives speak informally. The society, in conjunction with the other technical societies, sponsors weekly motion-picture shows of various industrial organizations and processes. All members receive the monthly bulletin published by the parent organization, and, upon graduation from college, membership is transferable directly to the parent society.

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 fifty 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. G. Carl Huber, Dean of the Graduate School, for information and application forms. Applications must be made before March 1.

University Scholarships

A limited number of University Scholarships in the Graduate School have been established giving remission 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.

University Fellowships

A limited number of fellowships and scholarships, ranging according to circumstances from $400 to $1,000, 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 $400 to $500. 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.

Joint Research Committee on Boiler Feedwater Studies Fellowship.—This fellowship is sponsored by a Joint Research Committee of several national organizations. Stipend, $600.

The M. W. Kellogg Company Fellowship in Chemical Engineering.—This fellowship is for the study of the distillation of petroleum.

Sir James Caird Traveling Scholarship is awarded to graduates of Scottish universities.

Detroit Edison Company Fellowship in Highway Engineering.—A fellowship is offered for the investigation of approved subjects relating to moderate-cost country roads. This fellowship pays $400; it will probably not be given in 1934–35.

Detroit Edison Company Fellowship in Metallurgy.—Stipend, $750.

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. **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.

Cornelius Donovan Scholarship.—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 the maximum amount of $400 each. To be eligible students must be American citizens, partially or entirely self-supporting, and must have completed a minimum of 45 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 15. The awards are published in May and are paid in half portions each when the recipients have enrolled for the first and second semesters of the following school year.

Robert Campbell Gemmell Memorial Scholarship.—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. "This scholarship is to be available for freshman and sophomore students in the College of Engineering . . . . . of general worthiness and deserving character." These scholarships are awarded in the approximate amount of $100 each. To be eligible, students must be American citizens, partially or entirely self-supporting, and must have completed a minimum of 15 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 15. 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.

Simon Mandlebaum 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 the amount of $500 or more, each. To be eligible students must be American citizens, partially or entirely self-supporting, and must have completed a minimum of 45 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 15. 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 $500 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 this fund in particular, since it is my purpose and intent that the income shall not lie idle and useless but shall be active and useful in contributing currently to the benefit of mankind through education.

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

> If after this bequest shall have been in operation for..... years or more the Regents within their discretion as trustees shall believe

that my general purpose in making this bequest, namely, the benefit of mankind through education, would be better served by the expenditure of both principal and income than by the continued expenditure of the income only, then and in that event the said Regents are expressly authorized and empowered to sell the securities or other property in which such principal shall then be invested, or to sell any part thereof, and to expend the proceeds thereof as may in their opinion at that time be as near as feasible to the purposes herein above 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 GRADUATE SCHOOL

49. Graduate courses are offered in the Graduate School leading to the degrees of Master of Science in Engineering, Doctor of Philosophy, Doctor of Science, Civil Engineer, Mechanical Engineer, Electrical Engineer, Chemical Engineer, Metallurgical Engineer, Naval Architect, Marine Engineer, Aeronautical Engineer, and Geodetic 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 Graduate School, which may be had on application.

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

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, 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, the time required depending on the necessary home work.

c) He must complete 30 credit hours of the 140 credit hours required, or have one year of residence, at the University of Michigan.

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.

NONTECHNICAL ELECTIVES

51. All regular students in the College of Engineering are required to complete not fewer than 6 hours of nontechnical electives selected from the following list:

Anthropology
Archaeology
*Astronomy
*Botany
*English
Fine Arts
†Foreign Language
*Geography
*Geology
*History
*Military Science and Tactics (not to exceed 4 hours)
Mineralogy
Music (courses listed in Literary Announcement)
Philosophy
*Political Science
Psychology
Sociology
Speech
*Zoology

Credit is withheld in the following groups until the completion of the second course (see Announcement of the College of Literature, Science, and the Arts):

Greek 1 and 2	8 hours
Latin 1 and 2	8 hours
French 1 and 2	8 hours
Spanish 1 and 2	8 hours
German 1 and 2	8 hours
Geography 1 and 2	8 hours
Geology 1 and 2	8 hours

Plane trigonometry and Chemistry 3 will be included in the list of nontechnical electives when college credit is given in these studies.

Students in areonautical and chemical engineering are advised to elect German; and students in astronomy, mathematics, and physics are advised to elect both French and German.

*Starred courses may be elected in the freshman year.
†Students who elect the beginning course in a language must continue with the second course.

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 registered 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	5	Metal Proc. 2 and Chem. Eng.	1
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

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

trigonometry and chemistry of the alternative requirements described in section 10. Should the student have entered without trigonometry or chemistry, or both, 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 5.

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 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, first half of the first semester. 1552 East Medical Building. Two hours credit.

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

113E. Practical Bacteriology. This course is open only to students of sanitary engineering. Three afternoons each week during the second half of the first semester, beginning in November. 2552 East Medical Building. Two hours credit.

55. BUSINESS ADMINISTRATION

Professors GRIFFIN, JAMISON, BLACKETT, and ELLIOTT; Associate Professors TAGGART and WOLAVER; Assistant Professors PHELPS and WATERMAN, and others.

The courses listed below are those which are deemed of special interest to engineering students. For the full list of courses in Business Administration, see the Announcement of the School.

101. **Principles of Organization and Production.** The purpose of this course is primarily to present the fundamental principles of business organization and management, as illustrated in the management of factories. The course stresses managerial control of labor, materials, and productive processes through the medium of modern, scientific methods. A textbook and collateral readings are used, as well as a liberal assortment of business cases to illustrate the principles involved. *Prerequisite: principles of economics.* Three hours credit. First semester.

102. **Principles of Personnel.** This course deals with the problems of human relations in business and industry. Reasons for the present emphasis on personnel relations are first considered. The course, however, is chiefly concerned with methods of selection, training, and maintenance of personnel in business and industrial organizations. Devices used in selection and training are appraised. Systems of wage payment and methods for keeping a continuous inventory of employees are analyzed. As far as possible the "case method" is used. Three hours credit. Second semester.

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 distribution, index numbers, time 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 market-

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

202. **Business Conditions.** This course endeavors to acquaint the student with the nature and limitations of business forecasting and with the statistical material used to measure the general conditions of business. The theory and history of business cycles is considered and the work of the leading commercial forecasting

services appraised. Particular emphasis is placed on the study of trends in particular industries. A course report is required of each student covering the history, current position, and future of a particular trade or industry. Familiarity with the technique of statistical analysis is presupposed. Three hours credit. Second semester.

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.

280. **Public Utility Accounting.** This course consists of an intensive comparative study of the standard systems of accounts prescribed for various utilities by the Interstate Commerce Commission and the state commissions. Some attention will be given the matter of consolidated income and financial statements in the utility field. Three hours credit. Second semester.

282. **Public Utility Management.** This course deals with problems of public utility management in such a way as to give the student an understanding of the peculiarities of utility enterprises. It presupposes a knowledge of the general principles of economics and business administration. Use of the case method of instruction is pointed to the consideration of such subjects as public utility finance, rate making, public relations, holding companies, and reorganizations. While the principles involved are general, the emphasis of the course is on the problems of gas and electric utilities. *This course must be preceded or accompanied by Course 280.* Three hours credit. Second semester.

Summer Session

Courses 102*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 GOMBERG, BIGELOW, WILLARD, SMEATON, and BARTELL; Associate Professor SCHOEPFLE; Assistant Professors CARNEY, MELOCHE, MCALPINE, FERGUSON, HODGES, WEATHERILL, ANDERSON, BACHMANN, HALFORD, and CASE.

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.

3, 6. General 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.

*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 three or more years have elapsed since they studied chemistry, in which case 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.

15E. Qualitative Analysis. In this course the distinctive properties of some of the more common chemical compounds are studied, with special reference to their use in analysis. A considerable number of unknowns are analyzed, and the student is required to show an understanding of the theory of dilute solutions in discussing the reactions employed in the laboratory. Two recitations and two four-hour laboratory periods. *Prerequisite: Chem. 5E or 6 or equivalent.* Four hours credit. Each semester.

43. Physico-Chemical 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.

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. 36, 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.* Five hours credit. Each semester.

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

67E, 69E. Organic Chemistry. The properties and classification of carbon compounds. Two lectures, one recitation, and two four-hour laboratory periods. *Prerequisite: Chem. 15E. Chem. 67E is a prerequisite for Chem. 69E.* Four hours credit each. Both courses are given 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. *Must be preceded by 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. **Physico-Chemical 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 physico-chemical 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 non-ferrous 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. **Physico-Chemical Methods in Quantitative Analysis.** Lectures and laboratory work. *Prerequisites: Chem. 47 and 145.* Two hours credit. Second semester.

Summer Session

Courses 3, 6, 43, 45, 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

Professor SHARFMAN, PATON, HANDMAN, WATKINS, and ELLIOTT; Associate Professor PETERSON; Dr. TIMOSHENKO; Mr. BRIGGS, Mr. HORTON, Mr. CRANDELL, Mr. LAING, and Mr. HORNER.

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. For further details with respect to these courses and for additional courses in the field of economics, consult the Announcement of the College of Literature, Science, and the Arts.

Students who elect any course without first completing the necessary prerequisites will be denied credit in that course.

53, 54. General Economics. For students of the College of Engineering and 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. 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, and monetary and banking reform are among other topics studied. *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.

104. Elements of Money and Credit. This course is a condensation of Courses 101 and 102, and is primarily designed for seniors, graduates, and other students in their last semester of residence. Unless special permission is given, it will not count as the prerequisite for courses for which Courses 101 and 102 are specified, and should not be elected by students who can elect those courses. *Prerequisites: Econ. 53 and 54.* Three hours credit. Second semester.

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.* 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.

130. Economics of Transportation. An analysis of the basic relations of transportation to economic organization and of the leading economic features of rail, water, road, and air transport. *Prerequisites: Econ. 53 and 54.* Three hours credit. First 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 is designed to acquaint the student with the system of government regulation of railroads which has been developed in the United States. *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 introductory course consists primarily in a study of the fundamentals of the double-entry system and an examination of the principal technical devices of accounting in terms of typical business transactions and conditions. Special attention is given to periodic operations, to the construction of work sheets and simple financial statements, and to the classification of accounts for managerial and other purposes. *Open to juniors, seniors, and graduates.* Three hours credit. Each semester.

172. **Principles of Accounting II.** This course, a continuation of Course 171, includes a study of the principal types of income statements and balance sheets, a survey of the problems of valuation and income determination, a consideration of partnership accounting, and an introduction to corporate accounting. *Open to juniors, seniors, and graduates.* Three hours credit. Second semester.

173. **Elements of Accounting.** A survey course with emphasis on the principles which are applicable to all types of business enterprises. In addition to covering the underlying features of accounting technique, considerable attention is devoted to the interpretation and use of published financial reports. *Open to juniors, seniors, and graduates,* but it should be understood that this course is not designed for students who plan to enter the School of Business Administration. Three hours credit. Each semester.

175. **Statistical Analysis.** Methods of statistical anlaysis applied to economic problems will be presented. Two hours of lecture and two hours of laboratory. *Prerequisites: Econ. 53 and 54.* Three hours credit. First semester.

176. **Economic Statistics.** This course is intended to give a critical knowledge of the chief sources of economic statistics and a familiarity with methods of analysis. The emphasis will be put on the application to economic data of the methods of correlation, index numbers, and time-series analysis. *Prerequisite: Econ. 175, or permission of instructor.* Three hours credit. Second semester.

181. **Public Finance.** A general survey of public expenditures, the character of taxation, the tax system of the United States, and the effects of public indebtedness. *Prerequisites*: *Econ. 53 and 54.* Three hours credit. First semester.

Summer Session

During the Summer Session the following courses are generally offered: 51*s*, 104*s*, 121*s*, 143*s*, 153*s*, 164*s*, 171*s*, 172*s*, 179*s*, 207*s*, and 251*s*.

58. EDUCATION

ENGINEERING—TEACHER'S CERTIFICATE

Engineering students may receive the degree of Bachelor of Science in Engineering and a Teacher's Certificate by satisfying the following requirements: completion of all the prescribed courses for the Bachelor of Science degree in the department in which they are enrolled, Psychology 31 or its equivalent, and 17 hours of work in education.

A minimum of 140 hours with a general average of 2.25 is required for admission to the School of Education as a candidate for the Teacher's Certificate.

Psychology 31 or its equivalent and 9 of the 17 hours in education will be accepted as electives in engineering. Eight hours in education must be elected in the School of Education after graduation in engineering.

Psychology 31 is a prerequisite for the courses in education.

Education A10 and Education C1 are prerequisites for the other courses in education.

A qualifying examination on the subject matter to be taught is a prerequisite for the course in directed observation and teaching.

The following courses in education are required:

a) Education in the United States A10*..... 3 hours

b) Educational Psychology, C1 ..... 4 hours

c) The Teaching of Special Subjects (selected from Department D in accordance with one's teaching major or teaching minor subject) ..... 3 hours

d) Directed Observation and Teaching, D100..... 4 hours

e) Elective ..... 3 hours

NOTE.—D150, a correlated course in education, may be elected instead of the previously listed courses. 17 hours credit.

Time Required

1. The student may elect Psychology 31 and 9 of the 17 hours in education while an undergraduate in engineering and complete the requirements for the degree of Bachelor of Science in Engineering and the Teacher's Certificate in one additional summer session.

*See footnote on page 69.

2. The student may elect Psychology 31 as an undergraduate, and Education D150, 17 hours credit, after graduation, and complete the requirements in one additional semester.

A10. Education in the United States. This course is designed to serve as an introductory course to all undergraduate work in Education. It is recommended that either it or C1 be pursued as the first course in Education and that both be elected in the junior year. The course will give a general survey of the purposes, history, organization, administration, financing, and outcomes of education in the United States, and will take the place of A1 and B20 formerly offered. (See * below.) After 1934–35 the course will be required of all candidates for the Teacher's Certificate. It should, however, be of value to students not planning to teach, inasmuch as each one will sometime inevitably be concerned with school problems as a citizen, taxpayer, parent, or school board member. Three hours credit. Each semester.

C1. Educational Psychology. The purpose of this course is to acquaint candidates for the Teacher's Certificate with the psychological principles involved in successful teaching. Among the topics discussed will be the following: the learning process as applied to educational problems; individual differences, their measurement and significance. Two hours of laboratory work a week are required. *Prerequisite: Psychology 31 or its equivalent.* Four hours credit. Each semester.

D100. Directed Observation and Teaching. This course aims to guide the work in observation and teaching in connection with the special-methods courses and supplements that work with conferences, reports, and discussions. It is advised that this course be elected by all students pursuing one of those courses. Experienced teachers are excused from certain requirements and may elect this course for 1 hour credit. Students electing the course must keep open 1 hour a day for observation and teaching, unless they have already done so in connection with one of the special-methods courses. Before being admitted to this course, the candidate must have passed successfully the qualifying examination provided in the subject which he expects to teach.

D101. The Teaching of Science in the Junior and Senior High School. Students desiring the Teacher's Certificate for teach-

* The new course Education A10 (Education in the United States) replaces the former requirement of Education A1 (History of Education in the United States) or A25 (Philosophy of Education) and B20 (Principles of Teaching—Introduction to Secondary Education). Education A1 and B20 as such have been abolished and incorporated into A10; Education A25 has become a wholly elective course. During the year one section each in A1 and B20 will be given (A1, second semester; B20, first semester) in order to accommodate those who have already begun their professional work on the campus. After the year 1934-1935 neither of these courses will be offered.

ing science must elect this course and, in addition, one of the following courses: D102, D105, D107. Two hours credit. First semester.

D135. The Teaching and Supervision of Junior and Senior High-School Mathematics. Three hours credit. Each semester.

59. ENGLISH

Professor NELSON; Associate Professors THORNTON, WENGER, and DAHLSTROM; Assistant Professors BRACKETT, BURKLUND, EGLY, and WALTON; MR. KIRSCHBAUM.

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.

Group I.—English 1, 2, and 3 are required of all engineering students. Courses 1 and 2 should be taken in a student's first semester; Course 3 in his second semester. Courses 1*a* and 2*a* are reserved for foreign students.

Group II.—These courses may be taken after a student has completed English 1 and 2. One of them completes the freshman requirement; the others give credit as nontechnical electives.

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.

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 Lecture: Scientific, Popular, and Technical.** 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, and 24, 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; Associate Professors KYNOCH, CRAIG, and BAXTER; Assistant Professors WIGHT and O'ROKE.

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

*See legend under caption "Group III."

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 lectures. *Not open for credit to candidates for a degree in forestry.* Three hours credit. Each semester.

160. **Foundations of Wood Utilization.** 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 finished product. Lectures, readings, and discussions. Three hours credit. Second semester.

161. **Logging and Milling.** Methods and costs of logging, with special reference to their applicability to different forest conditions; layout of logging operations. Sawmilling; methods and costs of manufacturing, grading, and marketing lumber and other rough forest products. Lectures, readings, and discussions. *Prerequisite: Surv. 12 or equivalent.* Three hours credit. First semester.

163. **Anatomy and Properties of Wood.** Anatomy of our native woods, with special reference to properties and identification; relation of properties to industrial utilization. Two lectures and two laboratory periods. *Prerequisites: Phys. 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. Two laboratory periods. *Prerequisite: Forestry 101.* Two hours credit. Second semester.

165. **Conditioning and Preservative Treatment of Wood.** Air seasoning, kiln drying, and preservative treatment of woods. The laboratory work includes operation of a semi-commercial kiln and wood-preserving plant. Two lectures and two laboratory periods. *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. One lecture and one laboratory period. *Prerequisite: Forestry 163 or 164.* Two hours credit. Second semester.

168. **Chemical Utilization of Wood.** Utilization of woods for the making of pulp and paper, artificial silk, and other cellulose products, and for distillation and miscellaneous products. Three

lectures and laboratory work. *Prerequisites: Forestry 163 or 164 and Chem. 5 or 6.* Three hours credit. Second semester.

170. **Principles of Lumber Grading.** Detailed discussion of American Lumber Standards. The relation of these standards to the various lumber associations, the retailer, and the ultimate consumer. Grade marking of lumber and benefits derived by retailer and user. Actual practice in lumber grading and identification. Two 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. Lectures, readings, and discussions. *Prerequisite: Econ. 51, 53, or 153.* Three hours credit. Second 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 lectures. *Open only to juniors, seniors, and graduates.* 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 lectures. 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.

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, 154, 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, and HOBART.

Drawing Courses 1, 2, and 3 carry the student through the subjects of elementary engineering drawing, descriptive geometry, and advanced engineering drawing. They have been arranged to form a continuous chain of instruction that will, first, fit those students who continue during the third and fourth years to take up with the least difficulty and proceed with the maximum efficiency in the courses in design, etc.; and, second, be of the maximum assistance to that large percentage of students who do not continue longer than from one to two years. Instruction is also given in statistical charting.

Courses in elementary mechanical drawing and sketching especially designed for dental and medical students are offered as Drawing 1*d* and 1*m*.

A long-sought aim of the Department has been realized in the reduction of its classes to fifteen men or less. This gives the opportunity for that personal contact and acquaintance between the instructor and his students that is of so great value. The work is conducted in well-lighted and well-equipped drafting rooms, and all necessary facilities essential to the proper teaching of the subjects named are available.

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, free-hand 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.

1d. Dental Drawing. Use of instruments; practice in lettering; practice in the making of working drawings, particularly of dental appliances; outline sketching of subjects of dental anatomy; pencil shading of sketches. Four hours drafting-room a week. One hour credit. Each semester.

1m. Medical Drawing. Use of instruments; practice in lettering; outline sketching of subjects of human anatomy; pencil shading of sketches; practice in the making of working drawings, particularly of medical appliances. Four hours drafting-room a week. One hour credit. Each semester.

2. Descriptive Geometry. Exercises, instruction, and drill through the medium of 80 printed plates of problems comprising combinations of the point, line, and plane, intersections, developments, tangent planes, and warped surfaces. Three two-hour drafting-room periods, three hours home work a week. *Prerequisite: Draw. 1.* Three hours credit. Each semester.

3. Advanced Engineering Drawing. Sketching of die-cast models in orthographic, isometric, and oblique projection; practice in the making of working drawings from sketches; free-hand lettering; special practice in, and applications of, drawing; charting. Two two-hour drafting-room periods, two hours home work a week. *Prerequisite: Draw. 2.* Two hours credit. Each semester.

12. Graphical Methods. Analytical methods of charting; construction, use, and analysis of statistical charts, and applications to industrial, social, transportation, or other statistical problems. Three hours drafting-room a week. Two hours credit. Each semester.

Summer Session

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

65. METAL PROCESSING

Professor BOSTON; Associate Professor CAMPBELL; Assistant Professor SPINDLER; Mr. KRAUS, Mr. GILBERT, 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. 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 off-hand, tool and cutter, drill, single-point tools, surface, and cylindrical grinding. A separate room contains polishing and buffing machines and auxiliary equipment. This room is connected with an air cleaning system. 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, gauges, and small tools for machine and hand use. Adjoining this tool crib is a room in which material 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 University Instrument Shop on the second floor at the east end has been equipped recently 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 hand work, 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. Adjoining the laboratory on the west side is the pattern and wood storage room.

The Machinability Laboratory, in a separate room on the second floor, contains drill presses, lathes, and millers equipped with dynamometers, potentiometers, and wattmeters to study problems of machinability and metal cutting.

The Metal Working and Treating Laboratory, 60 by 100 feet, on the third floor, is equipped with forges, a power shear, an abrasive cut-off wheel, and a power forging hammer with necessary gas furnace, hammer tools, and dies, grinding wheel stands, engine lathe, shaper, drilling machine, and work benches. For instruction in heat treating, electric and gas-fired box type and pot furnaces with necessary accessories, including thermo-electric pyrometers and controllers, are installed. A metallurgical microscope is available for observation of structural changes of steel resulting from heat treatment and mechanical work. The welding equipment consists of ten oxy-acetylene welding stations, alternating and direct current electric arc, 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, 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 sand-blast 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.

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

2. **The Working, Treating, and Welding of Steel.** This is a study of the principles relating to the constitution, properties, and application of steel. Manufacturing processes for these metals are outlined. The effects of mechanical working and heat treatment on the properties of various steels are studied and demonstrated. Attention is given to welding practice, as well as to methods for protecting the ferrous metals against corrosion. 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 castings of gray iron, malleable iron, steel, brass, bronze, aluminum alloys, and bearing metals. The constitution and properties of these metals, as well as the casting procedure, are studied. 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.** Studies are made of the following subjects: the cutting of metals—lathe work, milling, drilling, reaming, tapping, broaching, grinding, polishing, buffing, honing, and lapping—also gear cutting, jigs, special tools, standards, measuring instruments, gauges, turret lathes, screw machines, automatic turning machines, cutting fluids, die-casting, punch and die work, spinning, as well as associated subjects such as industrial organization, accounting and unit costs, stock records, standardization, time study, routings, and manufacturing layouts. 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. Two recitations and two three-hour laboratory periods a week. *Prerequisite: Metal Proc. 2.* Four hours credit. Each semester.

5. **Welding Processes.** This course consists of the study of the welding processes which include gas welding and cutting, electric arc welding, electric resistance welding, thermit welding, and other special welding processes. Attention is given to the advantages and applications of each of the welding processes. Sufficient time is provided for laboratory practice to permit each student to become acquainted with the procedure used in welding different metals. One lecture and one three-hour laboratory period a week. *Prerequisite: Metal Proc. 2.* Two hours credit. Each semester.

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

7. **Jig and Fixture Design.** This course consists of a study of the principles underlying the design, construction, and application of jigs, fixtures, punches and dies, special tools, gauges, and measuring instruments for different production quantities, and the cost analysis involved therein. Two classroom periods a week. *Prerequisite: Mech. Eng. 6.* Two hours credit. Second 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.

12. **Advanced Metal Working and Treating.** Further work on subjects scheduled in Course 2 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 tool-room 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 relating to 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. **Aircraft, Materials of 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 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 per week. *Prerequisite: Metal Proc. 2 and Aero. 4.* Two hours credit. Second semester.

Summer Session

Courses 2, 3, 4, 12, 13, and 14 are generally given during the Summer Session.

66. MILITARY SCIENCE AND TACTICS

Professor ROGERS; Assistant Professors FARISS, COURSEY, HARDY, and WALLINGTON.

The student elects his military science courses at the same time and place as he elects his other University courses and receives

academic credit therefor which counts toward graduation. He also enrolls at the Headquarters, Reserve Officers' Training Corps, on the campus. Students electing military science are excused from the required gymnasium work.

Enrollments are for a period of four semesters; that is, for either a basic group or an advanced group in its entirety. The first four semesters constitute the basic group, and the second four semesters the advanced group. Once enrolled in either group the completion of that group becomes a prerequisite to graduation unless the student is discharged from this obligation upon the recommendation of the Professor of Military Science and Tactics.

A deposit of $9.00 to cover property responsibility is required of each basic student. A deposit of $12.50 is required of each advanced-course student.

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.—For the first two years the student may follow any basic course. The infantry is recommended. During the last two years he gets special technical training in design and manufacture of ordnance, methods of supply and maintenance, and organization. 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 and business administration students.

Signal Corps.—After the first year, the student receives such instruction as will tend to make him expert in communication work. Open to prospective electrical engineers and others interested in electrical communications.

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.

The courses in Military Science and Tactics are designed to give a thorough groundwork in military subjects considered necessary as a part of the education of a commissioned officer in the Reserve Corps of the Army of the United States. Courses are offered in infantry, in ordnance, and in signal corps training organized as units of the Reserve Officers' Training Corps, in which membership is limited to male citizens of the United States who are physically fit for service in the field.

While taking work in the advanced group, members of the R.O.T.C. receive payment of commutation of subsistence from the Government amounting to over $200.

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

In the advanced group, there is a summer camp of six weeks' duration. Attendance at the advanced camp is a prerequisite to graduation for students in the advanced group. Equipment is furnished and expenses at the camps are paid by the Government.

Successful completion of the courses in any unit of the R.O.T.C. will lead to a recommendation for a commission in the corresponding branch of the Officers' Reserve Corps.

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.

The following courses are given within the various units:

SIGNAL CORPS

BASIC GROUP

41. **Elementary Infantry, Military Telephone, and Military Policy.** One hour credit. First semester.

42. Same as Course 2.

43. **Military Telegraphy and Telephony.** Recitations and lectures. One hour credit. First semester.

44. **Field Radio Sets.** Recitations, lectures, laboratory work, and code practice. Installation, operation, and care of radio sets, sending and receiving. One lecture, one recitation, and one drill period. One hour credit. Second semester.

ADVANCED GROUP

45. Same as Course 7.

46. **Signal Corps Organization and Tactics; and Signal Communications.** Lectures and laboratory work in organization and tactics of the Signal Corps and the combined arms, and in signal communications. Two lectures, one two-hour laboratory period, and one drill period. Two hours credit. First semester.

47. **Communication Engineering.** Electrical engineers take Elec. Eng. 21. All other engineers take (Elec. Eng. 23) Elements of Radio Communication. First semester.

48. **Communication Engineering.** Electrical engineers take (Elec. Eng. 10) Advanced Theory of Electrical Circuits. All other engineers take (Elec. Eng. 24) Elements of Radio Communication. Second semester.

INFANTRY

Basic Group

1. **Elementary Infantry.** Infantry drill regulations, marksmanship, and military policy. One lecture, one conference, and one drill period. One hour credit. First semester.

2. **Elementary Infantry, Continued.** Map reading, organization of infantry, infantry drill, military courtesy. One conference, one lecture, and one drill period. One hour credit. Second semester.

3. **Automatic Rifle; Musketry; Drill and Command.** Practical work in construction, operation, and use of the Browning automatic rifle. Lecture and practical work in the use of the combined fire of several rifles and the automatic rifle. One conference, one lecture, and one drill period. One hour credit. First semester.

4. **Combat Principles; Scouting and Patrolling; Drill and Command.** Theoretical and practical instruction in handling men, infantry organizations; training in the methods of gaining information of the enemy prior to and during combat. One conference, one lecture, and one drill period. One hour credit. Second semester.

Advanced Group

5. **Command and Leadership; Aerial Photograph Reading; 37mm Gun, 3″ Mortar, and Machine Guns.** Theoretical and practical instruction in handling men; lectures and practical work in reading and making military maps. Practical work in construction, operation, and use of the guns. One lecture, one drill period, and one three-hour laboratory period. Two hours credit. First semester.

6. **Field Engineering; Combat Principles; Drill and Command.** Lecture and practical work in field fortification and in the exercise of command appropriate to all grades. One conference, one drill period, and one three-hour laboratory period. Two hours credit. Second semester.

7. **Military Law; Military History and Policy; Administration; Drill and Command.** Elements of common law, military law, moot court-martial, rules of land warfare, military policy, company organization and administration. Two lectures, one drill period, and one two-hour laboratory period. Two hours credit. Second semester.

8. **Minor Tactics; Tanks and Mechanization; Drill and Command.** Lecture and practical work in the offensive and defensive combat of small units, tactical employment of infantry weapons, sand-table exercises, map and terrain problems. Disposition of infantry weapons and units for defensive combat. Employment of tanks and mechanized units. One lecture, one conference, one drill period, and one two-hour laboratory period. Two hours credit. First semester.

ORDNANCE

ADVANCED GROUP

31. **Materiel.** Small arms, guns, carriages, recoil and special mechanisms, tanks, tractors, self-propelled mounts, and fire control instruments. Two lectures, one two-hour laboratory, and one drill period. Two hours credit. First semester.

32. **Organization and Functions of the Ordnance Department.** The organization of the Army and the Ordnance Department, a study of the functions of the Field Service and Maintenance Divisions, current ordnance problems, and problems in ordnance design. Two lectures, one two-hour laboratory period, and one drill period. Two hours credit. Second semester.

33. Same as Course 7.

34. **Elective Technical Subjects.** Selected technical subjects offered by the College of Engineering may be substituted in this course with the approval of the Military Department. Credits will be allowed as listed for the substituted course. One hour drill will be required. Second semester.

GENERAL

Infantry Drill with Each Course.—Company drill for one hour a week is a required part of each course.

Rifle and Pistol Practice.—All R.O.T.C. students may practice on the indoor and outdoor ranges whenever practicable during scheduled periods. Membership on the R.O.T.C. Rifle or 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.

SUMMER CAMPS

ADVANCED

Attendance at an advanced camp is required and is a prerequisite to graduation. Transportation, equipment, quarters, rations, and medical attention are furnished by the Government. In addition the student draws pay at the rate of 70 cents a day. Ample time and facilities are allowed for recreation. All camps are of six weeks' duration and begin about June 15.

Signal Corps—Fort Sheridan, Illinois.

Infantry—Camp Custer, Michigan.

Ordnance—Aberdeen Proving Ground, Maryland.

67. MINERALOGY AND PETROGRAPHY

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

31. **Elements of Mineralogy.** This includes the elements of crystallography, and the physical and chemical properties, occurrence, uses, and determination of the more common minerals. Two lectures and two hours laboratory a week. *Prerequisite: a knowledge of elementary inorganic chemistry.* Two hours credit. Each semester.

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

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. In some of the more important courses in the College of Engineering a reading knowledge, at least, of one of these languages is required.

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.** Grammar, pronunciation, reading, dictation, and conversation. Four hours credit. Each semester.

2. **Elementary French, Continued.** Grammar, composition, dictation, conversation; reading of selections from modern authors. Four hours credit. Each semester.

31. **Intermediate French.** Reading of modern French prose (short story, novel, or drama); composition based on a thorough review of grammar; dictation and conversation. Four hours credit. Each semester.

32. **Intermediate French, Continued.** Reading of modern prose, composition, and conversation. 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.** Grammar, composition, reading, dictation, and conversation. Four hours credit. Each semester.

2. **Elementary German, Continued.** Grammar, composition, dictation, conversation; reading of selections from modern authors. Four hours credit. Each semester.

31. **Intermediate German.** Reading of modern German prose (short story, novel, or drama); dictation and conversation; grammar review to suit the needs of the class. Four hours credit. Each semester.

32. **Intermediate German, Continued.** Reading of scientific literature and masterpieces of classical and modern writers (drama, novel, story); discussion, conversation, interpretation. 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.

SPANISH

1. **Elementary Spanish.** Grammar, pronunciation, reading, dictation, conversation. Four hours credit. Each semester.

2. **Elementary Spanish, Continued.** Grammar, composition,

dictation, conversation; reading of selections from modern authors. Four hours credit. Each semester.

31. **Intermediate Spanish.** Reading of modern Spanish prose (short story, novel, or drama); composition based on a thorough review of grammar, dictation, and conversation. Four hours credit. Each semester.

32. **Intermediate Spanish, Continued.** Reading of modern prose; composition and conversation. 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; Professor NELSON, Editor of Publications; Assistant Professor GOOD, Assistant to the Director; Mr. SMALL, Assistant to the Director; Research Engineers CHIPMAN, CLARK, SCHNEIDEWIND, WALKER; Research Physicists ABBOTT, GEIGER, VINCENT, WOLFE; Research Associates DELP, MURPHY, SMITH.

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 several fellowships are administered through this Department, although the actual technical work is done in the various departments of the College. At present these fellowships are:

Michigan Gas Association Fellowship
Fellowship in Boiler Feed-Water Studies
Detroit Edison Co. Fellowship in Metallurgy

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 insuring a maximum of efficiency in their utilization.

Part V

PROFESSIONAL DEPARTMENTS

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 his 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; Assistant Professor THOMPSON; and 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 tunnel offers facilities for experimental work in all problems relating to this subject, and is 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 small eighteen-inch diameter tunnel is provided for routine instruction. Students, however, are given an opportunity to work in the large tunnel during their regular course.

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
Surveying 4	2
Eng. Mech. 1	3
Eng. Mech. 2, 2*a*	5
Eng. Mech. 3	3
Eng. Mech. 4	3
Civil Eng. 2	3
Mech. Eng. 2	4
Mech. Eng. 3	4
Mech. Eng. 5	3
Mech. Eng. 7	2
Mech. Eng. 14	3
Mech. Eng. 15	3
Mech. Eng. 26	3
Elec. Eng. 2*a*	4
Total	49

c) *Technical Courses and Electives*

Aero. Eng. 1, General Aeronautics	3
Aero. Eng. 2	3
Aero. Eng. 3	2
Aero. Eng. 4	3
*Aero. Eng. 5	2
Aero. Eng. 6	1
Elective	8
Total	22

Summary:

Preparatory Courses	69
Secondary Courses	49
Technical Courses, and Electives	22
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	5	Metal Proc. and Chem. Eng. 1	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

*Students specializing in aircraft power plants are to elect Mech. Eng. 15*a* in place of Aero. 5.

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

‡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

COURSES	HOURS
Metal Proc.	4
Elec. Eng. *2a*	4
	8

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
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	3
	18		18

FOURTH YEAR

Mech. Eng. 15	3	English, Group III	2
Mech. Eng. 26	3	Aero. Eng. 5	2
Aero. Eng. 4	3	Aero. Eng. 6	1
Surveying 4	2	Elective	10
Elective	4		
	15		15

COURSES IN AERONAUTICAL ENGINEERING

1. **General Aeronautics.** Lectures and recitations. 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. *Open to all students except freshmen.* Three hours credit. Each semester.

2. **Theory of Aviation.** Lectures and recitations. In this course a development of the underlying mechanics which forms 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. *Must be preceded or accompanied by Math. 103 or Math. 105 and 106.* Three hours credit. Each semester.

3. **Theory and Design of Propellers.** Lectures and recitations dealing 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. *Must be preceded by Eng. Mech. 2, and preceded or accompanied by Aero. Eng. 1.* Two hours credit. Each semester.

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

5. **Airplane Design.** Lectures and drawing. 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. *Prerequisites: Aero. Eng. 2 and 4.* Two hours credit. Each semester.

6. **Experimental Aerodynamics.** Lectures and laboratory. 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. The greater portion of this work is conducted in the eighteen-inch wind tunnel, but the students are also given an opportunity to conduct a test on a complete airplane model in the large tunnel. *Prerequisites: Aero. Eng. 2. Open only to seniors and graduates.* One hour credit. Each semester.

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

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

11, 11a. **Advanced Stability.** Lectures and recitations. Advanced study of more complicated phenomena of stability according to Bryan with Bairstow's applications of experimentally determined resistance derivatives and rotary coefficients. Study of spinning and experimental work in second semester. *Prerequisites: Aero. Eng. 2 and Math. 39 (Differential Equations). Aero. Eng. 11 is a prerequisite for 11a.* Two hours credit. First semester, 11; second semester, 11*a*.

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. **Research.** This course should be elected for analytical investigations.

The following subjects form a part of the Aeronautical Engineering curriculum.

Mech. Eng. 14. Aircraft Power Plants
Mech. Eng. 15. Internal Combustion Engines
Mech. Eng. 15*a*. Internal Combustion Engineering
Mech. Eng. 26. Aircraft Engine Laboratory
Mech. Eng. 38 and 39. Research
section 80.

For descriptions of these courses see Mechanical Engineering,
Eng. Mech. 9. Advanced Strength of Materials
Eng. Mech. 12. Vibration Problems in Engineering
Eng. Mech. 13*b*. Theory of Thin Plates
Eng. Mech. 25. Stability of Elastic Structures
For descriptions of these courses see Engineering Mechanics, section 77.

For information on flying, see Military Science and Tactics.

73. ASTRONOMY

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

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

Its equipment includes a 37½-inch equatorial reflecting telescope, which is used for stellar spectrographic work; a 12½-inch equatorial refractor; a 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 3,000 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.

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

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 two observers at Bloemfontein are devoting their time to research in the field of visual double stars.

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	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
Drawing 4, or Civil Eng. 2	2 or 3
Geology 31	3
Surveying 1, 2	7
Surveying 5, or Astronomy 154	2
Astronomy 31, 32, 33, 101, 151, 152, 201	18
Geodesy 1	3
Mathematics 105, 107, or 145, 146	5 or 6
Physics 181, 186	8
Psychology 31	3
Total	59

Summary:	
Preparatory Courses	65
Secondary and Technical Courses	59
Electives	16
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. 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.

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 exer-

cises, 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. Not offered in 1935-36.

Summer Session

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

74. CHEMICAL ENGINEERING

Professors A. H. WHITE, A. E. WHITE, BADGER, BRIER, UPTHEGROVE, BROWN, WOOD, and BAKER; Associate Professor MCCABE; Assistant Professors THOMASSEN and MCCREADY; Research Engineers CHIPMAN* and CLARK.*

The chemical engineer finds his principal work in the design or operation of plants in which materials undergo chemical as well as physical changes. 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

*Rank equivalent to Assistant Professor of Metallurgical Engineering.

as purely chemical, such as the manufacture of acids, alkalies, and salts; but in such industries as the manufacture of sugar, paper, leather, rubber, soap, fuels, petroleum products, paints and varnishes, cement, plaster, glue, food products, dyes, textiles, and many others. The metallurgist and the ceramist are chemical engineers with specific training for their particular work.

Statistics show that 23 per cent of chemical engineering graduates become teachers, are connected with research institutes, enter governmental employment, become consulting engineers, or enter the professions of law or medicine. Seventy-two per cent are directly connected with industry and are enrolled in the following industries arranged according to the numbers employed. The industry which at the present time is taking the largest proportion of chemical engineering graduates is petroleum, and it is 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.

Chemical Engineering may be subdivided into many other special branches of engineering and such titles as Metallurgical Engineering, Gas and Combustion Engineering, Ceramic Engineering, Petroleum Engineering, and Electrochemical Engineering are not unfamiliar and are sometimes recognized as independent divisions.

At the University of Michigan, pronounced distinction is not made in the various fields of Chemical Engineering and all instruction is given under the administration of the Department of Chemical Engineering. The first two years of undergraduate work are devoted largely to acquisition of fundamental subjects as 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, and begin his work in chemical engineering. He also should acquire some proficiency in the use of the English language, and it is advisable that he obtain a reading knowledge of German, so that there will be available to him valuable publications appearing in the German chemical literature.

In the last two years, attention is divided between studies in

Chemical 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 subjects as history, philosophy, and political science.

The work in Chemical Engineering subjects 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. Our chemical engineers, even on graduation from a four-year course, often accept positions where they become the sole chemical or metallurgical engineer in the organization, and these men must consequently be fitted to accept and carry creditably 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, unit operations, 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.

GRADUATE WORK

The mere fact that the chemical engineer must have considerable attainments in the important fields of chemistry, physics, and mathematics, as well as in chemical engineering, indicates the need of more than four years' study. Statistics from a number of universities show that 34 per cent of the graduates from the four-year courses continue for at least one year of graduate work.

The formative state of chemical engineering and its 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 its 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 present college year there are eighty-one graduate students in residence, and the size of this group makes it feasible to offer special courses not only in chemical engineering but also in mathematics and physics.

A notable development of recent years has been the call for men with a Ph.D. degree. These men have readily found employment even during the period of the 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.

The laboratories completed in 1923 provide unsurpassed facilities for the study of processes and apparatus. Generous provision in the way of private laboratories has been made to meet the needs of the advanced student.

FACILITIES FOR INSTRUCTION

Excellent facilities are available for theoretical and laboratory studies of the various branches of chemical engineering.

The Chemical 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 and chemical engineering. The total number of journals currently taken by the Department of Chemical Engineering is 90, and most of them are represented by complete sets. In addition to 6,000 books dealing distinctly with Chemical Engineering, there are many others dealing with more general engineering lines.

Chemical Engineering Facilities.—The Chemical Engineering Laboratories are housed in the East Engineering Building, already described. The Department of Chemical Engineering is not only fortunate in having assigned to it over one-third of the 160,000 square feet of space in this new building, but is also fortunate in its neighbors. The forge shop and foundry of the Engineering College 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. Especial pains have been taken to minimize noise and vibration. Fresh air is provided by fans in the basement, and the foul air is exhausted by fans in the attic. Ventilation of the hoods is furnished by special suction fans. Distilled water is furnished to three points on each floor. The storerooms and dispensing stands occupy a stack extending from the basement to the attic, with a freight elevator traversing the whole unit.

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 two 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 and has facilities for the following unit operations.

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. Other special evaporators for research purposes are available or are constructed as needed.

There is also a full complement of equipment for work in high-temperature evaporation. Besides a gas-fired diphenyl boiler rated at 150,000 B.t.u. per hour, it includes 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. Operations can be carried out at temperatures up to 850°F.

DISTILLATION.—Facilities for the study of batch and continuous distillation, and of dephlegmation, are available. The equipment includes a 250-gallon still, provided with a 10-plate, 10-inch steel bubbler-cap column, and a 3-plate bubbler-cap column in which the plate spacing can be adjusted at will. The upper half of this column is made of pyrex glass, thus permitting observation of the movement of liquid and vapor on the plates. Either column may be operated continuously, or as an apparatus of batch type. Suitable condensing, metering, and instrument equipment is available. Several smaller stills and columns complete the equipment of this division of the laboratory. All of the apparatus is designed with a view to studying the fundamental principles of fractional distillation and fractional condensation.

GAS ABSORPTION.—An absorption column that can be filled with various types of tower packing is available.

FILTRATION.—The present equipment consists of a 24-inch washing plate-and-frame filter press, with an assortment of special frames; 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 at-

tachment, a vacuum crystallizer with a jet injector for high vacuums, and a special 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. Additions will be made to the equipment of the laboratory as these become necessary or desirable. The aim at all times will be to provide facilities for fundamental investigations rather than to equip a museum of chemical machinery.

Gas, Fuel, and Combustion Laboratories.—In this group are included laboratories for general class work in the analysis and calorimetry of industrial gases and fuels, and special testing and research laboratories for petroleum products, motor fuels, combustion, furnaces, and gas manufacture.

THE GAS AND FUEL LABORATORIES occupy two large rooms on the fourth floor of the north wing. They contain apparatus for the analysis of flue and fuel gases; calorimeters for gas, liquid, and solid fuels; and equipment for testing boiler water, lubricants, and fuels.

THE PETROLEUM LABORATORY has facilities for study of motor fuels and other petroleum products. These are supplemented by the equipment available in the general chemical engineering laboratory, the fuel research laboratory, and in the automobile engineering laboratory.

THE FUEL RESEARCH LABORATORY is especially equipped to study the various factors involved in the utilization of motor fuel. Two electric absorption dynamometers and typical automobile engines are available for making engine performance tests, and a special high compressing engine for making anti-knock tests. The laboratory is also supplied with ammonia refrigeration for conducting tests at low temperatures. Special columns for fractional distillation of fuels and special equipment for measuring volatility are available in addition to the standard equipment.

THE COMBUSTION LABORATORIES have special facilities for research and testing in the field of gaseous explosions, particularly the explosion of hydrocarbon air mixtures in a closed vessel as occurs in internal combustion engines. These are supplemented by equipment in the fuel research and automotive laboratories.

THE FURNACE LABORATORY contains furnaces equipped for making heat balances, and for determining the properties of furnace

materials and the laws of heat transfer and gas flow as applied to furnaces. A diphenyl flash boiler with a capacity of 300,000 B.t.u. per hour with air preheater is available for testing purposes.

THE GAS ENGINEERING LABORATORY contains furnaces for manufacture of gas on a small scale and for measuring and testing the finished products. This laboratory is largely devoted to the research work of the Michigan Gas Association. The laboratory facilities are supplemented by the use of the production equipment in some one of the coal or carbureted water gas plants in Michigan when the laboratory results of the work in progress indicate that full scale plant tests are desirable.

Metallurgical Laboratories.—The Metallurgical Laboratories are located on the fourth floor of the East Engineering Building, adjacent to the Foundry and Metal Working and Treating Laboratory of the Department of Engineering Shops, and the Gas and Fuel Laboratories of the Department of Chemical Engineering, so that these facilities are also available. Equipment for heat treating and melting is provided in a large furnace room equipped with standard electric and gas furnaces. Facilities are provided for electrometallurgical work and experimental electric furnace work in this room. Power is furnished through three 50 kw. transformers. A 35 kva. high frequency furnace is available for alloy studies.

For instruction in *metallography* facilities are provided in the way of a large grinding and polishing room, a microscope and camera room, and well-equipped darkrooms. A smaller room fully equipped with grinding, polishing, and microscopic equipment, and special camera and darkrooms are available for graduate students.

For testing *physical properties* of metals a 60,000 lb. Olsen testing machine is equipped for studies at elevated temperatures. Special instruments such as the Brinell hardness machine, Shore scleroscope, Rockwell hardness tester, fatigue machines, Izod impact, and others are available. General physical testing equipment is available in the Engineering Mechanics Laboratory.

In the PYROMETRY LABORATORY unusual facilities are provided. 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 which will enable him to take charge of the installation and control of commercial pyrometric and temperature control systems.

THE X-RAY LABORATORY has a thoroughly modern equipment, including a transformer of capacity up to 280,000 volts for the radiography of metals and another smaller x-ray outfit which is used for researches on crystal structure, grain size, inner strains, and orientation of crystals with special reference to engineering materials.

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 pug mill and extruding machine, glass-topped tables, and other equipment used in preparing clays for burning. The laboratory is supplied with a Fairbanks testing machine, a 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 is also available as part of the facilities of the metallurgical laboratories.

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 temperatures, as well as spray gun equipment for the application of all kinds of finishing materials. Quartz mercury and carbon arc vapor lamps furnish ultra-violet 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 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 regularly made in connection with the various courses in chemical engineering. The great industrial development of the neighboring cities of Detroit and Toledo, as well as 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. At least one summer's work in an approved plant is required in the five-year program in chemical and industrial engineering.

Metallurgical Engineering embraces the extraction of metals from their ores, the melting, refining, alloying and casting, fabrication and heat treatment of metals, and their utilization in the various industries. The metallurgical engineer finds his field of endeavor 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. No better example is to be found than that offered by the automotive industry, where he is concerned primarily with the heat treatment and use of metals, and where he is recognized as an important member of the organization. In the metallurgical industries proper he is concerned with the quality and general improvement of both product and process. Constantly diminishing natural resources and the ever increasing demand for new alloys of superior qualities offer unlimited opportunities for research in both extractive metallurgy and the development of new products.

Gas Engineering.—The subject of gas manufacture and utilization has been given special attention in the Department for over twenty years. No prescribed curriculum has ever been required, and it is not felt that a special degree need be given. The undergraduate program in Chemical Engineering gives the necessary fun-

damental courses, and the options in the senior year provide room for some special courses. Those desiring to specialize in gas engineering should, preferably, continue as graduate students, and choose subjects in other engineering branches as well as chemical engineering.

The Detroit City Gas Company, the Consumers Power Company, and the Associated Gas and Electric System join with the University in a coöperative program which permits selected students to obtain fourteen months' practical experience in a program which requires five years for its completion.

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. Prospective students of chemical engineering are strongly urged to select German as the language to be studied, and to avoid specialization along the lines of chemistry and chemical engineering in their preparatory work. Students in doubt of elections to be made in the first three years' work are cordially invited to correspond with the Department of Chemical 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 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	5
Chem. 67E, Organic Chemistry	4
Chem. 69E, 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. 3, Structure and Properties of Metals	3
Chem. Eng. 4, Technology of the Inorganic Industries	2
Chem. Eng. 5, Technology of the Organic Industries	4
Chem. Eng. 9*a* and 9*b*, Unit Operations	6
Chem. Eng. 12, Special Problems	5
Chem. Eng. 29, Unit Operations Laboratory	2
Total	62

Summary:

Preparatory Courses	70
Secondary and Technical Courses	62
Electives	8
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 15 hours of chemistry (beyond Chem. 5E) for the following courses at present required in the mathematics curriculum (page 173): Astronomy 31, Eng. Mech. 3, and 4, Civil Eng. 2, and Surv. 1.

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 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	5	Metal Proc. 2 and Chem. Eng. 1	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. Eng. 2	3	Chem. 45	3
Chem. 15E	4	Chem. 57	5
Draw. 3	2	Math. 37	4
Math. 36	4	Mil. Sci.	(1)
Mil. Sci.	(1)	Phys. 46	5
Phys. 45	5		
	18		17

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

†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. Eng. 3	3	Chem. Eng. 4	2
Chem. Eng. 9*a*	3	Chem. Eng. 9*b*	3
Chem. 47	3	Chem. Eng. 29	2
Chem. 67E	4	Chem. 69E	4
Ec. or English	3 or 2	Eng. Mech. 2	4
Eng. Mech. 1	3	Mech. Eng. 3	4
	19 or 18		19

FOURTH YEAR

Chem. Eng. 5	4	Econ. 173	3
Mech. Eng. 2*a*	3	Elec. Eng. 2*a*	4
English (Group III) or Econ.	2 or 3	Chem. Eng. 12	5
		General Electives	3
Technical Electives	5	Technical Electives	3
Electives	3		
	17 or 18		18

THE FIVE-YEAR CURRICULUM IN CHEMICAL AND INDUSTRIAL ENGINEERING

A five-year curriculum including courses in chemical engineering and business administration has been prepared, leading to the degree of Bachelor of Science in Engineering (Chemical 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 program contains the full program in chemical 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.

COOPERATIVE PROGRAM IN GAS ENGINEERING

The Consumers Power Company, the Detroit City Gas Company, the Associated Gas and Electric System, the Peoples Gas Light and Coke Company of Chicago, Illinois, and the Brooklyn Union Gas Company have joined with the College of Engineering to maintain a coöperative program for students interested in gas engineering. This program will require for its completion four years and ten months, of which time eight semesters and one summer session will be spent at the University. There will be one preliminary employ-

ment period of eight weeks in the summer following the freshman year and two employment periods of seven months each, the first starting at the end of the second year and the second in the middle of the fourth year. There will be either one or two vacation periods of two weeks in each summer. Students in the Engineering College will be given an opportunity to learn details of the coöperative program at some time during the freshman year. Those who become interested and who are accepted will be employed by one of the companies for a preliminary period of eight weeks during the following summer. At the end of this preliminary period, students who have made a satisfactory record and are still interested may be formally enrolled for the coöperative program. A student thus enrolled will continue his second year of study in the Department of Chemical Engineering without interruption, and will be employed at the end of that period, by the company with which he has established relations, for a practice period which will continue for seven months, commencing July 1 and ending February 1. The student will then return to the University and remain in residence for twelve months, studying for two semesters and a summer school. On February 1 he will be reëmployed by the gas company for a second practice period of seven months, lasting until September 1. He will then return to the University for two semesters of study and should normally graduate in the following June.

The companies agree to give the students entering upon this work a somewhat varied employment which will put them in direct contact with various aspects of gas manufacturing, distribution, and accounting, and to pay them at the prevailing rate paid other workmen for the same type of work, but not less than fifty cents per hour. The company will retain the same rights to transfer, discharge, or alter the rate of pay of the student employees that it has over its regular employees.

COURSES IN CHEMICAL ENGINEERING

1. **Engineering Materials.** An elementary study of the manufacture and properties of the ferrous and non-ferrous alloys, cements, clay products, protective coatings, fuels, and water softening. Two lectures and two recitations. *Prerequisite: 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 temperatures, 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.

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.

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 and 9a, 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. 2 and 9a, and Chem. 45 and 67; preceded or accompanied by Chem. 69.* Four 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. 1 and Phys. 46; preceded or accompanied by 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.* Not open to students in chemical engineering. 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 both in 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: Chem. Eng. 4 and such other courses as are essential to a knowledge of the subject selected.* Three to eight 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.

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 processes 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. 9a.* Two hours credit. Each semester.

101 **(Formerly 9). Unit Operations.** A rapid treatment of the theory of unit operations for those who have some knowledge of the subject. Two lectures and two recitations. Three hours credit. First semester.

102 **(Formerly 28). 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 **(Formerly 11). Chemical Engineering Thermodynamics.** A study of the principles of the three fundamental laws of energy as applied to chemical 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 **(Formerly 61). Research Seminar.** Discussion of research of staff and graduate students. No credit. Each semester.

110 **(Formerly 21). Special Problems.** A continuation of Course 12. Laboratory work. *Open to graduates, and to seniors who receive special permission.* Three to eight hours credit. Each semester.

113 **(Formerly 13). 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.

114 **(Formerly 14). 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: Chem. Eng. 3 and 9b.* Two hours credit. First semester.

115 **(Formerly 15). 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 (Formerly 43). 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 eight hours credit. Each semester.

117 (Formerly 50). 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 eight hours credit. Each semester.

118 (Formerly 53). 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 eight hours credit. Each semester.

121 (Formerly 27). 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.

141 (Formerly 6). 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 and 3, or Chem. Eng. 1 and Mech. Eng. 3.* Two hours credit. First semester.

142 (Formerly 7). Non-Ferrous 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 and 3, or Chem. Eng. 1 and Mech. Eng. 3.* Two hours credit. Second semester.

143 (Formerly 18). Metallography of the Non-Ferrous Metals. An advanced study of the microscopic structure of the common non-ferrous 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: Chem. Eng. 3 and Chem. 47.* Two hours credit. Second semester.

144 (Formerly 37). X-ray Studies of Engineering Materials. Lectures and assigned work. *Prerequisites: advanced mathematics and physics as well as the necessary courses in chemical engineering.* Three hours credit. First semester.

145 **(Formerly 26). 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 and 241.* Two hours credit. Second semester.

146 **(Formerly 41). 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 eight hours credit. Each semester.

147 **(Formerly 47). Advanced Non-Ferrous Metallurgy.** Research work on structures and properties of non-ferrous metals and alloys. Laboratory work and conferences. *Open to graduates, and to seniors who receive special permission.* Three to eight hours credit. Each semester.

148 **(Formerly 54). 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.* Three to eight hours credit. Each semester.

151 **(Formerly 17). 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 **(Formerly 19). 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.

153 **(Formerly 25). 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.

156 **(Formerly 44). 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 eight hours credit. Each semester.

157 **(Formerly 48). 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 eight hours credit. Each semester.

158 (Formerly 52). **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 eight hours credit. Each semester.

166 (Formerly 42). **Hydraulic Cements.** Research work on the properties of hydraulic cements as influenced by chemical composition and temperature 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 eight hours credit. Each semester.

167 (Formerly 46). **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 eight hours credit. Each semester.

171 (Formerly 32). **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 (Formerly 38). **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 (Formerly 45). **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 eight hours credit. Each semester.

177 (Formerly 51). **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 eight hours credit. Each semester.

202 (Formerly 36). **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 (Formerly 22). **Applied Thermodynamics.** An advanced analytical study of chemical engineering processes from the standpoint of quantitative thermodynamics and physical chemistry. A continuation of Course 105. Two lectures and one recitation. Two hours credit. Second semester.

211 (Formerly 23). **Design of Chemical Plants.** A simple chemical process is selected, and the student proceeds to plan the steps in the process and select the type of apparatus for each. *Prerequisites: Chem. Eng. 113; preceded or accompanied by Chem. Eng. 114 and 115, and a course in Machine Design.* Three hours credit. Each semester.

212 (Formerly 33). **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.

241 (Formerly 8). **Advanced Physical Metallurgy.** An advanced study of the thermal, mechanical, and magnetic properties, and the macroscopic and microscopic structures of metals. One lecture, one laboratory period, reports, and discussions. *Open only to graduates.* Two hours credit. First semester.

243 (Formerly 30). **Metals at Elevated Temperatures.** Reading and reports on metallurgical subjects. *Open only to graduates.* Two hours credit. Each semester.

244. **Advanced X-ray Studies of Engineering Materials.** A study of the application of x-ray diffraction methods to selected problems in organic and inorganic processes, and to metallography, with special reference to the connection between crystal structure and fundamental physical properties. Conferences and assigned work. *Prerequisite: Chem. Eng. 144.* Two hours credit. Second semester.

245 (Formerly 40). **Thermodynamics of High Temperature Reactions.** Systematic calculations on the free energy of chemical substances and the application of thermodynamic data to reactions of industrial importance, especially those involved in metallurgical processes. Lectures, conferences, and reports. *Prerequisite: Chem. Eng. 105.* Two hours credit. Second 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: Chem. Eng. 144 (37).* Three to eight 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 eight hours credit. Each semester.

251 **(Formerly 34). Natural Gasoline and Compressed Gases.** A study of the 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. First semester.

252 **(Formerly 35). Petroleum Refinery Engineering.** A discussion of special problems and modern developments in the petroleum industry. *Open to graduates who have completed Chem. Eng. 105 or are actively engaged in research in this field.* Two hours credit. Second semester.

Summer Session

Courses 1, 3, 5, 9*a*, 12, 29, 110, 113, 114, 116, 146, 156, 166, and 176, or similar courses, will be given during the Summer Session.

75. CIVIL ENGINEERING

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

Civil engineering is divided into groups which correspond to the specialties of practicing civil engineers. Since these divisions have come about gradually through the requirements of actual practice, it is inevitable that there should be considerable overlapping of the various fields. The competent civil engineer must have a broad understanding of the scientific principles underlying all of the groups, as well as a high degree of skill in applying these principles to the specialized problems of his own group.

While the training of the civil engineer is essentially technical, it is not always as a technician that he achieves his greatest usefulness. It has come to be quite 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 field, 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. Many graduate civil engineers are successfully engaged in highway, railroad, municipal, or building contracting.

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,

*Honorary Professor of Civil Engineering.

retaining walls, etc., involving the use of steel, masonry (including reinforced concrete), and timber.

Hydraulic Engineering, which takes up problems involving the control and use of water, including irrigation, drainage, water power development, 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.

Sanitary Engineering, which deals with the design, construction, and operation of waterworks, sewers, water purification and sewage disposal works, and with all matters related to public sanitation. It offers many opportunities for advanced work and research along the line of prevention of disease by the proper construction and operation of engineering structures.

Municipal Engineering, which deals with the design, construction and maintenance of paving, sewers, sidewalks, street drainage, waterworks, and other municipal public works, the laws controlling their construction and operation, the proper design and laying out of cities and villages, and the construction and regulation of street railways and other utilities.

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 with 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 to 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 should confer with the professor in charge of the division relative to the completion of his program. The main divisions of civil engineering are described hereafter.

Before the end of the junior year, the student must definitely determine his major electives as required by the curriculum. These electives must be acceptable to the professor in charge of the division, and approved by the Head of the Civil Engineering Department, before the student may be classified as a senior. It is expected that the major electives will include work in nontechnical subjects cognate to a chosen field as well as in the technical and professional courses which are deemed essential.

Elections in military science (advanced group) to the extent of eight hours are accepted in Curriculum A as major electives in all divisions of civil engineering.

Coöperative courses as listed are considered as major electives in fulfilling the requirements of the curriculum.

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 General Announcement of the Graduate School of the University.

Fellowships of interest to students in civil engineering are described in section 44.

Highway Laboratories.—Through a coöperative arrangement between the University and the State Highway Department, all of the testing of materials for the State Trunk Line and Federal Aid roads, and all county roads which receive State aid, is done at the University. The work of the State is done in rooms immediately adjoining those used for the student work, so that the students secure the benefits to be derived from observing the work of full-time trained employees of the State, as well as from their own work.

The Highway Laboratory, which has 11,000 square feet of floor space, is located in the basement of the north wing of the East Engineering Building. There are laboratories for the testing of the following materials: cement, concrete, sand, gravel, rock, paving brick, and similar materials; asphalt, tars, oils, and bituminous mixtures; calcium chloride, metals, and paints; culvert pipe; and soils. The laboratories also contain a freezing room where temperatures as low as –40°F. may be obtained, and rooms for equipment, balances, concrete curing, storage samples, lockers, and showers.

The Laboratory is equipped with all the necessary apparatus for the testing of all kinds of non-bituminous and bituminous materials. Among the more important pieces of apparatus and equipment are a four-cylinder Deval abrasion machine, standard brick rattlers, ball mills, a briquette molding machine, Page impact machines, a Dorry hardness machine, diamond core drills, a 200,000-pound compression testing machine, a concrete wear testing machine, tensile testing machines, apparatus for testing cement, moist closets, mechanical shakers, microscopes, bituminous extraction machines, standard penetrometers, ductility machines, viscosimeters, constant temperature baths, electric ovens, analytical balances, field testing apparatus, and a freezing room.

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.

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 to be found 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.

CURRICULA IN CIVIL ENGINEERING AND REQUIREMENTS FOR GRADUATION

Candidates for the degree of Bachelor of Science in Engineering (Civil Engineering) are required to complete either Curriculum A or Curriculum B, as detailed on this and the following pages of this Announcement. For the definition of an hour of credit see section 50.

CURRICULUM A (WITHOUT SUMMER CAMP IN SURVEYING)

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, 3	8
Geology 11	4
Chem. Eng. 1 and Metal Proc. 2	5
Economics 53, 54	6
Total	70

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, Hydromechanics	3
Elec. Eng. 2*a*, Electrical Apparatus and Circuits	4
Mech. Eng. 3, Heat Engines	4
Civil Eng. 2, Theory of Structures	3
Civil Eng. 2*a*, Elementary Design of Structures	3
Civil Eng. 3, Masonry	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	55

c) *Major Electives*	
Technical or Nontechnical courses as approved by professor in charge of division	15

Summary:

Preparatory Courses	70
Secondary and Technical Courses	55
Major Electives	15
Total	140

CURRICULUM B (WITH SUMMER CAMP IN SURVEYING)

This curriculum is designed for the benefit of students who wish to avail themselves of the opportunity of electing the Summer Camp in Surveying.

		Hours
a)	*Preparatory Courses*	
	English 1, 2, 3, and a course from Group II	8
	English 6	2
	Nontechnical Electives, see section 51	4
	Astronomy 35	2
	Math. 3, 4, 36, 37	16
	Physics 45, 46	10
	Chem. 5E	5
	Drawing 1, 2, 3	8
	Geology 11	4
	Chem. Eng. 1 and Metal Proc. 2	5
	Economics 53, 54	6
	Total	70
b)	*Secondary and Technical Courses*	
	Surveying 1, 2, 3	15
	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, Hydromechanics	3
	Elec. Eng. 2*a*, Electrical Apparatus and Circuits	4
	Mech. Eng. 3, Heat Engines	4
	Civil Eng. 2, Theory of Structures	3
	Civil Eng. 2*a*, Elementary Design of Structures	3
	Civil Eng. 3, Masonry	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	63
c)	*Major Electives*	
	Technical or Nontechnical courses as approved by professor in charge of division	10
Summary:		
	Preparatory Courses	70
	Secondary and Technical Courses	63
	Major Electives	7
	Total	140

Program for Curriculum A

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	5	Metal Proc. 2 and Chem. Eng. 1	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	Surveying 2	4
Economics 53	3	Economics 54	3
Drawing 3	2		
	17		16

SUMMER SESSION

Eng. Mech. 1	3
Civil Eng. 40	2
Elective	3
	8

THIRD YEAR

Geology 11	4	Eng. Mech. 3	3
Eng. Mech. 2	4	Eng. Mech. 4	3
Eng. Mech. 2*a*	1	Civil Eng. 2	3
Mech. Eng. 3	4	Civil Eng. 2*a*	3
Civil Eng. 50	2	Civil Eng. 42*c*	1
Elective	2	Elective	3
	17		16

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

†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
Civil Eng. 3	3	Civil Eng. 12	2
Civil Eng. 10	3	Elec. Eng. 2*a*	4
Civil Eng. 30	3	English 6	2
Civil Eng. 32	2	Electives	9
Civil Eng. 26	2		
Electives	4		
	17		17

Program for Curriculum B

FIRST YEAR

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	5	Metal Proc. 2 and Chem. Eng. 1	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. 1	3
Surveying 1	3	Surveying 2	4
Economics 53	3	Economics 54	3
Drawing 3	2	Astronomy 35	2
	17		16

SUMMER SESSION

Surveying 3 (at Camp Davis)	8

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

†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 COURSES	HOURS	SECOND SEMESTER COURSES	HOURS
Physics 46	5	Eng. Mech. 3	3
Eng. Mech. 2	4	Eng. Mech. 4	3
Eng. Mech. 2*a*	1	Civil Eng. 2	3
Geology 11	4	Civil Eng. 2*a*	3
Civil Eng. 40	2	Civil Eng. 42*c*	1
Civil Eng. 50	2	Mech. Eng. 3	4
	18		17

FOURTH YEAR

Civil Eng. 3	3	Elec. Eng. 2*a*	4
Civil Eng. 10	3	Civil Eng. 12	2
Civil Eng. 30	3	Civil Eng. 26	2
Civil Eng. 32	2	Elective	8
English 6	2		
Elective	3		
	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	10
Math. 3, 4, 36, 37	16
Physics 45, 46	10
Chem. 5E	5
Drawing 1, 2, 3	8
Chem. Eng. 1 and Metal Proc. 2	5
Economics 53, 54, 173	9
Total	73

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. 2, Theory of Structures	3
Civil Eng. 3, Masonry	3

Civil Eng. 26, Specifications and Contracts	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. 55, Transportation	2
Civil Eng. 58, Inland Waterway Transportation	2
Mech. Eng. 3, Heat Engines	4
Mech. Eng. 29*a*, Automobile and Motor Trucks	2
Elec. Eng. 2*a*, Electrical Apparatus and Circuits	4
Elec. Eng. 8, Electric Traction	2
Naval Arch. 1, Ships and Ship Building	2
Aero. Eng. 1, General Aeronautics	3
Total	51

c) **Major Electives*

Technical courses as approved by professor in charge of department 16

Summary:

Preparatory Courses	73
Secondary and Technical Courses	51
*Major Electives	16
Total	140

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	5	Metal Proc. 2 and Chem. Eng. 1	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

**Major Electives.*—The student will take one of the following groups of subjects plus nine credit hours of work in cognate fields, as approved by the Head of the Department:—*Railroad:* Civil Eng. 27, 51, 52, 52*a*; *Aeronautical:* Aero. Eng. 1, 2, 5, 7, 16; *Highway:* Civil Eng. 42*a*, 44, 45, 46; *Automotive:* Mech. Eng. 30, 30*a*, 32; *Electrical:* Elec. Eng. 3, 4; *Marine:* Naval Arch. 2, 4, 5T, 13.

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

‡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
Surveying 1	3	Eng. Mech. 1	3
Economics 53	3	Economics 54	3
Drawing 3	2	Aero. Eng. 1	3
	17		18

SUMMER SESSION

Eng. Mech. 2	4
Civil Eng. 40	2
Nontechnical Elective	2
	8

THIRD YEAR

Eng. Mech. 2*a*	1	Eng. Mech. 3	3
Mech. Eng. 3	4	Civil Eng. 2	3
Civil Eng. 50	2	Civil Eng. 26	2
Civil. Eng. 55	2	Civil Eng. 42*c*	1
Economics 173	3	Mech. Eng. 29*a*	2
Nontechnical Elective	5	Naval Arch. 1	2
		Nontechnical Elective	3
	17		16

FOURTH YEAR

Civil Eng. 3	3	Elec. Eng. 2*a*	4
Civil Eng. 53	3	Elec. Eng. 8	2
Civil Eng. 58	2	Major Elective	9
English 6	2		
Major Elective	7		
	17		15

Cooperative Courses with Industry. Courses 9*s*, 19*s*, 29*s*, 39*s*, 49*s*, and 59*s* are offered to students in civil engineering. The work under these courses consists of employment by an approved company engaged in work in which civil engineering students are interested, during the summer vacation, June to October, or during a semester. While employed, the student will be paid standard wages for work done. Work under these courses when completed carries a minimum of five hours credit for ten months of work and an additional hour for each additional two months of work up to a total of sixteen months. These courses must be elected during the freshman and

sophomore years. The work is done in accordance with a prearranged plan and schedule and under close supervision of some member of the Civil Engineering staff.

Graduate Students in Civil Engineering may specialize in any of the divisions of the Department. Such students will ordinarily be required to complete at least eight hours of work in that division. Additional work sufficient to complete the requirements for the M.S. degree may be selected from cognate subjects.

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., 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.

2. **Theory of Structures.** Analysis of stresses in simple structures under various kinds of static and moving loads. Graphical and analytical methods discussed and applied to practice problems. Lectures, text, problems. *Prerequisite: Eng. Mech. 2.* Three hours credit. Each semester.

2a. **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. *Prerequisites: Draw. 3, and preceded or accompanied by Civil Eng. 2.* Three hours credit. Each semester.

3. **Masonry Construction.** Properties of materials; analysis of stresses in plain and reinforced concrete structures; foundations for engineering structures. *Prerequisite: Eng. Mech. 2.* 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. 2.* Two hours credit. Each semester.

5. **Design of Structures.** Design work covering general design of reinforced concrete, steel, and timber structures. Computations, drawing work. *Prerequisites: Civil Eng. 2a and 3.* 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.

7. Advanced Design of Structures. A group of optional specialized courses as listed below for students desiring advanced and specialized instruction in the design of various classes of structures. Students may elect these courses simultaneously. *Civil Eng. 7 group is open to graduates, and to qualified seniors by special permission. Each semester.*

7a. Structural Engineering. Special studies in the field of structural engineering with emphasis on the modern structure, preparation of bibliographies, library research, and class discussion. Credit and hours to be arranged. Each semester.

7b. Reinforced Concrete. Structural features of reinforced concrete building construction; drafting room practice in the general design and detailing of reinforced concrete. Lectures, drawing work. *Prerequisite: Civil Eng. 3.* Three hours credit. Each semester.

7c. Arches. Analysis of stresses and design of arches, especially reinforced concrete arches. Lectures, drawing work. *Prerequisite: Civil Eng. 3.* Two hours credit. Each semester.

7d. Timber Construction. Physical characteristics of structural woods; selection of timber; grading rules; commercial practice; design of typical structures. Lectures, drawing work. *Prerequisite: Civil Eng. 2a.* One hour credit. Each semester.

7e. Wind Stresses. Intensity and distribution of wind pressures on different types of structures. Methods of computing the wind stresses in towers and tall buildings. *Prerequisite: Civil Eng. 3.* Three hours credit. Each semester.

7f. Short-Span Suspension Bridges. Analysis and design of suspension bridges by methods which neglect the effect of the changes in dimensions produced by live load and temperature. Lectures and assigned problems. *Prerequisite: Civil Eng. 4.* Two hours credit. Each semester.

7g. Long-Span Suspension Bridges. Analysis of suspension bridges by exact methods. Application of Fourier's series. Stiffening trusses, simple and continuous, with constant and variable moment of inertia. Lectures and individual problems. *Prerequisites: Civil Eng. 7f and Math. 105.* Two hours credit. 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. Lectures, class discussion. *Open to seniors and graduates.* Two hours credit. Second 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. *Open to seniors and graduates.* 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. *Prerequisite: Eng. Mech. 4. Open to seniors and graduates.* Three hours credit. Each semester.

11. **Hydraulics.** Principles of non-uniform 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. *Prerequisite: Eng. Mech. 4. 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; navigable rivers. Lectures with lantern slides showing important hydraulic structures; theses by students. *Prerequisite: Eng. Mech. 4.* Three hours credit. Second semester.

16. **Hydraulic Engineering Design.** Description of hydraulic structures; hydraulic and structural computations; design of hydraulic structures; water conveyance structures; dams; power houses; 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. *Pre-*

requisite: 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.* Two hours credit. Second semester.

34. **Municipal and Industrial Sanitation.** The scientific foundations of public sanitation; the prevention of typhoid fever, malaria, and other diseases 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.

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, but 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: Chem. 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. Each 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. Each 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.

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, but 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, but not restricted to engineering students.* Two hours credit. Second 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, but 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 Chem. Eng. 45 be preceded or accompanied by this course. Open to seniors and graduates.* Two hours credit. Each 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 one 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. Second 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. 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. First semester.

55a. Transportation. The relation of transportation to the political and economical development of the nation. Lectures, library research, seminar. *Open to juniors, seniors, and graduates, but not restricted to engineering students.* Two hours credit. Second semester.

58. Inland Waterway Transportation. Engineering and economic problems involved in the development of American inland waterway transportation. Lectures, library reading, recitations. *Open to juniors, seniors, and graduates, but not restricted to engineering students.* Two hours credit. First 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 under the direction of Professor Timoshenko. *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, 7*c*, 26, 30*s*, 34*s*, 40, 45, 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 Professor ATTWOOD; Assistant Professors STOUT, 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 his 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 each year several fellowships are offered 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, 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 six 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, thermo-ammeters and the usual types of auxiliary apparatus. A cathode ray oscillograph is 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-Northrup manufacture, the best obtainable. There are at this writing eleven 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 of moderate accuracy. 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 spectro-photometer 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 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 of response of grid-controlled rectifiers. A varied assortment of electron tubes and photo-sensitive 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 electronic control assemblies as individual projects. Two smaller cathode-ray oscillographs of differing sensitivities are available for study and demonstration of repeating transient and high-frequency currents and voltages. Mercury rectifiers with and without grid 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.

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 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, non-sinusoidal 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 the Graduate School fellowship must be made before March 1. See sections 44 and 45.

CHOICE OF ELECTIVE WORK

With regard to electives in the nontechnical group, the student is advised to select such courses in the arts and sciences as will contribute to a broad, liberal education. Students feeling the lack of sufficient facility in the use of English are strongly urged to elect advanced courses in this subject, as the ability to speak and write good English is essential to a broad education in general, as well as to the highest success in the engineering profession.

The 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, anticipates 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. 14, Electronics in Power Transmission
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
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. 71, Interior Illumination—Study of Design
Elec. Eng. 73, Photoelectric Cells
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

Electrical Engineering Design:—

Elec. Eng. 6, Advanced Theory of the Induction Motor
Elec. Eng. 51, Electromagnetic Problems in Electrical Design
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. 40, Telephone Equipment
Elec. Eng. 41, Telephone Communication
Physics 174, Sound
Physics 176, Laboratory Work in Sound

General Theory and Measurement:—

Elec. Eng. 10, Advanced Theory of Electrical Circuits
Elec. Eng. 14, Electronics in Power Transmission
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

Electronics:—
Elec. Eng. 14, Electronics in Power Transmission
Elec. Eng. 16, Electrical Rectification
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. 22, Radio Communication
Physics 166, High Frequency Measurements
Physics 265, Conduction of Electricity through Gases
Physics 196, Atomic and Molecular Structure

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 nine credit hours which may be counted as nine 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.

	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, Hydromechanics	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 Vacuum 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	5	Metal Proc. 2 and Ch. E. 1	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	Economics 54	3
Economics 53	3	Mil. Science	(1)
Mil. Science	(1)		
	(18) or 17		(17) or 16

SUMMER SESSION

Eng. Mech. 2	4
Mech. Eng. 3	4
	8

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

†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
Elec. Eng. 1	4	Elec. Eng. 7	2
Elec. Eng. 3	4	Elec. Eng. 12	4
Math. 39	2	Elec. Eng. 17	4
Eng. Mech. 2*a*	1	Eng. Mech. 4	3
Eng. Mech. 3	3	Mech. Eng. 3*a*	1
Nontechnical Elective	3	Nontechnical Elective	3
	17		17

FOURTH YEAR

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.

COÖPERATIVE COURSE IN ELECTRICAL ENGINEERING AND INDUSTRY (FIVE YEARS)

The time required is five years, divided tentatively as follows:

YEAR	FIRST SEMESTER	SECOND SEMESTER	SUMMER SESSION
1	University	University	Free
2	University	Industry	University
3	University	Industry	University
4	University	Industry	University
5	University	Industry	

The periods spent in industry, during the second to fifth years inclusive, may be taken in the first, instead of the second, semester.

Credit for the course will be as follows:

Required university work	127 hours
Elective university work	4 hours
Credit for completing the industrial work	9 hours
Total	140 hours

No credit will be given for industrial work except as arranged under the coöperative plan.

It is contemplated that the student will spend all four outside periods with one industrial concern. This, if mutually agreeable, may lead to permanent employment. During his employment the student will work in various departments of the industry and will receive pay.

Coöperative relations shall be established only with such industries as are able and willing to offer a definite program of graded work of educational value.

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 four-hour computing period, and one four-hour laboratory period. *Prerequisite: Eng. Mech. 1.* 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 non-electrical 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. *Prerequisites: Elec. Eng. 2, and preceded or accompanied by Elec. Eng. 1.* 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. 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 Elec. Eng. 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 distributions of light; light output of any source having symmetrical distribution; calculations regarding light in an inclosure, utilization factor, 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 Math. 36, and must be preceded or accompanied by Math. 36.* 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. Second 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 Elec. Eng. 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 Course 18 in that the instructor is in close touch with the work of the student. Course 9 may be elected by seniors who have suitable preparation. Course 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. *Prerequisites: Elec. Eng. 3, and preceded or accompanied by 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. 3 or Elec. Eng. 2a.* Five hours credit. Each semester.

12. **Electronics and Electron Tubes.** Elementary electron dynamics and cathode-ray devices; kinetic theory of conduction and electron emission; work function. Space charge vs. potential in simple geometries; space-charge-limited currents. Electron tube characteristics, simple amplifier circuits, gain, distortion, and coupling; brief survey of radio oscillators, modulators, detectors. Atoms and radiation; energy-level diagrams, ionizing processes and potentials, photo-electric currents and their uses. Grid-controlled rectifiers, illustrative of arc characteristics and of the application of kinetic theory to densely ionized regions; probes, ion and electron sheaths, electron temperature. Arc reignition in circuit-interrupters, arc ignition, transfer from glow to arc, arc extinction. Three lec-

tures and one three-hour laboratory period. *Prerequisites: Elec. Eng. 1, and preceded or accompanied by Elec. Eng. 3.* Four hours credit. Each semester.

14. **Electronics in Power Transmission and Distribution.** Advanced study of gaseous electrical conduction; static and dynamic electrical characteristics, also physical dimensions of arcs and glow discharges; arc ignition, transfer from glow to arc, a-c. and d-c. arc extinction, with application to circuit-breakers, high-voltage fuses, mercury rectifiers, lightning, lightning arresters; corona streamers, growth of a spark, methods used in surge voltage tests of transmission equipment and in lightning investigations. Electron optics as applied to cathode-ray oscillograph. Two lectures. *Prerequisites: Elec. Eng. 12, and preceded or accompanied by Elec. Eng. 11 and Elec. Eng. 17.* Two hours credit. Second semester.

15. **Advanced Lighting.** Selection of a topic, with instructor's approval, for continued and intensive study, which is pursued either until 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.** Studies of modern power station design and performance; a brief treatment of prime mover application; detailed study of electrical equipment, generators, excitation system, auxiliary power, switchboard, relays, automatic operation, circuit breaker control and application; special problems of interconnection, stability, single-phase short circuit study through use of symmetrical coördinates. *Prerequisites: Elec. Eng. 11 and Elec. Eng. 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 Elec. Eng. 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.

22a. **Radio Communication.** This course is a continuation of Elec. Eng. 22 and will be given upon request of a sufficient number of students. The course will consist of advanced work in radio such as antennae and principles of electromagnetic radiation; field measurements; and high frequency measurements. Any other subjects of special interest to the class will be taken up. Lectures and laboratory. *Prerequisite: Elec. Eng. 22.* Three hours credit.

23. **Elements of Electrical Communication.** This course together with Elec. Eng. 24 is designed for non-electrical students who are desirous of obtaining a general knowledge of the communication field. After a review of direct and alternating currents the following subjects are considered: equivalent networks; multisection uniform networks, propagation constant; uniform lines; loading, telephone repeaters; phantom circuits; line characteristics. Lectures and laboratory. *Prerequisite: Elec. Eng. 2a or equivalent. Not open to electrical students.* Three hours credit. First semester.

24. **Elements of Electrical Communication.** This course is a continuation of Elec. Eng. 23. Series, parallel and coupled circuits; vacuum tubes; audio and radio frequency amplifiers;

detection; receiving sets; oscillators; modulation; short-wave and broadcast transmitters; antennae. Lectures and laboratory. *Prerequisite: Elec. Eng. 23.* 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 Elec. Eng. 3.* Three hours credit. First semester.

25a. **Engineering Applications of Electromagnetic Field Theory.** Lorentz's 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. *Elected by permission of the instructor.* Two hours credit. Second semester.

27. **Electric 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, non-linear circuits, batteries. Lectures and recitations. *Prerequisite: Elec. Eng. 12.* 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. Ratio and phase angle tests of current and potential instrument transformers, and their use with wattmeters and watt-hour meters are considered. Opportunity is provided for working with a-c. bridges and oscillo-

graphs of various types, including the cathode-ray oscillograph. One afternoon of laboratory. *Must be preceded or accompanied by Phys. 147.* 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. *Prerequisite: to 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 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. *Must 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.

40. **Telephone Equipment.** Study of equipment used in telephone communication, including practices in manual and mechanical central offices, toll offices, telephone repeater stations, carrier current systems, and outside plant. Lecture and discussion. *Prerequisite: to be preceded by Elec. Eng. 3.* Two hours credit. First semester.

41. **Telephone Communication.** Study of the characteristics of circuits, networks, and telephone apparatus at audio frequencies. Lecture and laboratory. *Prerequisite: to be preceded or accompanied by Elec. Eng. 10.* Two hours credit. Each semester.

51. **Electromagnetic Problems in Electrical Design.** Further work in field mapping, mainly by rough analyses rather than by finished maps; further work in mmf. and flux distribution in apparatus; various magnetic problems, such as furnished by commutation, equalizer connections, the magnetic bridge, the watthour meter, etc. *Prerequisite: Elec. Eng. 5 and permission of instructor.* Two hours credit. Given when demand is sufficient, either semester or in summer school. Courses 51 and 52 are not, in general, given at the same time.

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 towards making heat transfer and temperature rise available to electrical engineers in the fields of design, application, and operation of apparatus in general. *Prerequisite: permission of the instructor.* Two hours credit. Given when demand is sufficient, either semester or in summer school. Courses 51 and 52 are not, in general, given at the same time.

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, especially 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. Two hours credit. First semester.

73. **Photo-Electric Cells and Their Applications.** Study of operating characteristics of photo-electric cells; selection of suitable amplifying circuits and relays; industrial applications; photo-electric photometers. Lectures and laboratory work. *Prerequisite: permission of instructor.* Two hours credit. First semester.

Summer Session

Courses 2*a*, 3, 4, 7, 17, and 18 are generally offered in the Summer Session. Courses 10, 11, 25, 26, 31, and 51 or 52 may be given if there is sufficient demand. Those wishing to elect any of these should, if possible, 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 TIMOSHENKO; Associate Professors STEVENS and SWINTON; Assistant Professors DODGE, LIDDICOAT, HANSEN, and OLMSTED; Mr. YOUNG and Dr. EVERETT.

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 hydromechanics 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 nine-foot transverse bending machine and a power saw and grinder, an electric furnace, a polishing table and wheel with photographic equipment, and cement-testing equipment for all standard cement tests.

The special accessory equipment consists of one six-element telemeter strain gauge, one Huggenberger extensometer, one Martens mirror strain gauge, one electrical micrometer gauge, one contact micrometer gauge, several Berry gauges, 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
b) *Secondary Courses*	
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.

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.

1D. **Survey Course in Mechanics.** Sixteen lectures on the principles of statics and strength of materials for non-engineering students. *Open to upperclassmen and graduate students.* One hour credit. Second semester.

2. **Strength and Elasticity of Materials.** A study of the application of mathematics and principles of mechanics to solution

*See section 51.

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. *Prerequisites: Eng. Mech. 1, and accompanied or preceded 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. *Prerequisite: Eng. Mech. 1.* 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. **Hydromechanics.** Pressures, centers of pressure, gauges, effects of translation and rotation, Bernoulli's theorem, orifices, tubes, weirs, pipes, open channels, meters, dynamic action of jets and streams. Recitations, lectures in Hydraulic Demonstration Room, problems. *Prerequisite: Eng. Mech. 1.* 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. Lectures, 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.** Dynamics of a particle. More complicated problems of vibration. Dynamics of a system of particles. Lagrange's equations. Vibration of a system. Dynamics of a rigid body. Application in gyroscopes. *Prerequisite: Eng. Mech. 3.* Two hours credit. First semester.

9. **Advanced Strength of Materials.** Lectures, problems. *Prerequisite: Eng. Mech. 2, with a grade of B.* Three hours credit. Each semester.

10. **Research in Strength of Materials.** Special problems involving laboratory tests, and application of theory in Eng. Mech. 2, 2*a*, 3, and 5. 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.* Two hours credit. Second 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 photo-elastic 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. Photo-elastic 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 fly wheels, 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 or compression; buckling of solid, tubular, and built-up columns under various conditions; buckling of thin plates, such as flanges and webs of built-up sections, and the web of a plate girder; bending of slabs under various conditions, with application to highway and structural engineering. Designed principally for students interested in structural design. *Prerequisite: Eng. Mech. 2.* Two 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.** The theory of strength and resistance of structures built of structural steel with reference to the ductility of the material. *Prerequisite: Eng. Mech. 2.* Three 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. Leuders 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 Mechanics of Materials.** History of development of fundamental principles of strength of materials will be discussed. The origin of statics. Origin of strength of material. The work of Galileo. Hooke's law. Theory of beams by Mariotte and Coulomb. Theory of elastic curves by Daniel Bernoulli, Euler, and Lagrange. The equations of the theory of elasticity by Navier, Canchy, and Poisson. Exact theory of torsion and bending of prismatical bars by Saint Venant. Reciprocity theorem. Theorem of least work. Modern development of the theory of elasticity. *Prerequisites: Eng. Mech. 2 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, 9, 12, 13*a*, 14, and 24, 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 the 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 1935 instruction begins on Monday, June 24. 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 project. 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. For those unable to complete a two-hour course in practical astronomy, as a part of their preparation, a second course of two hours, Surveying 6, given at the Camp, must be elected.

Students should be able to complete the camp work at a cost of about $150. The University fee is $42. The cost of board is approximately $45. This leaves a balance of practically $60, which should cover round trip transportation costs from almost any part of the United States and leave a balance which would enable students 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.

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
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:

Preparatory Courses	62
Secondary and Technical Courses	68
Electives	10
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	5	Metal Proc. 2 and Chem. Eng. 1	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

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

†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. Military science is for a period of four semesters.

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
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

SUMMER SESSION

Surveying 3 8

FOURTH YEAR

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 for 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 for 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 keep-

ing. 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. 4.* 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.* 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 drawing period. *Prerequisite: Math. 4.* 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 and Camera Surveying.** 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; color work; defects in negatives; reduction and intensification; principles of photo-engraving; mapping. Lectures, reference work, one hour recitation and one four-hour field or laboratory period. *Prerequisites: elementary chemistry and physics. Surveying 2 or 13.* A section in photography is offered for students having no training in surveying. Arrangements should be made with instructor for admission to this section. Two hours credit. Each semester.

22. **Advanced Topographic Surveying.** History of the development of topographic methods and practice of foreign countries; status of such surveys in this country; purpose of topographic surveys; use of topographic maps. Lectures, reference work, recitations, problems. *Prerequisite: Surv. 3. Open to fourth- and fifth-year students only.* Four hours credit. First 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 longitude; 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; Astron. 35.* See section 19 relating to fees. Eight hours credit. Summer camp.

4s. **Surveying.** Use of instruments, same as Surveying 4; given at Ann Arbor. Lectures, text, one recitation, and one four-hour field period. *Prerequisite: Math. 4.* Two hours credit. Summer Session.

6. **Surveying.** Given only at Camp Davis. Credit two to eight hours, depending upon the character of the work.

79. MATHEMATICS

Professors J. W. GLOVER, FIELD, RUNNING, HILDEBRANDT, and LOVE; Associate Professors POOR and AYRES; Assistant Professors ROUSE and CHURCHILL; Dr. DUSHNIK and Dr. MILLER.

Complete offerings of the Department of Mathematics will be found in the special bulletin published by the Department of Mathematics, which may be obtained from any University officer and, particularly, from Professor J. W. Glover.

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.

For students who desire to pursue their mathematical studies beyond the required work, a considerable number of advanced elective courses are offered.

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 intro-

duction 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.

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 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 Courses*	
	Astronomy 31 or Math. 145	3
	Surveying 1	3
	Eng. Mech. 1, 2, 3, 4	13
	Elec. Eng. 2*a*	4
	Civil Eng. 2	3
	Mech. Eng. 3	4
	Total	30
c)	*Advanced Courses*	
	Technical Group	14
	Mathematics Group	12
	Electives	8
	Group Options in Engineering Mechanics, Astronomy, Physics, Mathematics, or Technical Engineering	8
	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 fifteen hours of chemistry (beyond Chem. 5E) for the following courses at present required in the mathematics curriculum (page 173): Astronomy 31, Eng. Mech. 3 and 4, Civil Eng. 2, and Surveying 1.

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 Engineering and Mathematics Departments, 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.

9. **Solid Analytic Geometry.** Surface tracing and locus problems in space; direction cosines; plane; straight line; quadric surfaces; space curves. Two hours credit. First 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.

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: Course 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. Two hours credit. Each semester.

49. **Introduction to the Mathematical Analysis of Statistics I.** This course deals with the elementary theory and applications of mathematical statistics, treating in detail the following topics: averages, dispersion, skewness, sampling, and correlation. Assignments require the operation of computing, punching, sorting, and tabulating machines. The course is designed to serve as a background for students dealing with statistical and observational data. Two hours credit. Each semester.

51. **Mathematics of Finance.** The elementary theory of compound interest functions is developed as a preliminary to the solution of practical problems in annuities, sinking funds, depreciation, amortization, building and loan associations, capitalized cost and replacement, and the valuation of various types of contracts, bonds, and other securities. Systematic and accurate computation with the use of compound interest and seven-place logarithmic tables is stressed throughout the course. Three hours credit. Each semester.

103. **Differential Equations.** An elementary course in ordinary differential equations. *Prerequisite: one year of calculus.* Three hours credit. Each semester.

105. **Differential Equations.** Should be preceded by Math. 39. Solutions of differential equations by elementary methods. 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

*See footnote on previous page.

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. This course is intended primarily for students of engineering and other cognate subjects. Students of mathematics should elect Courses 201 and 202. *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.

143, 144. **Engineering Mathematical Physics.** Partial derivatives, line and surface integrals, vectors, complex variables, Fourier series, generalized coördinates, ordinary and partial differential equations, calculus of variations, and other topics; applications to fluid motion, elasticity, electricity, heat, mechanical vibrations, light, and sound; individual programs, adapted to previous preparation and present needs. Three hours credit each. Beginning either 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. Three 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. First semester.

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. First 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. Each semester.

177. **The Theory of Elasticity.** This is a general course in the elastic solid theory. It will be adjusted to the preparation and maturity of the students. Two hours credit. First semester.

178. **Hydrodynamics.** This is a general course in hydrodynamics. The subject matter will be chosen in accordance with the interest and ability of the students. Two hours credit. Second semester.

201, 202. **Theory of Functions of a Complex Variable.** Properties and manipulation of complex numbers; functions of a complex variable, their differentiation and integration and related theorems; developments in power series; properties of analytic functions; singularities and similar topics; applications to mathematical physics and to other branches of mathematics. Three hours credit each. Throughout the year.

209. **Partial Differential Equations of Physics.** Derivation and solution of some of the principal partial differential equations occurring in the theories of sound, elasticity, hydrodynamics, electricity, and light. Three hours credit. Second semester.

214. **Mathematical Theory of Heat Conduction.** Fourier's conduction equation; flow of heat in one dimension; Fourier's series; flow of heat in more than one dimension; solution of problems of the flow of heat in different substances. Three hours credit. Second semester.

232. **Advanced Mechanics.** Analytical dynamics. Equations of motion in generalized coördinates, principles available for inte-

gration, problems of particle and rigid dynamics, theory of vibrations, principles of Hamilton and Gauss. Hamiltonian systems. Three hours credit. Second semester.

237. **Mathematical Theory of Aerofoils.** Advanced study of the Jowkoosky, von Mises, and Witosynski theory of wing profiles and the Prandtl theory of the induced drag, preceded by a brief review of the fundamentals of the mathematical theory of hydrodynamics. *Must be preceded by Math. 39 and Math. 110.* Two hours credit. First semester.

238. **Advanced Stability.** Advanced study of the more complicated phenomena of stability according to Bryan, with Bairstow's applications of experimentally determined resistance derivatives and rotary coefficients. *Must be preceded by Math. 39.* Two hours credit. Second semester.

241. **Applied Mathematics—Engineering Problems.** The problem will first be formulated mathematically and then the necessary mathematical theory for a solution will be developed. The problems will be so selected that their solutions will cover a wide field mathematically; such as ordinary and partial differential equations, difference equations, harmonic analysis, and approximate solutions. Three hours credit. First semester.

245, 246. **Advanced Celestial Mechanics.** Studies in continuation of Math. 146 will be arranged for those qualified to take them, analytic differential equations with applications to periodic orbits, cosmogony and stellar dynamics, lunar theory, and research in mathematical astronomy. Two or three hours credit each. Throughout the year.

Summer Session

Courses 4, 8, 36, 37, 49, 170, 176, and 241, or similar courses, will be offered in the Summer Session.

80. MECHANICAL ENGINEERING

Professors ANDERSON, BURSLEY, EMSWILER, HAWLEY, LAY, SHERZER, and KEELER; Associate Professors NICKELSEN, MICKLE, GOOD, GORDY, and MARIN; Assistant Professors WATSON, LLOYD, KESSLER, CALHOON, and KOHLER.

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 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.

Hydro-Mechanical Engineering, one of the oldest branches of mechanical engineering, deals with the theory, design, construction, installation, testing, and operation of water wheels, water turbines, 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 automobile engines. The very complete and modern Washington Street power plant of the University (for description see section 41) is available for use, and a test of this plant constitutes a regular part of the second course in Mechanical Laboratory. 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 hydro-mechanical work the laboratory is equipped with a pair of 600-cubic-foot tanks on scales, a large Duplex pump, a Francis turbine, a Doble tangential water wheel, two Rees Roturbo pumps, two three-inch single-stage centrifugal pumps, one 50-horsepower Sprague electric dynamometer arranged for direct connection to centrifugal pumps, and all necessary accessories for testing.

The Automotive 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, or in marine service. 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 six-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 serves 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 depart-

ment 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

		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	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, Hydromechanics	3
	Mech. Eng. 2, Elements of 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	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	16
	Total	140

SELECTION OF ELECTIVE COURSES

The sixteen hours of elective work is 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*, 12*a*, 15*a*, 16*a*, 17*a*, 20*a*, 25*a*, 30*a*, 31*a*. Of this group, Course 15*a* must be preceded or accompanied by 15. Courses 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, 12, 13, 15, 16, 17, 19, 20, 25, 30, 31, 35, 55.

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 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	5	Metal Proc. 2 and Chem. Eng. 1	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.

†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	4
or		or	
b) Metal Proc. 4	4	*b*) Mech. Eng. 7 and Chem. Eng. 10	3
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	9
Civil Eng. 2	3		
Surveying 4	2		
Electives	3		
	18 or 19		15

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 Engineering (Mechanical Engineering) is given at the end of the fourth year. For the fifth year, registration must be made in the

*To be selected from Mech. Eng. 11, 12, 13, 15, 16, 17, 19, 20, 25, 30, 31, 35, 55.

†To be selected from Mech. Eng. 9*a*, 11*a*, 12*a*, 15*a*, 16*a*, 17*a*, 20*a*, 25*a*, 30*a*, 31*a*.

Graduate School; on the successful completion of this year, the degree of Master of Science (Industrial Engineering) is awarded.

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 Mgt., Mech. Eng. 20, 35, 36	8
Chem. Eng. 1, 10	4
Elec. Eng. 2*a*	4
Civil Eng. 2	3
Economics 53, 54, 171, 172	12
Bus. Ad. 113	3
Electives (in addition to nontechnical)	2
Total	142

Subjects—Fifth Year	*Hours*
Math. 49	2
Mech. Eng. 40, 42	6
Bus. Ad. 161, 162, 202	9
Economics 121	3
Elective	10
Total	30

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	5	Metal Proc. and Chem. Eng. 1	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.

† 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
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
Metal Proc. 4	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
Mech. Eng. 2	4	Electives	2
	17		18

Fourth Year

Mech. Eng. 35	3	Metal Proc. 7	2
Mech. Eng. 9	3	Mech. Eng. 36	3
Elec. Eng. 2*a*	4	English	2
Bus. Ad. 113	3	Mech. Eng. 20	2
*Nontechnical electives	4	*Nontechnical electives	4
		Civil Eng. 2	3
	17		16

Fifth Year

Math. 49	2	Bus. Ad. 162	3
Bus. Ad. 161	3	Bus. Ad. 202	3
Mech. Eng. 40	3	Mech. Eng. 42	3
Economics 121	3	Electives	6
Electives	4		
	15		15

* For nontechnical elective see section 51.

COURSES IN MECHANICAL ENGINEERING

2. **Elements of Machine Design.** Application of theory to elementary machine design for shafts, journals, bearings, couplings, keys, cotters, spur gearing, belts, ropes, chains, clutches, brakes, flywheels, springs, fastenings, cylinders, and riveted joints. 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 students 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.** General principles involved in the action of the various forms of heat engines, including the steam engine and boiler, the steam turbine, and the internal combustion engine with special attention given to the different types in use; the general problem of a modern power plant is considered for the benefit of those who do not devote further time to the subject. Required of all engineering students. Lectures, recitations. *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.** Second Course. Analysis of forces for the design of machine parts, considering dynamic forces, critical speeds, and the application of the theory of elasticity. Analytical and graphical problems in kinematics and valve gears. 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. This course includes elementary tests of a steam engine, steam turbine, gas or oil engine, power pump, and steam boiler. The use and calibration of instruments used in mechanical engineering work exemplified in connection with these tests and in the calculation of the results. Laboratory, computations, 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, a Diesel engine, fan, steam injector, air compressor, refrigerating machine, steam power plant, and several forms of hydraulic machinery. Laboratory, computations, 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 Boilers.** A study of commercial types of boilers, stokers, and superheaters; principles of boiler economy and operation; combustion of fuels; theory of heat transference; purchase of coal by specifications; storage of coal; feed-water treatment; problems of design. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 3.* Three hours credit. First semester.

11a. **Design of Steam Boilers.** 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.

12. **Steam Reciprocating Engines.** A study of the general theory and thermodynamics of the steam engine; the various commercial types, and problems on design. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 5.* Two hours credit. Second semester.

12a. **Design of Reciprocating Steam Engines.** Complete design of a steam engine; including the calculation and drawing of important details. Drawing, problems; two four-hour periods a week. *Prerequisite: Mech. Eng. 6.* Three hours credit. Second semester.

13. **Steam Turbines.** A course in the advanced study of the flow of fluids, kinetic effects, thermodynamics, with the steam turbine used as a concrete example. Attention is given to the influence of vacuum, pressure, and superheat; stage bleeding; the bleeder turbine; governing; and the field of application of the turbine. Lectures, recitations, problems. *Prerequisite: Mech. Eng. 5.* Three hours credit. Each 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. *Prerequisites: preceded or accompanied by Mech. Eng. 3.* Three hours credit. Each semester.

15. **Internal Combustion Engines.** Theory of Otto and Diesel engines; thermodynamics; fuels and combustion; carburetion; ignition; injection; cooling; lubrication; starting; performance; engine mechanics; balancing and vibration. Discussions, problems. *Prerequisites: Eng. Mech. 3, and preceded or accompanied 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. *Prerequisite: 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. First 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; the solution of problems. 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 involved in the use of mechanical handling equipment and also to the effect on labor. Lectures, recitations, problems, reports, and plant inspection. *Prerequisite: Mech. Eng. 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 transmissions 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.

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. Second 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 spread, 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.

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 a 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—Purchasing and Traffic.** 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.

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. Drawing. *Prerequisite: Mech. Eng. 15a.* 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—Advanced.** Special problems for study and investigation. Problems, reports. *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. Second semester.

50. **Gyroscopic Action and Critical Speeds.** Fundamental principles and applications of gyroscopic action; synchronous action in general; mathematical study of critical speeds; empirical treatment of complex cases. Lectures, recitations. *Prerequisite: Eng. Mech. 3.* Two hours credit. Each semester.

53. **Personnel Problems in Engineering.** This course is designed to give the student an appreciation of the personnel or human problems as affecting engineering design and production. Typical problems and situations are featured. Lectures, demonstrations, discussions, and recitations. *Not open to freshmen or sophomores.* Three 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 both with 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; Assistant Professors ADAMS and BAIER.

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 the displacement and buoyancy, 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. A clay mould is first made approximately to the shape desired, and a core inserted. The paraffin is then poured into the mould, 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 any desired speed. 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. 2*a*, Laboratory—Strength of Materials	1
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Hydromechanics	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. 2*a*, 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

Summary:

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; and

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	1
Electives	13
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

*Students electing Group C, Water Transportation, for their group options, will substitute an elective in place of Civil Eng. 2.

C. WATER TRANSPORTATION

Economics 130, Transportation	3
Economics 173, Accounting	3
Naval Arch. 13, Specifications	1
Civil Eng. 55, Transportation	2
Electives	16
Total	25

In this group students will substitute an elective for Civil Eng. 2 in the regular schedule.

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	5	Metal Proc. 2 and Chem. Eng. 1	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
Economics 53	3	Economics 54	3
Mil. Science (1)		Mil. Science (1)	
	(18) or 17		(18) or 17

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

†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. Military science is for a period of four semesters.

SUMMER SESSION

Elective	4
Elec. Eng. *2a*	4
	8

THIRD YEAR

FIRST SEMESTER		SECOND SEMESTER	
COURSES	HOURS	COURSES	HOURS
Eng. Mech. 3	3	Eng. Mech. 4	3
Mech. Eng. 2	4	Naval Arch. 2	3
Mech. Eng. 3	4	Mech. Eng. 5 or Naval Arch. 6	3
Naval Arch. 5	4	Mech. Eng. 7	2
Surveying 4	2	Nontechnical Elective	6
	17		17

FOURTH YEAR

Mech. Eng. 4	3	Naval Arch. 7 or Mech. Eng. 8	3
Civil Eng. 2	3	Naval Arch. 4	3
Mech. Eng. 15 or Naval Arch. 3	3	English (Group III)	2
Elective	4	Elective	8
Naval Arch. 9	3		
	16		16

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; free board and tonnage; launching; calculation of bending moments and stresses in vessels under various conditions. Lectures and recitations. Three hours credit. Second semester.

3. **Stability of Ships and Preliminary Design.** This course includes investigations of the stability of vessels and means of determining the same; discussion upon the rolling and seagoing qualities of ships; and methods of reducing rolling. 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 (formerly Naval Arch. 1 and 5).** 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 strength 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.

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 pre-

pared, 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 and Contracts. One hour 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.

19. **Estimating.** Lectures and problems in cost estimating as applied to ship construction and repair. *Open to seniors.* One hour credit. Second semester.

82. PHYSICS

Professors RANDALL, WILLIAMS, COLBY, SMITH, SAWYER, GOUDSMIT, and BARKER; Associate Professors LINDSAY, UHLENBECK, MEYER, DENNISON, DUFFENDACK, and CORK; Assistant Professors SLEATOR, LAPORTE, and FIRESTONE.

The instruction in general physics covers a thorough course with the use of trigonometry and extends throughout an entire year. The first semester is devoted to mechanics, sound, and heat; the second to electricity and light. The subjects are amply illustrated with appropriate experiments accompanying the lectures. One period a week is devoted to laboratory work. The numerous courses, both experimental and theoretical, which the Department offers, are open to students wishing 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 sub-basement, all seven floors connected by an elevator.

Laboratories are provided for 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. Sound has a two-story structure extending through the first and second basements entirely disconnected from the walls of the surrounding building. X-ray research has ample quarters in the first and second basements. The high potential generators are housed in a two-story room which permits ready distribution of power to a number of adjacent research rooms. 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. Three storage batteries contain altogether 640 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.

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.

CURRICULUM IN PHYSICS

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.

	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	8
Math. 3, 4, 36, 37, 39	18
Physics 45, 46	10
Chem. 5E and 45†	8
Drawing 1, 2, 3	8
Metal Proc. 2 and Chem. Eng. 1	5
Economics 53, 54	6
Total	73
b) Secondary and Technical Courses	
Eng. Mech. 1, Statics	3
Eng. Mech. 2, Strength and Elasticity	4
Eng. Mech. 3, Dynamics	3
Eng. Mech. 4, Hydromechanics	3
Mech. Eng. 3, Heat Engines	4
Elec. Eng. 1, Principles of Electricity and Magnetism	4
Elec. Eng. 2, Direct Current Apparatus and Circuits	4
Elec. Eng. 3, Alternating Current Circuits	4
Physics 105, Modern Physics	2
Physics 147, Electrical Measurements	4
Physics 165, Vacuum Tubes	2
Physics 186 and 188, Light	4
Physics 196, Atomic Structure	3
Total	43
c) Group Options and Electives	
Group Options in Physics and Mathematics to meet the particular needs of the individual student	12
General Electives	12
Total	27

It is suggested that Sound (Courses 175 and 177) and Heat (Courses 181 and 183) be included under *c*.

Summary:	
Preparatory Courses	73
Secondary and Technical Courses	43
Group Options and Electives	24
Total	140

*Students intending to do graduate work in physics should elect German or French.

†Students in this curriculum may elect Chem. 45 without having had Chem. 15E.

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. Students transferring their credits from the College of Literature, Science, and the Arts will be required to offer Physics 35, 36, 37, and 38 as equivalents of Physics 45 and 46. *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.

121. **X-ray Equipment and Apparatus.** This course is intended primarily for students not specializing in physics. The work is partly experimental and will be conducted in the Department of Physics and in the Department of Roentgenology in the University Hospital. It will consist of the study of the underlying electrical principles and the electrical apparatus necessary; various types of tubes and their characteristics; the production and fundamental principles of x-rays, including demonstration of present-day measuring instruments, their use, and the practical dosage of x-rays in therapy. *Prerequisite: Phys. 36 or Phys. 46.* One lecture and one two-hour laboratory period a week. Two hours credit. First semester.

130. **Architectural Acoustics.** Lectures with illustrative problems on sound transmission, distribution, and absorption, and an

experimental study of the acoustic properties of certain rooms. *Prerequisite: Phys. 45 (or 35).* Two hours credit. Second semester.

145. **Electrical Measurements.** This course is not intended for electrical engineers. In the class work the principles of electrical behavior are critically studied and discussed. The laboratory exercises are designed to illustrate and emphasize these principles, and to give the student some personal experience in the careful use of electrical measuring instruments. The course includes the modern methods of measuring current, resistance, electromotive force, and power, and the calibration of the instruments employed. Three lectures and one four-hour laboratory period a week. Four hours credit. First 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 the regular one for electrical engineering students. *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 are studied graphically by vector methods, and analytically by the use of complex quantities. Application of the bridge to various problems. Hysteresis curves and losses for different kinds of steel are determined, and the efficiencies of transformers are measured. A Rosa curve tracer is used to trace the wave form of alternating currents and voltages. *Prerequisite: Phys. 145.* Four hours credit. Second semester.

156. **Electron Theory and Radioactivity.** Among the topics considered in this course are the radioactive disintegration of atoms, the nature and properties of alpha, beta, and gamma rays, the determination of the electronic charge, the arrangements of electrons and protons to form atoms, electrical mass, positive rays, isotopes, thermionic currents, and metallic conduction. Two hours credit. Second semester.

158. **Radioactivity.** The laboratory work is largely with radioactive substances. The distinguishing characteristics of alpha rays, beta rays, and gamma rays are studied, and the half life periods of several substances are determined by each student. One two-hour laboratory period a week. *Must be preceded or accompanied by Phys. 156.* One hour credit. Second semester.

165. **Electron Tubes.** The theory of the transmission of electricity through gases and through vacua is traced in this course, together with the different types of tubes and circuits used in radio

communication. The experimental work deals with the characteristics of tubes, the determination of amplifying factors, the different kinds of detector action, and the operation of generator systems. *Prerequisite: Phys. 154 or its equivalent; a knowledge of alternating current theory is necessary.* Two hours credit. First semester.

166. **High Frequency Electrical Measurements.** A laboratory course consisting of selected problems. Open to a limited number of students who have had adequate preparation. Two three-hour laboratory periods a week. *Prerequisite: Phys. 165.* Two hours credit. Second semester.

171. **Mechanics.** The mechanics of solids, liquids, and gases, involving such topics as the various types of motion, equilibrium, centroids, moments of inertia, friction, viscosity, and capillarity. Elementary operations with vectors are applied in the solution of certain problems. Three hours credit. First semester.

175. **Sound.** Lectures and problems covering the theory of vibrating systems, resonance, the use of complex numbers and impedance methods in the discussion of waves and vibrations, the radiation and propagation of sound waves, and subjective phenomena. First semester. Two hours credit.

177. **Laboratory Work in Sound.** A course to accompany or follow Course 175. The work is devoted to experiments on vibrating systems; to the absolute measurement of sound intensity with the condenser microphone and thermophone in conjunction with vacuum tube amplifiers and oscillators; to the measurement of ear sensitivity, masking, and minimum perceptible differences; and special problems. First semester. Two hours credit.

181. **Heat.** The work covers the fundamental principles of heat phenomena. Such subjects as temperature measurement, thermal expansion, heat transfer, specific heats, change of state, elementary kinetic theory, and thermodynamics are treated. Lectures and recitations. Two hours credit. First semester.

182. **Measurements of High Temperature.** A survey of the various types of furnaces now in use in the industries for the production of high temperatures is briefly made. Opportunity is given the student to work with laboratory models of such various types as the gas combustion furnace, electric arc, electric conduction and electric induction furnaces. In the measurement of high temperatures, practice is given in the calibration and use of resistance thermometers, thermo-electric devices, total radiation and optical pyrometers, as well as temperature recording and controlling devices and transition point apparatus. The subject matter is taken up from both practical and theoretical standpoints. Opportunity for work on special prob-

lems may be given to students qualified. Two hours credit. Second semester.

183. **Laboratory Work in Heat.** A course to accompany or follow Physics 181. Four hours per week in the laboratory are given to a study of modern accurate methods of measuring various thermal quantities, the need of the determination of which often arises in the course of scientific research. The student is given opportunity to become familiar with any of the modern temperature measuring devices, the determination of thermal expansion by several methods, including the interferometer and x-rays, measurement of specific heats, ratio of specific heats, thermal conductivities, etc. Two hours credit. First semester.

186. **Light.** An intermediate theoretical course treating the subjects of interference, diffraction, law of extreme path and aplanatic surfaces, polarization and double refraction, the nature of white light, and experiments on ether drift. Two hours credit. Second semester.

187. **Geometrical Optics.** A course in the 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, a study of the characteristics of optical instruments and exercises in the design of simple instruments, and discussions of the various types of optical glass. Three lectures or recitations a week and occasional laboratory exercises. Three hours credit. First semester.

188. **Laboratory Work in Light.** A course to accompany or follow Physics 186. The laboratory work includes the study of refraction, interference, diffraction, the examination of spectra and practice in the use of optical instruments. Four hours per week, Thursday afternoon. Two hours credit. Second semester.

196. **Atomic and Molecular Structure.** A review of recent developments in the theory of atomic and molecular structure and the solid state, with numerous references to current literature. Three hours credit. Second semester.

201, 202. **Physics Pro-Seminar.** Discussion groups for the study of the current literature of physics. Recommended for all graduate students in their first year of residence. Required of all candidates for the master's degree. Hours to be arranged. One hour credit each. First semester, 201; second semester, 202.

203, 204. **Molecular Physics.** An introduction to the theory of matter, with emphasis upon the mechanics of gases, mean free path phenomena, and specific heats. Spectroscopy and the quantum hypothesis are presented as tools for the study of the structure and

properties of matter. This course is intended primarily for students in Chemical Engineering. *Phys. 203 is a prerequisite for 204.* Three hours credit each semester. First semester, 203; second semester, 204.

205, 206. **Electricity and Magnetism.** A fundamental treatment of the Maxwell electromagnetic theory. Discussion of electrostatic and electromagnetic phenomena on the basis of Maxwell's equations. In the second semester the theory of electromagnetic waves and radiation from a Hertzian oscillator is developed. The connection with the special relativity theory is discussed. *Prerequisite: Phys. 154. Phys. 205 is a prerequisite for 206.* Three hours credit each semester. First semester, 205; second semester, 206.

207, 208. **Theoretical Mechanics.** The Lagrange equations of motion. Principles available for the integration of the equations with numerous applications to particle and rigid-body motion. The principles of least action and of Hamilton. Transformation of the canonical coördinates. The Hamilton-Jacobi equation. Poisson brackets. *Prerequisite: An adequate knowledge of differential equations. An introductory course in mechanics is desirable. Phys. 207 is a prerequisite for 208.* Three hours credit each. First semester, 207; second semester, 208.

209. **Thermodynamics.** A discussion of the two laws and their foundation. Applications to gas equilibria and dilute solutions. The phase rule of Gibbs. Theory of binary mixtures after van der Waals. *Prerequisite: Phys. 181.* Three hours credit. First semester.

210. **The Kinetic Theory of Matter.** Development of the kinetic and statistical method of Boltzmann, in connection with the explanation of the second law of thermodynamics. Extension to the quantum theory. Non-ideal gases and the theory of the solid body. Dissociation equilibria and the theorem of Nernst. The theory of radiation. Fluctuation phenomena. *Prerequisite: Phys. 209.* Four 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: Phys. 196. Phys. 211 is a prerequisite for 212.* Three hours credit each semester. First semester, 211; second semester, 212.

213, 214. **Introduction to Theoretical Physics.** The partial differential equations of mathematical physics and their boundary condition problems. Potential theory. The method of the particular solution. Distinction between elliptic, parabolic, and hyperbolic partial differential equations. The method of conformal representation. Eigen value problems. The connection with the theory of integral

equations and the calculus of variations. *Phys. 213 is a prerequisite for 214.* Four hours credit each semester. First semester, 213; second semester, 214.

250. X-rays. The fundamental facts and theories connected with the production and properties of x-rays, together with a study of the development of the subject. X-rays in their relation to theories of radiation and of the structure of matter. Considerable emphasis is placed on spectroscopy, and opportunity is afforded to do some experimental work. Three hours credit. Second semester.

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.

285. German Reading. In this course the subject of physics is studied in German to acquaint the student with the technical terms used in modern German physics. This course may be taken only by such students as convince the instructor of their satisfactory preparation. One hour credit. First semester.

Summer Session

Physics 35, 36, 37, 38, 39, 40, 45, 46, 105, 145, 165, 181, 183, 188, 196, 205*s*, 207, 247*s*, 250*s*, 265*s*, 280, 281, and 297, or similar courses, will be offered in the Summer Session.

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 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.

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 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 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. For the definition of an hour of credit see section 50.

CURRICULUM IN ENGINEERING-BUSINESS ADMINISTRATION

		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. 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, Hydromechanics	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

*See section 35 for the grading system.

c) Electives to be selected from the following group: Economics, Engineering, English, History, Modern Language, Philosophy, Political Science, Psychology, and Sociology 12

Summary:

Preparatory Courses 54
Secondary and Technical Courses 45
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	5	Metal Proc. 2 and Chem. Eng. 1	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. 2a	1
Economics 53	3	Economics 54	3
Mil. Science	(1)	Mil. Science	(1)
	(18) or 17		(18) or 17

Summer Session

Elec. Eng. 2a	4
Mech. Eng. 3	4
	8

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

†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 UTILIZATION) 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 Utilization).

Students should note that application for admission to the School of Forestry and Conservation must be made before April 20,

*Elective courses must be selected from the following group: Economics, Engineering, English, History, Modern Language, Philosophy, Political Science, Psychology, Sociology.

and that the College of Engineering requires a higher average grade for the combined curriculum than for graduation in the regular four-year curricula.

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 Utilization).

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 substitutions 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.

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, Hydromechanics	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, Exam. of Gas and Fuel	1
Chemistry 63, Organic Chemistry	4
Economics 53, 54	6
Botany 1	4
Total	48

Summary:

Preparatory Courses	60
Secondary and Technical Courses	48
Total for three years in Engineering	108

PROGRAM, COLLEGE OF ENGINEERING

First Year

FIRST SEMESTER COURSES	HOURS	SECOND SEMESTER 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	5	Metal Proc. 2 and Chem. Eng. 1	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

*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.

SUMMER SESSION

Elec. Eng. 2*a* (D.C. and A.C. Apparatus and Circuits)	4
Metal Proc. 4 (Machine Shop)	4
	8

THIRD YEAR

FIRST SEMESTER COURSES	HOURS	SECOND SEMESTER COURSES	HOURS
Eng. Mech. 3 (Dynamics)	3	Eng. Mech. 4 (Hydromechanics)	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 (Woodworking)	2	Botany 1	4
	16		16

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. 166 (Timber Mechanics)	2
English (Group III)	2	For. 154 (Logging and Wood Utilization)	4
For. 191 (Forest Policy)	2		
	17		16

SECOND YEAR

For. 165 (Conditioning and Preservative Treatment of Wood)	4	For. 168 (Chemical Utilization of Woods)	3
For. 181 (Elements of Forest Management)	3	For. 170 (Lumber Grading and Specifications)	3
Forestry Problem	3	For. 176 (Forest Economics)	3
For. 131 (Wood Prod. Insects)	3	Forestry Problem	3
For. 159 (Wood-Using Industries)	2	For. 172 (Plywood and Laminated Construction)	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, 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.

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
Shop 2 and Chem. Eng. 1	5
Total	54

*See section 35 for the grading system.

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, Hydromechanics	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
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
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	5	Metal Proc. 2 and Chem. Eng. 1	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.

†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

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

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

1931-1932

	1st Yr.	2d Yr.	3d Yr.	4th Yr.	5th Yr.	Specials	P.T.	Totals
Civil Engineering		41	78	69		3	2	191
Mechanical Engineering		68	100	107		4	2	281
Electrical Engineering		51	73	65		1	4	194
Chemical Engineering		75	73	41		3	1	193
Naval and Marine Engineering		26	16	12				54
Aeronautical Engineering		73	89	48		1	3	214
Geodesy and Surveying		3		3				6
Mathematics			4	9			1	14
Physics		4	6	8				18
Engineering Mechanics			1	2				3
Mechanical and Industrial		6	5	9	3			23
Electrical and Industrial		2			1			3
Chemical and Industrial		3	6					9
Engineering and Law		10	9	2			1	22
Transportation Engineering		1	11	10				22
Unclassified, first year	274					3	3	280
Unclassified, part time						5		5
Grand Total	274	363	471	385	4	20	15	1,532
Counted more than once								74
Net Total, Engineering								1,458
Undergraduates, College of Engineering								1,458
Students in Engineering enrolled in the Summer Session of 1931								376
Students in Engineering enrolled in the Graduate School								199
Students enrolled in Engineering *Extension courses								192
Numbers of students in Engineering, net								1,921

1932-1933

Civil Engineering		28	48	87		3		166
Mechanical Engineering		66	86	122		6		280
Electrical Engineering		42	50	77		2		171
Chemical Engineering		61	68	66				195
Naval and Marine Engineering		18	22	15		1		56
Aeronautical Engineering		63	63	65		1		192
Geodesy and Surveying		2	2	3		1		8
Mathematics		1	4	8				13
Physics		3	8	7				18
Engineering Mechanics		1		1				2
Mechanical and Industrial		3	9	4	7			23
Electrical and Industrial								
Chemical and Industrial		3	2	3				8

*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 Division students in the Schools and Colleges.

	1st Yr.	2d Yr.	3d Yr.	4th Yr.	5th Yr.	Specials	P.T.	Totals
Engineering and Law		5	20					25
Transportation		2	7	15				24
Unclassified, first year	253							253
Unclassified, part time	3							3
Grand Total	256	298	389	472	7	14		1,437
Counted more than once								84
Net Total, Engineering								1,353
Undergraduates, College of Engineering								1,353
Students in Engineering enrolled in the Summer Session of 1932								336
Students in Engineering enrolled in the Graduate School								250
Students enrolled in Engineering *Extension courses								41
Number of students in Engineering, net								1,697

1933-1934

Civil Engineering		32	31	54		4	121
Mechanical Engineering		70	76	99		2	247
Electrical Engineering		41	53	58		2	154
Chemical Engineering		58	83	71		3	215
Naval and Marine Engineering		19	10	25		2	56
Aeronautical Engineering		58	55	58		1	172
Geodesy and Surveying		1	2	4			7
Mathematics		3	5	8			16
Physics		3	6	8			17
Engineering Mechanics				1			1
Mechanical and Industrial		4	8	7	2		21
Electrical and Industrial			1				1
Chemical and Industrial			3	1	1		5
Engineering and Law		10	7	5			22
Transportation		1	4	16			21
Unclassified, first year	259						259
Special, first year	2						2
Grand Total	261	300	344	415	3	14	1,337
Counted more than once		15	14	33			62
Net Total, Engineering	261	285	330	382	3	14	1,275
Undergraduates, College of Engineering							1,275
Students in Engineering enrolled in Summer Session of 1933							254
Students in Engineering enrolled in the Graduate School							203
Students enrolled in Engineering *Extension courses							127
Number of students in Engineering, net							1,645

*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 Division students in the Schools and Colleges.

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