CORNELL UNIVERSITY
OFFICIAL PUBLICATION

Volume XXVII Number 9

Announcement of the

College of Engineering

The School of Civil Engineering
The Sibley School of Mechanical Engineering
The School of Electrical Engineering

With the Announcement of

The Engineering Division of
The Graduate School

for

1936-37

Ithaca, New York
Published by the University
December 15, 1936

THE UNIVERSITY CALENDAR FOR 1936–37

FIRST TERM

1936				
Sept.	21,	*Monday,*	Entrance examinations begin.	
Sept.	28,	*Monday,*	Registration and assignment of new students.	
Sept.	29,	*Tuesday,*	Registration and assignment of old students.	
Oct.	1,	*Thursday,*	Instruction begins at 8 A. M.	
Oct.	22,	*Friday,*	Last day for payment of tuition for the first term.	
Nov.	26,	*Wednesday,*	Instruction ends at 6 P. M.	Thanksgiving Recess
Dec.	1,	*Monday,*	Instruction resumed at 8 A. M.	
Dec.	19,	*Saturday,*	Instruction ends at 1 P. M.	Christmas Recess
1937				
Jan.	4,	*Monday,*	Instruction resumed, 8 A. M.	
Jan.	11,	*Monday,*	Founder's Day.	
Jan.	30,	*Saturday,*	Instruction ends.	
Feb.	1,	*Monday,*	Term examinations begin.	
Feb.	10,	*Wednesday,*	Term ends.	
Feb.	11,	*Thursday,*	A holiday.	

SECOND TERM

Feb.	12,	*Friday,*	Registration of all students.	
Feb.	15,	*Monday,*	Instruction begins at 8 A. M.	
March	8,	*Monday,*	Last day for payment of tuition for the second term.	
April	3,	*Saturday,*	Instruction ends at 1 P. M.	Spring Recess
April	12,	*Monday,*	Instruction resumed, 8 A. M.	
May	—,	*Saturday,*	Spring Day: a holiday.	
June	7,	*Monday,*	Term examinations begin.	
June	15,	*Tuesday,*	End of term examinations.	
June	21,	*Monday,*	COMMENCEMENT.	

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A PART OF THE CORNELL CAMPUS, INCLUDING THE BUILDINGS OF THE COLLEGE OF ENGINEERING

In the middle of this picture is the University's main Quadrangle. At the lower left, around the end of the Quadrangle, are the College's buildings. Above and to the left of the Quadrangle are shown the laboratories of Chemistry and Physics.

A HISTORY OF THE COLLEGE OF ENGINEERING

CORNELL UNIVERSITY had its beginning in the Federal Government's grant, for the endowment of education in the several States, of a large portion of the public lands, under the authority of the Morrill Act, an Act of Congress approved by President Lincoln in 1862. The purpose of the Morrill Act was to endow in each State at least one college; by an express provision of the Act, a leading object of each of those colleges was to be the teaching of "such branches of learning as are related to...the mechanic arts." The State of New York devoted all the proceeds of its share of the land grant to Cornell University, which was established by charter in 1865 and was opened at Ithaca in 1868. In the very first plan of this University, therefore, was the foundation of a college of Engineering.

EZRA CORNELL, who had brought an eminent talent for practical affairs to the organizing and upbuilding of the telegraph business before and after the creation of the Western Union Telegraph Company, and who had retired in 1858, gave generously of his wealth and lavishly of his powers to the University's establishment. His wise management of New York's share of the land grant multiplied the endowment.

When Cornell University began its work, in 1868, it included a College of Mathematics and Engineering and a College of Mechanic Arts. The former of these consisted of two schools, namely, a school of mathematics and a school of civil engineering. In 1871 mathematics was set apart, and architecture was associated with civil engineering in a single college until 1873, when another separation took place, and civil engineering was organized as a department; it retained that form until 1890, when the College of Civil Engineering was established.

HIRAM SIBLEY OF ROCHESTER, the founder and first president of the Western Union Telegraph Company, a trustee of the University from 1865 until his death in 1888, was a liberal benefactor of the University's department of mechanical engineering. In 1871 he erected a building to house what was then called the College of Mechanic Arts, equipped it, and endowed the Sibley Professorship of Mechanic Arts to the amount of fifty thousand dollars. During the years from 1870 to 1887, Mr. Sibley gave more than $180,000 for the building and equipment of lecture halls, shops, and laboratories. His benefactions have been continued by his son, Mr. Hiram W. Sibley, who has given about $170,000 for construction and equipment.

The original College of Mechanic Arts offered instruction in shop work, drawing, and elementary engineering, in conformity with the provisions of the Morrill Act and the Charter, and provided a theoretical and practical course of four years leading to the bachelor's degree in mechanical engineering. In 1885, in recognition of the

growth in importance of the profession of mechanical engineering, the college was renamed The Sibley College of Mechanical Engineering and the Mechanic Arts.

Courses in electrical engineering were first established at Cornell in 1883, under the guidance of the Department of Physics. In 1889 the direction of the professional courses in electrical engineering was transferred to Sibley College and the present course in electrical engineering was developed within that college.

In 1919 thc Board of Trustees, recognizing that all practice in engineering has a common groundwork, voted to consolidate all instruction in engineering at Cornell in a single institution to be called The College of Engineering. This single college comprises three schools, namely, the School of Civil Engineering, the Sibley School of Mechanical Engineering, and the School of Electrical Engineering. The last-named school has grown from the former department of electrical engineering in Sibley College. The combination has proved itself to be sound educationally, to be in harmony with the progress of industry, and to have administrative merit. In 1931 a five-year course leading to the degree of Chemical Engineer was organized.

Besides the College of Engineering, Cornell University comprises the Graduate School, in which the student's work may lead to the degree of Doctor of Philosophy, to the degree of Doctor of the Science of Law, or to the master's degree in arts, science, agriculture, architecture, fine arts, landscape architecture, forestry, chemistry, laws, education, civil engineering, mechanical engineering, or electrical engineering; the College of Arts and Sciences, whose courses lead to the degree of Bachelor of Arts or that of Bachelor of Chemistry; the Law School; the Medical College, which gives most of its instruction in its main building at 1300 York Avenue, New York City; the New York State Veterinary College; the New York State College of Agriculture; the New York State College of Home Economics; and the College of Architecture, in which a student may earn the degree of Bachelor of Architecture, Bachelor of Landscape Architecture, or Bachelor of Fine Arts. There are about nine hundred persons in the University's teaching staff and its students number about five thousand.

The College of Engineering has intimate relations with the rest of the University. Its students, constituting about one-fourth of the University's whole enrollment, are associated with the faculties and students of the other colleges.

The University is situated at Ithaca, in the central part of the State of New York, about seven hours by rail from the City of New York and about three hours from Buffalo. Ithaca is accessible by way of two trunk lines, the Lackawanna and Lehigh Valley Railroads, and it has connections by rail with several stations on the New York Central system. The University's campus and contiguous lands occupy about fifteen hundred acres. The campus is on a hill, overlooking the city of Ithaca and a good many miles of Cayuga Lake.

THE FACULTY

THE COLLEGE OF ENGINEERING

LIVINGSTON FARRAND, A.B., M.D., L.H.D., LL.D., President of the University.
ALBERT RUSSELL MANN, A.M., D.Sc., D.Agr., LL.D., Provost of the University.
HERMAN DIEDERICHS, M.E., Dean of the College, John E. Sweet Professor in Engineering, and Professor of Experimental Engineering.
SOLOMON CADY HOLLISTER, B.S. C.E., Associate Dean of the College and Professor of Civil Engineering.
MAUDE S. NEWMAN, Secretary of the College.

THE SCHOOL OF CIVIL ENGINEERING

SOLOMON CADY HOLLISTER, B.S., C.E., Director of the School, and Professor of Civil Engineering.
HENRY SYLVESTER JACOBY, C.E., Professor of Bridge Engineering, Emeritus.
HENRY NEELY OGDEN, C.E., Professor of Sanitary Engineering.
FRED ASA BARNES, M.C.E., Professor of Railroad Engineering.
SIDNEY GONZALES GEORGE, C.E., Professor of Mechanics of Engineering.
JOHN THOMAS PARSON, Professor of Drawing.
ERNEST WILLIAM SCHODER, Ph.D., World War Memorial Professor of Experimental Hydraulics.
FRANCIS JOSEPH SEERY, S.B., Professor of Hydraulic Engineering.
SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy.
ERNEST WILLIAM RETTGER, Ph.D., Professor of Mechanics of Engineering.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering and Secretary of the College Faculty.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Surveying.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials.
WALTER L. CONWELL, C.E., Professor of Highway Engineering.
LEONARD CHURCH URQUHART, C.E., Professor of Structural Engineering.
CHARLES EDWARD O'ROURKE, C.E., Professor of Structural Engineering.
GILMORE DAVID CLARKE, B.S., Professor of Regional Planning.
MILES ALBION POND, Ph.B., Assistant Professor of Descriptive Geometry, Emeritus.
EARLE NELSON BURROWS, M.C.E., Assistant Professor of Structural Engineering.
LEONARD ALEXANDER LAWRENCE, B.S., Assistant Professor of Surveying.
CARL CRANDALL, C.E., Assistant Professor of Railroad Engineering, and Secretary of the Faculty of Civil Engineering.
JOHN EDWIN PERRY, B.S. in C.E., Assistant Professor of Railroad Engineering, and Personnel Officer of the School of Civil Engineering.
ERIC VAIL HOWELL, M.C.E., Assistant Professor of Mechanics.
ROMEYN Y. THATCHER, C.E., Assistant Professor of Railroad Engineering.
HERBERT THEODORE JENKINS, Assistant Professor of Drawing.
CLAUDE M. PENDLETON, C.E., Marc Eidlitz Instructor in Civil Engineering.
FRED J. SPRY, M.C.E., Instructor in Surveying.

The Sibley School of Mechanical Engineering

Herman Diederichs, M.E., Director of the School, John E. Sweet Professor in Engineering, and Professor of Experimental Engineering.

Albert William Smith, B.M.E., M.M.E., Professor of Mechanical Engineering, Emeritus.

Dexter Simpson Kimball, A.B., M.E., D.Sc., D.Eng., LL.D., Professor of Mechanical Engineering, Emeritus.

George Robert McDermott, Professor of Structural Design, Emeritus.

Millard Clayton Ernsberger, A.B., M.E., Professor of Power Engineering, Emeritus.

William Nichols Barnard, M.E., Professor of Heat-Power Engineering.

Edgar Harper Wood, M.M.E., Professor of Mechanics of Engineering.

Calvin Dodge Albert, M.E., Professor of Machine Design.

Albert Edward Wells, Sibley Professor of Mechanic Arts.

Frank Oakes Ellenwood, A.B., M.E., Professor of Heat-Power Engineering.

Will Miller Sawdon, B.S., M.M.E., Professor of Experimental Engineering, assigned to Engineering Research.

George Burr Upton, M.M.E., Professor of Experimental Engineering.

Seymour Stanton Garrett, C.E., World War Memorial Professor of Industrial Economics.

Victor Raymond Gage, M.M.E., Professor of Experimental Engineering.

Myron A. Lee, M.M.E., Professor of Industrial Engineering.

Frederick George Switzer, M.M.E., Professor of Hydraulic Engineering.

Clarence Ellsworth Townsend, M.E., Professor of Engineering Drawing.

Fred Stillman Rogers, B.S., M.E., Professor of Machine Design.

Adam Clarke Davis, jr., M.E., Professor of Experimental Engineering.

Walter Rodney Cornell, B.S., C.E., Professor of Mechanics of Engineering.

John Robert Bangs, jr., M.E., Professor of Administrative Engineering and Personnel Director of the College of Engineering.

Roy Edwards Clark, M.E., Assistant Professor of Heat-Power Engineering.

Enoch Francis Garner, M.E., Assistant Professor of Machine Design.

Warren Howard Hook, M.E., Assistant Professor of Heat-Power Engineering.

William Emerson Mordoff, M.E., Assistant Professor of Machine Construction.

Harold Charles Perkins, M.E., Assistant Professor of Mechanics of Engineering.

William Cook Andrae, M.M.E., Assistant Professor of Experimental Engineering.

Karl Dawson Wood, M.E., M.S., Assistant Professor of Mechanics of Engineering.

Charles Osborn Mackey, M.E., Assistant Professor of Heat-Power Engineering.

Stephan Farrell Cleary, M.M.E., Assistant Professor in Engineering Drawing.

George Raymond Hanselman, M.E., Assistant Professor in Administrative Engineering.

Leslie A. Fenner, M.E., Instructor in Engineering Drawing.

Robert Cunningham Morris, Instructor in Machine Design.

Carroll Bromley Clark, M.E., Instructor in Experimental Engineering.

Joseph Olmstead Jeffrey, M.M.E., Instructor in Experimental Engineering.

Clyde Ira Millard, E.E., Instructor in Administrative Engineering.

HARRISON LOUIS GOODMAN, M.E., Instructor in Experimental Engineering.
LUDOLPH FRISCH WELANETZ, M.E., McMullen Research Scholar and Instructor in Mechanics of Engineering.
JOHN ROBERT MOYNIHAN, M.M.E., McMullen Research Scholar and Instructor in Experimental Engineering.
FLOYD CLEVELAND KNIGHT, M.E., Instructor in Machine Design.
CYRIL WALDIE TERRY, M.E., Instructor in Machine Design.
ROLAND LLOYD ROY, B.S. in E.E., M.S., Instructor in Industrial Engineering.
RALPH W. HODGES, Instructor in Introductory Engineering Laboratory.
HARRY J. LOBERG, M.E., Instructor in Administrative Engineering.
KENNEDY FURLONG RUBERT, jr., M.M.E., Aero.E., Instructor in Experimental Engineering.
FREDERICK GOTTLIEB BAENDER, B.S. in M.E., M.M.E., Instructor in Experimental Engineering.
WILLIAM DUNHAM VANDERBILT, M.E., Instructor in Industrial Engineering.
BURDETTE N. HOWE, Foreman in the Machine Shop.
CHARLES E. PATTERSON, Foreman in the Foundry.
WALTER LISTON HEAD, Assistant in Introductory Engineering Laboratory.
HOWARD STANLEY BUSH, Assistant in the Pattern Shop.
ERNEST STANLEY YAWGER, Assistant in the Pattern Shop.
RUDOLPH P. SCHALLOWITZ, Assistant in the Machine Shop.

THE SCHOOL OF ELECTRICAL ENGINEERING

PAUL MARTYN LINCOLN, M.E. (in E.E.), LL.D., Director of the School and Professor of Electrical Engineering.
VLADIMIR KARAPETOFF, C.E., M.M.E., Professor of Electrical Engineering.
WILLIAM CYRUS BALLARD, jr., M.E. (in E.E.), Professor of Electrical Engineering.
ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Professor of Electrical Engineering.
BURDETTE KIBBE NORTHROP, M.E. (in E.E.), Assistant Professor of Electrical Engineering.
LAWRENCE ADAMS BURCKMYER, jr., B.S. (in E.E.), E.E., Assistant Professor of Electrical Engineering.
EVERETT MILTON STRONG, B.S. in E.E., Assistant Professor of Electrical Engineering.
TRUE MCLEAN, E.E., Assistant Professor of Electrical Engineering.
MICHEL GEORGE MALTI, B.A., B.S. in E.E., M.E.E., Ph.D., Assistant Professor of Electrical Engineering.
MILES GORDON NORTHROP, E.E., Assistant Professor of Electrical Engineering.
WALTER WENDELL COTNER, M.E.E., Instructor in Electrical Engineering.
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DIMITER RAMADANOFF, B.S. in E.E., Ph.D., McMullen Research Scholar and Instructor in Electrical Engineering.
EDMUND ROBERT PAIGE, B.E., M.E.E., Instructor in Electrical Engineering.
FRANK JESSUP BRISTOL, E.E., Instructor in Electrical Engineering.
WILLIAM DANIEL MOEDER, E.E., Instructor in Electrical Engineering.
ARNE WIKSTROM, E.E., Ph.D., Instructor in Electrical Engineering.

JOHN PALEN WOOD, M.E., M.E.E., Instructor in Electrical Engineering.
HARRY SOHON, M.E.E., Ph.D., McMullen Research Scholar and Instructor in Electrical Engineering.

COURSE IN CHEMICAL ENGINEERING

SUPERVISORY COMMITTEE

Course in Chemical Engineering offered jointly by the College of Arts and Sciences (Department of Chemistry) and the College of Engineering.

FRED HOFFMAN RHODES, Ph.D., Professor of Industrial Chemistry. Chairman of the Committee.
EMILE MONNIN CHAMOT, Ph.D., Professor of Chemical Microscopy and Sanitary Chemistry.
HERMAN DIEDERICHS, M.E., Director Sibley School of Mech. Engineering and John E. Sweet Professor of Engineering.
WILLIAM NICHOLS BARNARD, M.E., Professor of Heat-Power Engineering.
EDGAR HARPER WOOD, M.M.E., Professor of Mechanics of Engineering.
JACOB PAPISH, Ph.D., Acting Head, Department of Chemistry and Professor of Chemical Spectroscopy.
GEORGE BURR UPTON, M.M.E., Professor of Experimental Engineering.
CALVIN DODGE ALBERT, M.E., Professor of Machine Design.
CLYDE WALTER MASON, Ph.D., Professor of Chemical Microscopy and Metallography.
CHARLES CALVERT WINDING, Ph.D., Instructor Industrial Chemistry.

STAFF OF INSTRUCTION

HERMAN DIEDERICHS, M.E., Director Sibley School of Mechanical Engineering.
WILLIAM NICHOLS BARNARD, M.E., Professor of Heat-Power Engineering.
EDGAR HARPER WOOD, M.M.E., Professor of Mechanics of Engineering.
CALVIN DODGE ALBERT, M.E., Professor of Machine Design.
GEORGE BURR UPTON, M.M.E., Professor of Experimental Engineering.
VICTOR RAYMOND GAGE, M.M.E., Professor of Experimental Engineering.
FRANK OAKES ELLENWOOD, A.B., M.E., Professor of Heat-Power Engineering.
THOMAS ROLAND BRIGGS, Ph.D., Professor of Physical Chemistry.
FREDERICK GEORGE SWITZER, M.M.E., Professor of Hydraulic Engineering.
CLARENCE ELLSWORTH TOWNSEND, M.M.E., Professor of Engineering Drawing.
ADAM CLARKE DAVIS, jr., M.E., Professor Experimental Engineering.
FRED HOFFMAN RHODES, Ph.D., Professor of Industrial Chemistry.
WALTER RODNEY CORNELL, B.S., C.E., Professor of Mechanics of Engineering.
ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Professor of Electrical Engineering.
MELVIN LORREL NICHOLS, Ph.D., Professor of Analytical Chemistry.
CLYDE WALTER MASON, Ph.D., Professor of Chemical Microscopy and Metallography.
JOHN RAVEN JOHNSON, Ph.D., Professor of Organic Chemistry.
WARREN HOWARD HOOK, M.E., Assistant Professor of Heat-Power Engineering.
ENOCH FRANCIS GARNER, M.E., Assistant Professor of Machine Design.

HAROLD CHARLES PERKINS, M.E., Assistant Professor of Mechanics of Engineering.

WILLIAM COOK ANDRAE, M.M.E., Assistant Professor of Experimental Engineering.

KARL DAWSON WOOD, M.E., M.S., Assistant Professor of Mechanics of Engineering.

ALBERT WASHINGTON LAUBENGAYER, Ph.D., Assistant Professor of Inorganic Chemistry.

CHARLES OSBORN MACKEY, M.E., Assistant Professor of Heat-Power Engineering.

JOHN GAMBLE KIRKWOOD, Ph.D., Assistant Professor of Physical Chemistry.

CHARLES CALVERT WINDING, Ph.D., Instructor in Industrial Chemistry.

OTHER MEMBERS OF THE COLLEGE STAFF

LULU M. MARKELL, Secretary to the Dean.

DOROTHY S. WILLIAMS, Recorder.

MARY R. KORHERR, Secretary to the Director of the School of Civil Engineering.

J. GRACE SIMPSON, Secretary to the Director of the Sibley School of Mechanical Engineering.

KATHERINE HANDLEN, Secretary to the Director of the School of Electrical Engineering.

MARGARET KOMAROMI, Clerk of Personnel and Employment Department.

MABEL H. WALBRIDGE, Librarian of the School of Civil Engineering.

LENA GERTRUDE MARSH, Librarian of the Sibley School of Mechanical Engineering.

MRS. I. M. BATCHELOR, Librarian of the School of Electrical Engineering.

CLINTON D. CASS, Mechanician of the School of Civil Engineering.

GEORGE WASHINGTON RACE, Mechanician in the Sibley School of Mechanical Engineering.

SAMUEL CORNELIUS PATCH, Mechanician in the Sibley School of Mechanical Engineering.

ALFRED WILLIAM NEIGH, Engineer in the Sibley School of Mechanical Engineering.

VIRGIL NEIGH, Assistant Mechanician in the Sibley School of Mechanical Engineering.

GEORGE ALFRED CULLIGAN, Mechanician in the School of Electrical Engineering.

GENERAL INFORMATION

INSTRUCTION OFFERED IN ENGINEERING

Cornell University offers both undergraduate and graduate instruction in engineering, the former in the College of Engineering and the latter in the Engineering Division of the Graduate School of the University. The first part of this Announcement relates primarily to the undergraduate instruction. For information regarding graduate work in engineering, see page 131.

THE COLLEGE OF ENGINEERING AND ITS SCHOOLS

Organization for Instruction

With the object of increasing the effectiveness of its instruction and supervision of its work, the College of Engineering is subdivided into three main Schools—those of Civil Engineering, Mechanical Engineering, and Electrical Engineering,—and these schools are further divided into Departments, each with a staff specializing in its own particular branch. In addition there is administered through the joint control of the College of Engineering and the College of Arts and Sciences, Department of Chemistry, a five-year course in Chemical Engineering. The close association of the Engineering College with the other Colleges of the University makes it possible for the engineering student to receive his instruction in mathematics, physics, chemistry, and in certain other required courses, in those departments of the University best equipped to teach these subjects. This close association also broadens the intellectual horizon and interests of the engineering student and gives him a clearer understanding of the relation of engineering to other human interests; and it affords him opportunity to elect with the approval of his faculty adviser any course in any college or school of the University, provided he has available the necessary time and has the required preparation.

As the character of all instruction depends primarily on the qualifications of the teaching staff, particular emphasis is placed on the careful selection of teachers and on supplying them with adequate facilities, rather than on providing elaborate buildings. The facilities for instruction, both fundamental and advanced, are quite extensive. The College is sufficiently large to permit each course to be taught by specialists in that subject, and yet is not so large that the student fails to receive the personal attention of his instructors.

Purpose of the Instruction

THOROUGH TRAINING IN FUNDAMENTALS

The curricula of the Schools of the College of Engineering consist, primarily, of courses designed to teach the fundamental principles,

theoretical and practical that underlie the various branches of engineering. In addition, such work is required in pure and applied economics as is needed by the engineer of the present time. Late in the course some degree of specialization is permitted; but since the time allowed for this is quite limited, specialization cannot be carried very far. In fact, the Faculty of Engineering is strongly of the opinion that the duty of the technical school to its undergraduates is to train them thoroughly in the fundamental subjects and that the four-year course is not too long for this purpose. Hence the demand for the introduction of specialization early in the course has always been resisted, a policy that is strongly recommended by many of the larger employers of engineering graduates.

It is well recognized that theoretical instruction must be supplemented by experience in practice and by contact with life before one can attain his greatest usefulness in the profession; hence an effort is made to bring the student into contact with teachers who are closely in touch with engineering practice, to the end that he may thus become familiar with problems encountered in modern engineering and with practical methods of solving them. It is hoped in this way to shorten somewhat the period of adjustment for the graduate when he begins actual engineering work.

General Scope of Instruction Offered

It has been stated that the engineering profession has more major divisions than any other profession; and each of these main divisions has many special branches. In just which branch, or branches, the future engineer will specialize can not usually be predicted, hence the engineering student should have as broad and fundamental a training as can be given him.

Civil, Mechanical, Electrical and Chemical Engineering constitute the broadest of the main divisions of engineering and furnish much of the fundamental training required for practice in the more specialized divisions or branches. Therefore, the instruction in the College of Engineering at Cornell University is confined primarily to these four fundamental divisions, but with it is afforded opportunity for some degree of specialization in many of the other important branches through the special options and elective courses offered.

Recognizing the need for men trained in the fundamentals of business and finance as well as in engineering, the College offers, through its engineering schools, both optional courses and complete curricula in what is generally called Administrative Engineering.

Courses Offered

The undergraduate College offers four-year, five-year, and six-year courses. Since the work of the regular four-year courses in this college is largely technical, it is urgently recommended that the stu-

dent who can afford the additional time and expense take one of the longer courses in order to broaden his training.

The Regular Four-Year Courses

Each of the regular curricula in engineering covers four years of instruction devoted mainly to a sequence of prescribed courses forming a carefully selected program in which in the senior year some degree of specialization is possible. Owing to the high requirements in mathematics for admission to the college, the underlying scientific and other fundamental studies,—such as college mathematics, physics, chemistry, theoretical mechanics, surveying, drawing, and kinematics—are completed in the first two years of the program; thus, the third year may be devoted mainly to fundamental engineering courses, which in turn prepare the student for the more advanced and special courses given in the senior year.

The main curricula and fields of specialization in them are discussed somewhat in detail later. The following is a very brief summary:

Civil Engineering (Degree of C.E.) with specialization in Hydraulic Engineering, Sanitary Engineering, Railroad Engineering, Structural Engineering, Highway Engineering, Administrative Engineering, or Geodetic Engineering. (For more complete description see p. 53.)

Mechanical Engineering (Degree of M.E.) with specialization in Power Plant Engineering, Heat Engineering (including Fluid Flow, Heat Transmission, Air Conditioning, and Refrigeration), Industrial Engineering, Automotive Engineering, Aeronautical Engineering, Metallurgical Engineering, Hydraulic Power Plant Engineering, or Specially Selected Subjects. (For more complete description, see p. 83.)

Electrical Engineering (Degree of E.E.) with specialization in Electrical Power Stations, Electrical Design, Electrical Communication, Electric Traction, Illumination, Physics, etc. (For more complete description, see p. 119.)

Administrative Engineering (Degree of B.S. in A.E.), consisting in large part of basic engineering courses in C.E., M.E., or E.E., combined with instruction in various courses related to Business and Industrial Management, Marketing, Production, Finance, Accounting, etc. (For more complete description, see p. 79 (C.E.), p. 85 (M.E.), p. 124 (E.E.)

Chemical Engineering is a five-year course, see p. 25.

Five-Year Courses

Course Leading to Degree of B.Chem., and Degree of Chemical Engineer

This five-year course is offered by the College of Engineering in conjunction with the Department of Chemistry of the College of Arts and Sciences. Students are admitted to this course upon presentation

of the entrance requirements specified for the degree of Bachelor of Chemistry. Students in this course are registered jointly in the College of Engineering and in the College of Arts and Sciences. The degree of Bachelor of Chemistry is conferred upon the satisfactory completion of the first four years of work; upon the satisfactory completion of the fifth year of work the student receives the degree of Chemical Engineer.

FIVE-YEAR COURSES LEADING TO TWO DEGREES

In Civil Engineering, the A.B. degree and the degree of Civil Engineer may be obtained in five years plus two summer sessions.

In Administrative Engineering it is possible so to arrange the work of the five-year course that the degree of Mechanical Engineer, Civil Engineer, or Electrical Engineer is obtained at the end of the first four years and the degree of Bachelor of Science in Administrative Engineering at the end of the fifth year. Declaration of intention to take these five-year combinations should be made at the end of the second year.

The entrance requirements for the above courses must correspond to those for the first degree taken.

FIVE-YEAR COURSES LEADING TO THE DEGREE OF C.E., M.E., OR E.E.

These courses consist of the regular curricula of engineering modified by the introduction of the equivalent of one year of broadening training. Students must fulfill the entrance requirements of any one of the regular four-year courses. There are no regular schedules for such curricula, the student being referred to the Director of the School concerned for the arrangement of studies at the beginning of each term.

Six-Year Courses

These courses lead to the degree of A.B. and one of the Engineering degrees (C.E., M.E., E.E., or B.S. in A.E.). The entrance requirements are those for admission to the College of Arts and Sciences and include less mathematical preparation than is specified for the four-year or five-year courses. The student is registered in the College of Arts and Sciences during the first four years. The necessary arrangement of the studies in this course is set forth on page 25.

The General Plan of Studies

As already stated, the course of preparatory and professional studies has been planned with a view of laying a substantial foundation for the general and technical knowledge needed by practitioners in Civil, Mechanical, Electrical, Administrative, and Chemical Engineering, so that the graduates, guided by their theoretical education, and as much of engineering practice as can well be taught in schools, may develop into useful investigators, designers, constructors, operators, and administrators.

All students entering upon the work of the first year in the College of Engineering take practically the same courses during that year, it being recognized that the fundamental instruction should be substantially the same for all engineers. In general, the work of the first year comprises fundamental training in mathematics, physics, chemistry, drawing, surveying, and shop work. (For Courses of Instruction in the First Year of the regular four-year curricula, see page 49.)

Upon entering the college the student designates the main course which he then intends to follow; but the original selection is not binding, for at the end of the first year, or, in some cases, at the end of the second year, he may change his course if he so desires.

After the first year the student in a regular course is registered in one of the Schools of the College and follows one of the curricula designated therein.

CIVIL ENGINEERING students follow the first year with as thorough a preparation as possible for the general purpose of the profession in the following subjects: the survey, design, and construction of buildings, roads, railroads, canals, sewers, and water works; the construction of foundations under water and on land, and of superstructures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical coordinates for geodetic and other purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of arches, girders, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewerage of towns and irrigation and reclaiming of land; the application, and tests of hydraulic and electric motors; the preparation of drawings, plans, specifications, and the proper inspection and tests of the materials used in construction. Instruction is given in engineering economy, finance, and jurisprudence. The latter subject deals in an elementary manner with the questions of easements and servitudes, and the fundamental principles of the law of contracts and riparian rights. Opportunity is also given to seniors to specialize to a limited extent, or to broaden their training, by the election of fifteen credit hours, nine of which may be chosen from approved courses in any department of the University. (For outline of the regular course, see page 53.)

MECHANICAL ENGINEERING students are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, boilers and power plant auxiliaries, gas and oil engines, hydraulic machines, pumping engines, railway equipment, compressed air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air

conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries.

Based upon the fundamental instruction of the freshman year, and that given in the sophomore year in the mechanics of engineering, materials of construction, kinematics and drawing, economics, accounting, and machine construction, the junior student in Mechanical Engineering receives training in advanced applied mathematics, fluid mechanics (including hydraulics), machine design, shop processes, industrial organization, heat-power engineering, experimental engineering, and electrical engineering. In the senior year the student receives further training in the last three subjects and in heating, ventilating, and refrigeration, and also takes the courses outlined in one of the Senior Options. The respective Options provide for some degree of specialization in either Steam Power Plant Engineering, Industrial Engineering, Automotive Engineering, Aeronautical Engineering, Water Power Engineering, Metallurgical Engineering or in some other field allied to Mechanical Engineering; and they also offer opportunity to elect various other courses of an advanced nature, such as those listed on page 97. The special work in these Options (A to G incl.) is described on pages 90 to 98. (For complete outlines of the four-year, five-year, and six-year courses in Mechanical Engineering see pages 89 to 102.)

ELECTRICAL ENGINEERING students in the last three years of the course receive a thorough training in electrical engineering, in addition to training in applied mechanics, machine design, thermodynamics and heat power, and mechanical laboratory. The instruction in electrical engineering is of a distinctly scientific character and requires analytical ability of a high type. Instruction is given in the theory of electricity and magnetism, electrical machinery, radio tubes, rectifiers, electrical circuit analysis, mathematical applications, and the theory and practice of electrical engineering. Laboratory work serves to amplify and is given in parallel with the theory. Opportunity is offered seniors to specialize to a limited extent in such subjects as application of electricity to transportation problems, electric power generation, transmission and distribution, electric lighting, communication engineering, and research. Opportunity is also offered to those students who have a special liking for physics or chemistry to specialize in those subjects. (For curricula, see page 122.)

ADMINISTRATIVE ENGINEERING students in the three Schools of Engineering receive substantially the same basic training in Mathematics, Physics, Chemistry, Geology, Economics, Mechanics, Surveying, Shopwork, Materials, etc., as the other Engineering students. In the more specialized technological subjects covered in the latter part of the regular courses in Civil, Mechanical or Electrical engineer-

ing the work is shortened by not quite one half to provide place for a coordinated group of courses in Business Organization and Management, Accounting, Money and Banking, Statistical Theory and Practice, Marketing and Business Law, together with English, Technical Writing and Public Speaking. The aim of these courses is to preserve the basic content and spirit of the engineering training but to incorporate with it training in the fundamentals of business management. (For outlines of courses, see pages 65 (C.E.), 100 (M.E.), 124 (E. E.)).

CHEMICAL ENGINEERING students receive, during the first two years, a thorough training in the fundamental subjects upon which their specific professional work is based: mathematics; physics; introductory, analytical and organic chemistry; English and German. The third and fourth years include more strictly technical and more advanced courses in engineering and in chemistry, and the fundamental courses in the specific field of chemical engineering. The fifth year includes the more advanced work in engineering and in the specialized field. (For outline of curriculum, see page 101.).

OPPORTUNITIES FOR EMPLOYMENT AFTER GRADUATION

A training in civil, mechanical, electrical, administrative, or chemical engineering opens wide opportunities for employment in the many branches of industry.

CIVIL ENGINEERING graduates find employment in both technical and general business enterprises. In the technical field they are employed in the various branches of civil engineering; in surveying operations of all kinds, including land surveying, construction surveys, aerial surveys, and in the geological and geodetic surveys of the U. S. Government; in the design and construction of irrigation, reclamation, river and flood control, harbor improvement, and hydroelectric projects; in designing and constructing water supply systems, sewerage systems, filtration and purification plants; in the location, maintenance, construction, and operation of railroads; in all classes of highway work; in the design and construction of steel and reinforced concrete bridges and also of steel frame and reinforced concrete buildings; and in examining and testing the properties of materials. There is a growing field of service for the civil engineer in city and regional planning and in city management. Many civil engineers are also engaged in contracting. In the field of general business, experience clearly indicates increased opportunity in many business enterprises for the graduate in Civil Engineering because the training in analysis and precision are assets of value in the fields of finance valuations and real estate, and in other kindred activities of the business world.

MECHANICAL ENGINEERING applies to nearly all branches of the industries; hence, it is called upon for the design, construction, operation, and testing of prime movers and other machinery, and of complete plants of many kinds, not only in its own immediate province

but in the various other fields of engineering. Mechanical engineers serve also as planners of new projects and processes, and as power plant engineers, industrial engineers, fuel and combustion engineers, automotive engineers, aeronautical engineers, refrigeration engineers, air conditioning engineers, and water power engineers—to mention but a few of the many special fields open to them. Their training often serves also as an important foundation for employment in various branches of business connected directly or indirectly with engineering.

ELECTRICAL ENGINEERING graduates find employment with manufacturing companies in connection with the design, construction, testing and application of electrical equipment; with public utilities in connection with the generation, transmission and distribution of electrical energy, and in the sale of the same to the consumer. They are also employed to determine the costs involved, and the utilization of electricity and the rates charged for this service.

With the continued increase in use of electricity in industry, Electrical Engineers are needed in all industrial plants to select and install new equipment for Motor Drives, Electric Heating Processes, Electric Welding, Transportation, Electro-Chemical and Electro-Metallurgical Processes, etc.

In the Communication field many graduates are employed in connection with the design and manufacture of radio receiving sets, broadcasting equipment and the design and operation of broadcasting stations, as well as in the telephone and telegraph industries.

Those men gifted with originality and scientific imagination find opportunities for employment in research work, and in the development of new applications for electric power.

The analytical and practical training provided in the course in electrical engineering is of great value in the field of general business and many graduates are so employed.

ADMINISTRATIVE ENGINEERING, considered as an application of Civil, Mechanical and Electrical Engineering, occupies the wide border region in which there is an overlap of business management and technological engineering. Administrative Engineering graduates, having had the same basic training as graduates in Civil, Mechanical, and Electrical Engineering, are fitted to start in on essentially all kinds of positions open to the latter. They do not, however, as a rule, take positions leading definitely toward careers in technical design or research. To do so is to waste a part of their special training. Their ultimate work is normally in the fields of production, accounting, finance, marketing, contracting, valuation, city management, research in problems of management, etc., or in general, any part of the field covered by the general term management.

CHEMICAL ENGINEERING graduates find employment in the design, development, operation and administration of chemical engineering plants. There is also some demand for men with chemical engineering training for technical sales work in connection with the selling

of chemical products and chemical engineering equipment. A relatively large number of the graduates in Chemical Engineering continue their specialized training as graduate students in Chemical Engineering or in Chemistry and eventually receive industrial positions as research chemists or research chemical engineers.

From the foregoing very brief outline of some of the fields covered by the branches of engineering for which the students of the College of Engineering are fundamentally prepared, it is seen that the opportunities for graduates to obtain employment are broad. Graduates after gaining requisite experience in practice, usually occupy such positions as designers, supervisors of construction, inspectors, testers, research engineers, superintendents of departments, works managers, industrial engineers, specialists in welfare work and in labor problems, consulting engineers, insurance investigators, commercial representatives, engineering salesmen, educators, and executives of commercial organizations.

Each school maintains an EMPLOYMENT BUREAU for its graduates. Correspondence should be addressed to the Director of the school concerned.

PERSONNEL SYSTEM

The College of Engineering operates a personnel system to aid the student in deciding the nature of the work for which he is best suited. It endeavors to point out his desirable as well as his undesirable characteristics with a view to correcting the latter if possible.

During the first and second years, the student is rated by his instructors. In the third and fourth years he is rated by a committee of five members of the faculty and five members of his own class whom he has selected as being especially capable of giving him an accurate rating. The complete rating is compiled by the personnel director and given to the student for his guidance. By this system there is available to every student information that he could not obtain otherwise and which should be of great value to him in laying part of the foundation for a successful career.

The personnel director acquaints himself with the desirable and undesirable traits of each student as indicated by the composite rating; points out to the student the advantages of carefully developing his desirable traits; decides which of the undesirable traits may be changed and advises the student accordingly. With such advice the student is in a position during the highly formative period of his life, to develop the characteristics which will aid him materially in later life.

VOCATIONAL COUNSEL. During the senior year each student is interviewed and an analysis of his aptitudes is made in order that he may intelligently interview representatives of business and industry.

A FIVE-YEAR SERVICE PLAN for graduates consists of circularizing the class at the beginning of each year for five years after graduation to learn of their work, success, and desires as to change in position.

Information regarding opportunities reaches the Dean's office, and graduates frequently are enabled to make very desirable connections through having up-to-date information regarding themselves on file with the personnel director.

Military Science: Physical Training

All men in the first two years of undergraduate courses must take, in addition to the scholastic requirements for the degree, three hours a week in the Department of Military Science and Tactics. This department is a unit of the Reserve Officers' Training Corps of the United States Army. For details of the work in the Department of Military Science and Tactics, see the General Information Number.

All women in the first two years of undergraduate courses, and all men of those two classes who are excused from military drill, must take, in addition to the scholastic requirements for the degree, three hours a week in the Department of Physical Training. For details of this work in the Department of Physical Training, see the General Information Number.

Hygiene and Preventive Medicine

Each entering student is required to report to the Medical Adviser's office during the registration days of the first term to make an appointment for a physical examination. Such examination is repeated periodically thereafter as indicated by the results of the first or subsequent examination.

Seniors are required to make appointments for physical examinations during the regular registration days of their last term of residence.

ADMISSION TO THE COLLEGE

All correspondence concerning admission to the College of Engineering should be addressed to The Director of Admissions, Cornell University, Ithaca, N. Y., who will forward the necessary blank form of application on request. All credentials relating to the admission of a new student should be sent to the Office of Admissions as early as possible, in no case later than the first day of September. A prospective applicant should read carefully the paragraph headed Rules Governing Admission, a page or so further on. He should also read the General Information Number, for which application should be addressed to The Secretary, Cornell University, Ithaca, N. Y.

ADMISSION TO THE FRESHMAN CLASS

The Requirements for Entrance to the Regular Four-Year Course

For admission to the freshman class in the regular four-year course, the applicant must offer fifteen specific units of entrance subjects, as follows: English, 3 units; History, 1 unit; Elementary Algebra, 1 unit; Intermediate Algebra, 1 unit; Plane Geometry, 1 unit; Solid Geometry, ½ unit; Plane Trigonometry, ½ unit; foreign language equivalent to 3 units in either Greek, Latin, German, French, Spanish, or Italian, or 2 units in each of two of them; and in other entrance subjects, elected by the applicant, 3 or 4 units. Applicants offering fifteen units which do not differ materially from the specific list may present their credentials for consideration.

It is recommended that French or German be offered to satisfy the language requirement for the reason that a knowledge of either of these tongues gives the student immediate access to a large part of the standard literature in the theory and practice of engineering.

The student preparing to enter the college is strongly advised to offer at least three of his elective units in Language and History. His work in the four-year course in engineering will necessarily be almost entirely scientific or technical and will leave him little opportunity for instruction in other fields. He will do well, therefore, during his preparatory years, to avoid unnecessary specialization and to make his studies as liberal as possible. Applicants who have not had this broader education are recommended to take either a five-year course or a six-year course, if they can afford the additional time and expense involved.

Students who have had some practical experience in engineering usually gain more than others from the courses offered by the College of Engineering; hence it is recommended that prospective students spend at least one summer vacation in practical work in connection with some kind of engineering.

The applicant must be at least sixteen years of age. Under special circumstances the committee on admissions will admit students who lack not more than one-half unit in Advanced Mathematics, (Solid Geometry, Plane Trigonometry), if fifteen units are offered and all other requirements are met. Such students may so arrange the course as to graduate in four years plus attendance in one Summer Session. More detailed information about courses requiring more than four years for graduation will be furnished upon application to the Secretary of the College of Engineering.

SUBJECTS THAT MAY BE OFFERED FOR ENTRANCE

The subjects that may be offered for admission to the College of Engineering are named in the following list. The figure in parenthesis opposite the name of each subject indicates its value expressed in units and shows the maximum and minimum amount of credit allowed in that subject. A unit represents a year's study in any subject in a secondary school, constituting approximately a quarter of a full year's work. Two hours of laboratory work are counted the equivalent of one hour of prepared recitation, but in Drawing or Manual Training 300 hours of actual work are required for one unit. If an applicant counts Biology (1) he may not also offer Botany (½) or Zoology (½).

1. English.....(3)
2a. First Year Greek.....(1)
2b. Second Year Greek.....(1)
2c. Third Year Greek.....(1)
3a. First Year Latin.....(1)
3b. Second Year Latin.....(1)
3c. Third Year Latin.....(1)
3d. Fourth Year Latin.....(1)
4a. First Year German.....(1)
4b. Second German.....(1)
4c. Third Year German.....(1)
4d. Fourth Year German.....(1)
5a. First Year French.....(1)
5b. Second Year French.....(1)
5c. Third Year French.....(1)
5d. Fourth Year French.....(1)
6a. First Year Spanish.....(1)
6b. Second Year Spanish.....(1)
6c. Third Year Spanish.....(1)
6d. Fourth Year Spanish.....(1)
7a. First Year Italian.....(1)
7b. Second Year Italian.....(1)
7c. Third Year Italian.....(1)
8a. Ancient History.....(½–1)
8b. Modern History.....(½–1)
8c. English History.....(½–1)
8d. American History, Civics..(½–1)
9a. Elementary Algebra.....(1)
9b. Intermediate Algebra.....(1)
9c. Advanced Algebra.....(½)
9d. Plane Geometry.....(1)
9e. Solid Geometry.....(½)
9f. Plane Trigonometry.....(½)
10. Physics.....(1)
11. Chemistry.....(1)
12. Physical Geography.....(½–1)
13. Biology.....(1)
14. Botany.....(½–1)
14a. Zoology.....(½–1)
15. Bookkeeping.....(½–1)
16. Agriculture.....(½–1)
17. Drawing.....(½–1)
18. Manual Training.....(½–1)
19. Any high school subject or subjects not already used...(½–2)

WAYS OF OBTAINING ENTRANCE CREDIT

There are four ways in which credit for entrance subjects may be obtained. They are:

1. By passing the required Cornell University entrance examinations held in September in Ithaca and New York City, and in January (for applicants for the College of Engineering only) in Ithaca.

2. By passing the College Entrance Examination Board Examinations (the "Comprehensive" examinations are accepted excepting Mathematics Cp.H.) held in June in various places. Address the Secretary of the College Entrance Examination Board, 431 West 117th St., New York City.

3. By passing the Regents' examinations (for students who have prepared in New York State).

4. By presenting an acceptable school certificate.

RULES GOVERNING ADMISSION

Besides satisfying the entrance requirements, candidates for admission must comply with the following rules:

1. Every candidate for admission to an undergraduate course must deposit twenty-five dollars with the University. Candidates are warned not to send cash through the mails. A check, draft, or order should be payable to Cornell University and should be sent to the Office of Admissions, Cornell University. The deposit must be made not later than June 1 if the candidate is to be admitted in September to the College of Arts and Sciences or the College of Architecture, or the College of Home Economics, and not later than August 1 if he is to be admitted in September to any of the other colleges. It must be made not later than January 1 if the candidate is to be admitted in February to any of the colleges.

If the candidate matriculates, the deposit will be credited to his account, $10 for the matriculation fee, $1 for an examination-book fee, and $14 as a guaranty fund, which every undergraduate student is required to maintain and which is to be refunded upon his graduation or permanent withdrawal, less any indebtedness to the University.

If admission is denied a candidate, the deposit is refunded in full at any time.

A candidate may withdraw the application for admission, but a charge of $10 is regularly made for accrued expenses unless the application is withdrawn and a refund of the deposit in full is claimed before the due date, which is June 1 in the College of Arts and Sciences, the College of Architecture, and the College of Home Economics and August 1 in the other colleges. If an application is not withdrawn until after the due date of the college concerned, but is withdrawn before August 31, the $10 charged for accrued expenses is deducted and $15 of the deposit is refunded. No refund is made to an applicant who withdraws the application after August 31.

In the case of applications for admission in February, a withdrawal after January 1 incurs the regular charge of $10, and no refund is made for withdrawal after January 31.

The winner of a New York State Tuition Scholarship in Cornell University may apply for admission to the University and make the required deposit of $25 immediately after receiving formal notice of his appointment from the Commissioner of Education at Albany.

2. Every candidate for matriculation must submit to the Director of Admissions a satisfactory certificate of vaccination against smallpox, not later than August 1 if he is to be admitted in September, or not later than January 1 if he is to be admitted in February. It will be accepted as satisfactory only if it certifies that within the last five years a successful vaccination has been performed or three unsuccessful attempts at vaccination have been made.

3. Every candidate for admission to an undergraduate course must file with his application at the Office of Admissions either a certificate of good moral character or, if he has attended some other college or university without graduating from it, a certificate of honorable dismissal from it.

ADMISSION AT THE BEGINNING OF THE SECOND TERM

Certificates and credentials for admission at midyear should be in the hands of the Director of Admissions not later than January 15. Admission at midyear is possible only under the following conditions: (a) A student must meet the regular entrance requirements. (b) If a student enters as a freshman without advanced college credit the time required for his graduation may be more than four years, and may require attendance during one or more Summer Sessions at Cornell University. On application made to the Director of Admissions on or before January 15 in any year, special entrance examinations in any of the University entrance subjects may be ar-

ranged for students who must be examined in one or more subjects to complete their requirements for admission to the College of Engineering at midyear. These special entrance examinations are held in Ithaca on or about January 25 of each year.

Admission to the Course in Administrative Engineering

The requirements for admission to this course are the same as those for the regular Four-Year Course, page 22.

Admission to the Five-Year Courses in Engineering

For admission to this course, the entrance requirements are those of the four-year course. The student completes the regular engineering work, spending more time on the advanced engineering work, and adding the equivalent of about one year of liberal arts work.

Admission to the Five-Year Course in Chemical Engineering

For admission to the course leading to the degree of Chemical Engineer the applicant must satisfy the requirements for admission as a candidate for the degree of Bachelor of Chemistry. Further information can be obtained from the "General Information Number" published by Cornell University, copy of which will be sent on request.

Admission to the Six-Year Course

The six-year course, leading to the degrees of A.B. and C.E., or A.B. and M.E. or A.B. and E.E., requires admission to the College of Arts and Sciences, in which college the student is registered during the first four years. In order to make it possible to obtain the C.E., M.E., or E.E. degree at the end of the sixth year, the student must complete the freshman engineering subjects before the beginning of his fourth year, and must complete the list of sophomore subjects in Civil Engineering, Mechanical Engineering, or Electrical Engineering before the beginning of his fifth year. Advice and assistance in arranging such a course may be obtained by applying to the Director of the school concerned.

Owing to the large amount of liberal work in the curriculum of the School of Civil Engineering the two degrees of A.B. and C.E. may be obtained in five years plus two summer sessions.

ADMISSION FROM ANOTHER COLLEGE

A student who has attended another college may be admitted to advanced standing, provided he is in good standing in the college from which he comes and provided also that he meets the full entrance requirements of the College of Engineering. An applicant for admission in this way should file by mail with the Director of Admissions of Cornell University, on an official blank to be obtained

from him, a formal application for admission stating definitely the branch of engineering desired, along with an official certificate, from the college or university already attended, of his honorable dismissal; his entrance credits in detail; his terms of attendance and the amount of work that he has completed; a detailed statement of tbe courses pursued; and the drawings and reports for which credit has been secured. He should also send a catalogue of the institution attended, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

SPECIAL ENTRANCE STUDENTS

The College of Engineering admits special entrance students, that is to say, applicants who have not fifteen acceptable units of entrance credit, only under exceptional circumstances. They must have had equivalent training satisfactory to the committee on admissions, and must be at least 21 years of age. After admission, such special students pursue the regular undergraduate courses, but will receive degrees only upon the completion of the regular entrance requirements.

ADMISSION AS A GRADUATE STUDENT

Graduates of this college or other colleges may enter the Graduate School of Cornell University and pursue work in the College of Engineering. Such a student may enter either as a candidate for a degree (M.C.E., M.M.E., M.E.E., M.S. in Engineering, or Ph.D.) or not, according to the character of his previous training. A prospective student should consult the Announcement of the Graduate School and apply to the Dean of the Graduate School. See also page 131.

A NECESSARY PRECAUTION

Before coming to the University, the student should consult an occulist and have any defect of vision corrected. Unless he does so, he may begin his work under a disadvantage and run the risk of failure. The large amount of close work that is required in reading and drafting puts a strain on farsighted or otherwise imperfect eyes. Such a weakness, unless discovered and remedied before the student begins his work, may delay his progress and impair his health.

UNDERGRADUATE TUITION AND OTHER FEES

Information about the amount and the manner of payments to be made by a student to the University should be looked for in the General Information Number. Fees for graduate students are given on page 134.

Tuition. The University charges undergraduate students registered in the College of Engineering tuition at the rate of four hundred dollars a year, payable $220 at the beginning of the first term and $180 at the beginning of the second term.

A student enrolled only for the second term of the academic year is required to pay tuition at the rate of the first term. The installment for any term becomes a liability at once when the student registers.

A Matriculation Fee of $10 and an examination book fee of $1 are required of every student upon entrance into the University; this fee must be paid at the time of registration. A new undergraduate student who has made the required deposit of $25 with the Treasurer need not make an additional payment of the matriculation fee, because the Treasurer will draw on the deposit for this fee.

A Laboratory Fee is required of all students registered in the College of Engineering, one-half of the fee at the beginning of each term, at the following rates: Freshmen in the College of Engineering, $25 a year; sophomores, juniors, and seniors in Mechanical Engineering and Electrical Engineering, $25 a year; sophomores, juniors, and seniors in Civil Engineering, $8 a year. Students taking a five-year course in the college pay this fee for only eight terms. Students in the College of Engineering who take laboratory courses in other colleges of the University are required to pay to the Treasurer a fee or deposit for materials used in the work. Students not registered in the College of Engineering but taking work in the shops are required to pay a laboratory fee at the rate of $3.50 a record hour. (A student who has taken, while in a non-engineering college of the University, part of the work required for an engineering degree shall, before receiving such technical degree, be required to pay to the University Treasurer such amount as would have been necessary if he had taken all such work while registered in the College of Engineering.)

A Health and Infirmary Fee of $6 a term is required at the beginning of each term, of every student. For a statement of the privileges given in return for this fee, see the General Information Number.

A Willard Straight Hall Membership Fee of $5 a term is required, at the beginning of each term of every student. Its payment entitles the student to share in the common privileges afforded by the operation of Willard Straight Hall, subject to regulations approved by the Board of Managers of the Hall. A fee of $5 a term is required of all graduate students except those who are members of the instructing staff, for whom membership is optional. The use of the hall is restricted to those who have paid this fee.

A Physical Recreation Fee of $4 is required at the beginning of each term of every undergraduate man and of every woman of the freshman and sophomore classes. Its payment entitles the student either to the use of the gymnasium and the University Playgrounds and to the use of a locker, with bathing facilities and towels, in the Gymnasium, the New York State Drill Hall, or the Schoellkopf Memorial Building, or else to the use of the women's gymnasium, recreation rooms, and playgrounds, and to the use of a locker if that is necessary.

A Graduation Fee is required, at least ten days before the degree is to be conferred, of every candidate for a degree. For a first or baccalaureate degree the fee is $10; for an advanced degree it is $20. The fee will be returned if the degree is not conferred.

Tuition and other fees become due when the student registers. The University allows twenty days of grace after the last registration day of each term. The last day of grace is generally printed on the registration coupon which the student is required to present at the Treasurer's office. Any student who fails to pay his tuition charges, other fees, and other indebtedness to the University, or who, if entitled to free tuition, fails to claim it at the Treasurer's office and to pay his fees and other indebtedness, within the prescribed period of grace, is hereby dropped from the University unless the Treasurer has granted him an extension of time to complete payment. For the conditions and terms of any such extension, see the General Information Number.

A tuition fee or other fee may be changed by the Trustees at any time without previous notice.

CHARGES FOR DELINQUENCIES

Every student is held responsible for any injury done by him to any of the University's property.

Assessments are levied upon the student in certain circumstances, under the following rules of the University:

A student desiring to be reinstated after being dropped from the University for delinquency in scholarship or in conduct shall first pay a fee of $25.

A matriculated student desiring to register after the close of registration day shall first pay a fee of $5. (Students in the Graduate School are excepted.)

A student desiring to file his registration of studies after the date set by his college for filing the same shall first pay a fee of $2.

A student desiring to take an examination or other test for the removal of a term condition (including the making up of a mark of "absent" or "incomplete") shall first pay a fee of $2 for each examination or other test.

A student desiring to make an appointment for the required medical examination or conference after twenty days from the last registration day of the term shall first pay a fee of $2.

For reasons satisfactory to the proper authority any of the above-mentioned assessments (except that levied for examination or other tests to remove a condition) may be waived in any individual case if the student's failure to comply with the regulation was due to ill health or to other reasons beyond his control. Application for waiver should be made to the dean of the college enrolling the student, except in the case of the medical examination, in which case it should be made to the chairman of the Faculty Committee on Health.

SCHOLARSHIPS: PRIZES: LOANS

The University has no means of remitting the usual tuition charges in any instance except to students of certain classes which are exempted by statute of New York State or the Board of Trustees. Those classes are defined in the General Information Number. There are no undergraduate tuition scholarships available to residents of the State of New York except the Padgham Scholarship (which is described below) and the Cornell Tuition Scholarships, which are awarded annually by the State Commissioner of Education after a competitive examination; and there are none available to non-residents of the State.

More particular information is given about undergraduate scholarships and loans in the General Information Number; about graduate scholarships and fellowships in the Announcement of the Graduate School and page 134 of this pamphlet; and about prizes in a pamphlet entitled Prize Competitions. Any of these publications may be obtained from the Secretary of the University.

UNDERGRADUATE SCHOLARSHIPS

GEORGE W. LEFEVRE SCHOLARSHIPS: Five awarded annually, each having an annual value of $400 and tenable each year so long as the holder remains in good standing in the University; only those candidates are eligible who furnish proof of their financial need. See the General Information Number.

THE CORNELL TUITION SCHOLARSHIPS: Open only to residents of the State of New York; awarded by the State Commissioner of Education. For particulars, see the General Information Number.

THE UNIVERSITY UNDERGRADUATE SCHOLARSHIPS: Eighteen awarded annually, each paying $200 a year for two years; awarded by the University each year to members of the incoming freshman class. For particulars, see the General Information Number.

THE EUDORUS C. KENNEY SCHOLARSHIPS: Two awarded annually, each paying $250 a year for four years; open annually, to *bona fide* residents of the town of Truxton, Cortland County, New York; in case of a vacancy in any scholarship the value of the scholarship may be awarded by the University Faculty's Committee on Scholarships in such manner as it may deem best. For particulars, see the General Information Number.

UNDERGRADUATE SCHOLARSHIPS IN ENGINEERING

THE JOHN MCMULLEN REGIONAL SCHOLARSHIPS, each having annual value of $200, are awarded each year to carefully selected freshmen entering the College of Engineering from each of several districts of the country and may be retained by the recipients throughout their undergraduate attendance provided they maintain satisfactory academic records. At present thirty scholarships are awarded in fifteen districts, the State of New York being excluded. About February 1st of each year application blanks and instructions are sent to principals of accredited schools for them to use in recommending outstanding candidates interested in obtaining an engineering education. The recommendations are to be sent to the Dean, College of Engineering, Cornell University, Ithaca, N. Y. A faculty committee selects the five most promising candidates in each region and forwards their applications to the respective regional alumni scholarship committees for personal investigation. The appointments are made by the President of the University upon the final recommendation of the Dean of Engineering.

THE JOHN MCMULLEN UNDERGRADUATE SCHOLARSHIPS: Open to undergraduates in Civil, Mechanical, or Electrical Engineering. These scholarships were

founded by a bequest of John McMullen of Norwalk, Conn., to Cornell University "for the purpose of creating and maintaining free scholarship or scholarships for the education of young men as engineers, the details as to the amounts of said scholarships and the qualifications of the beneficiaries to be left to said institution to determine, said scholarships to be known as the John McMullen Scholarships." With the avails of this bequest the Board of Trustees has established at the present time a considerable number of undergraduate scholarships of an annual value of $200 each, and divided them among the three schools of the College of Engineering. Applications should be made to the Director of the school concerned.

THE FRANK WILLIAM PADGHAM SCHOLARSHIP, founded by Amos Padgham of Syracuse, New York, in memory of his son, Frank William Padgham, M.E. '88, entitles the holder to free tuition and engineering fees in the regular courses in the Sibley School of Mechanical Engineering or in the School of Electrical Engineering. It cannot be held in connection with a New York State Scholarship. It will be awarded to the candidate, if any, who has had his preparatory education in the public schools of Syracuse, New York, and who, having been admitted to the regular course in either of the Schools named, shall be approved by the University Faculty's Committee on Undergraduate Scholarships. If no candidate from the schools of Syracuse applies, the scholarship may be awarded to a student who has received his preparatory education elsewhere. Application should be made to the Dean of the College of Engineering.

THE FRED LEWIS WILSON SCHOLARSHIP: Open to undergraduates in Mechanical or Electrical Engineering. Mrs. Mary Northrup Wilson bequeathed Cornell University about $4,000 to found and perpetuate one or more scholarships in honor of her son, Fred Lewis Wilson, who was graduated from Sibley College with the class of 1892. These scholarships are awarded, for a period of not more than two years each, to undergraduates who have been at least one year in the University, under the following rule: "Scholarships arising out of this bequest shall be awarded by a committee consisting of the President of the University, the Dean of the College of Engineering, and one other person chosen by them; and in making such awards the following attributes shall be given the weight indicated; scholarship, evidenced by written examination, 30 per cent; character, in the broadest sense, 30 per cent; probable usefulness in the world at large, 30 per cent; proficiency in mechanic arts, 10 per cent; it being understood that these scholarships are intended to assist such students as are in need of financial aid to complete their courses."

THE JOHN LEISENRING WENTZ SCHOLARSHIP: Open to undergraduates in Mechanical or Electrical Engineering; consists of the income of a fund of $5,500, given the University in 1920 by Mrs. Lewis Audenried in memory of John Leisenring Wentz, a member of the class of 1898. It is awarded at the end of each academic year to a member of the incoming senior class who is in need of pecuniary aid; the beneficiary must have maintained a high scholastic standing during his junior year. The award is determined by a committee approved by the President of the University from the Faculty of the College of Engineering, and is reported to the University Faculty for the purpose of record.

THE WILLIAM DELMORE THOMPSON SCHOLARSHIP: Open only to undergraduates in Mechanical Engineering; established in memory of William Delmore Thompson of the class of 1918; pays $40 a year and is for the benefit of self-supporting students of mechanical engineering. It is awarded at the beginning of the junior year, and if the student's work proves satisfactory it is continued through the senior year.

THE JUDSON N. SMITH SCHOLARSHIP: Open to upperclassmen in the School of Civil Engineering; pays $160 a year, the income of a fund given by Mrs. Sarah L. Smith of Saranac Lake, New York, in memory of her son. It is awarded by the Faculty of the School of Civil Engineering at the end of each year to a student of the incoming senior or junior class in that school, of good character and scholarship and needing pecuniary aid. Applications must be made before May 1.

OTTO M. EIDLITZ SCHOLARSHIPS: Open to undergraduates in the College of Engineering. These scholarships were founded in 1929 by a bequest of Otto M. Eidlitz, C.E. '81, of $25,000 to Cornell University to establish a scholarship fund

in the College of Engineering for students who require financial assistance. With the avails of this bequest three scholarships of an annual value of $325 have been established. These scholarships are awarded by the Dean of the College of Engineering to such students as appear to be most deserving because of their character and intellectual promise.

THE SYLVESTER EDICK SHAW SCHOLARSHIP, the income of a fund of $4,000 given in 1929 by Sylvester Edick of Newfane, is awarded to a student designated by the alumni of Cornell University who are residents of Niagara County at the time of the award. If the alumni fail to make such designation, the award is made by the principal of the Lockport High School, preference being given to the student who is most in need of financial assistance and who is studying Mechanical or Electrical Engineering. The student has the benefit of the scholarship for the entire period of his course, provided his conduct and progress in his work are satisfactory.

THE JOSEPH N. EVANS SCHOLARSHIP, consisting of the annual income from a bequest of $3,000 given by the will of Mrs. Joseph N. Evans in memory of her husband. Open to any undergraduates in the College of Engineering upon application to the Dean.

PRIZES IN THE COLLEGE OF ENGINEERING

THE FUERTES MEDALS: Established by the late Professor E. A. Fuertes; two gold medals, each of the value of one-half the amount of income provided by the endowment fund. One of these medals is awarded annually by the University Faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of his course, provided he has been in attendance at the University for at least two years; the other medal is awarded annually by the Faculty to a graduate of the School of Civil Engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the Faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction. Candidates are recommended to the University Faculty by the School of Civil Engineering annually.

THE FUERTES MEMORIAL PRIZES IN PUBLIC SPEAKING: Founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $100, one of $25, and one of $15, are awarded annually to members of the junior and senior classes in the Colleges of Engineering and Architecture for proficiency in public speaking. The conditions of the award are as follows: (1) The competition shall be open to seniors and juniors in the Colleges of Engineering and Architecture. (2) The competition shall be held on the evening of the third Friday in April. (3) A preliminary contest shall be held before a committee of four, representing each of the three Schools of Engineering and the College of Architecture, at such time and place as this committee may decide. Each contestant in this preliminary contest shall (a) submit a letter of not more than 400 words outlining the purpose and argument of his proposed address; (b) speak from a platform, without notes, for not more than five minutes, either on the subject of the proposed address or on some other subject, at the contestant's option. From the contestants at this preliminary contest not more than seven candidates shall be selected by the committee for the final contest. (4) The speeches delivered in the competition must be on technical subjects original in character. Any technical subject may be chosen by the competitor that may seem to him best suited to furnish an opportunity for persuasive argument. Questions relating to his profession that would naturally come before semi-technical or non-technical commissions, boards of directors, and conventions are of peculiar fitness. In making the award, both the character of the argument and the manner of presentation shall be considered. Each speech shall be limited to fifteen minutes. (5) The delivery must be without notes, but illustrative materials such

as diagrams, plans, models, or lantern slides may be used. (6) The judges of the final contest shall be six in number—one selected by the College of Architecture, one selected by each of the three Schools of the College of Engineering, one selected by the Department of Oratory and one selected by the President of the University from men prominent in business life in the city of Ithaca. (7) A student who has already received the first prize is not eligible for subsequent competition.

THE CHARLES LEE CRANDALL PRIZES: Founded in 1916 by alumni of the School of Civil Engineering; prizes of $75, $50, $35, and $20. They are awarded each year, by a committee appointed by the Director of the School of Civil Engineering, for the best paper written by seniors or juniors in that school on suitable subjects, provided both the substance and the written form of the papers submitted show real merit. If, in any year, no papers of sufficient merit are presented for these prizes, the income from the fund for that year is added to the principal and the additional income used from time to time to increase the amount of the prizes. The fund was established to provide prizes to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before May 1 of each year.

THE SIBLEY PRIZES IN MECHANIC ARTS: Awarded to undergraduates in Mechanical or Electrical Engineering. Under a gift of the late Hiram Sibley, made in 1884, the sum of one hundred dollars is awarded annually in five prizes to juniors and seniors in the School of Mechanical Engineering and in the School of Electrical Engineering who have received the highest marks in scholarship in at least three full terms of work required in the course and done in the schools named. The prizes are $30, $25, $20, $15, and $10.

THE J. G. WHITE PRIZE IN SPANISH. Through the generosity of James Gil bert White (Ph.D., Cornell, '85) three prizes, established in 1914, each of the value of $100 are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering, who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University. The prize is awarded mainly on the basis of linguistic attainments, in determining which a general knowledge of the language, including its grammar and literature, counts one-half, and ability to speak the language fluently and correctly counts one-half. For further details consult "Prize Competitions," a pamphlet published by the Secretary of the University.

THE ROBERT HARRIS SIMPSON PRIZE: Founded in 1933 by Mrs. Simpson in memory of her late husband, Robert Harris Simpson, C.E. '96. This prize of $25 will be awarded annually to that senior in the School of Civil Engineering who submits the best technical description or design of a civic improvement of sufficient substance and merit to justify the award. Papers or designs must be submitted on or before December 15 of each year, and will be judged by a committee appointed by the Director of the School of Civil Engineering.

LOAN FUNDS: AWARDS: OTHER PECUNIARY AIDS

Cornell University has two general funds that are used to make loans to students. They are (1) the F. W. GUITEAU STUDENT LOAN FUND, established by the will of Frederick William Guiteau and augmented by the will of his sister, Mrs. Nancy Guiteau Howe, both of Irvington-on-Hudson, the income of which fund is by the terms of the bequest available for loans to young men; and (2) THE WOMEN STUDENTS' LOAN FUND, consisting of a former student loan fund, increased in 1913 by $7,000 assigned to this fund by the late President Andrew D. White from funds placed at his disposal by the late Trustee Andrew Carnegie.

Both these funds are administered for the Trustees of the University by a standing committee. Applications for loans are received by the Secretary of the

University for submission to that committee. The benefits of these funds are reserved to undergraduate students who have been in attendance at Cornell University for at least one year, and preference is given to seniors and juniors. Account is taken of the applicant's character, scholastic record, and need of financial assistance. Loans are made ordinarily to assist students who would otherwise be unable to meet the tuition charges. The student must not regard the loan fund as a normal or assured resource. No student should enter upon a year at the University with the expectation of paying a part of the year's expenses with money yet to be borrowed. The use of the loan fund is a privilege reserved to the industrious student of proved merit and earning power whose means are so nearly exhausted and whose training is so nearly completed as to warrant going into debt in order to complete the training without delay. Money borrowed from either of the funds is to be repaid to the fund with interest at five per cent per annum.

THE WURTS LOAN FUND, the gift of Alexander Jay Wurts, in memory of his mother, Laura Jay Wurts, was founded in 1912 to assist needy students of the two upper classes in the Sibley School of Mechanical Engineering. Upon the recommendation of the Dean of the College of Engineering, loans from the income of this fund may be awarded by the Faculty of the College of Engineering, with the approval of the Treasurer, to one or more students each year.

THE CARL RICHARD GILBERT AWARD was founded in 1929 by Mr. and Mrs. A. S. Gilbert in memory of their son, Carl Richard Gilbert, who died during his Junior year. The value of the award is about $190 annually and is available for students in the School of Electrical Engineering. Awards from this fund are made on the recommendation of the Dean of the College and the Director of the School of Electrical Engineering, and with the approval of the Faculty of Engineering, to one or more worthy students each year.

THE MARTIN J. INSULL LOAN FUND was founded in 1924 by Martin J. Insull, M.E., '93, of Chicago, to be used for making loans to deserving students in the Sibley School of Mechanical Engineering who have been pursuing their studies there for at least one year. Loans are made on the unsecured promissory note of the student borrowing, bearing five per cent. interest annually, and payable within three years from the time the borrower leaves the University through graduation or otherwise. This fund is administered for the Trustees by the University's standing committee on loans, and applications are received by the Secretary of the University for submission to that committee.

THE ROBERT CRITCHLOW DEWAR LOAN FUND, the joint gift of Mrs. James M. Dewar and the Cornell Society of Civil Engineers, in honor of Robert Critchlow Dewar, C.E., 1909, who lost his life in the performance of his duties as a civil engineer, is available for undergraduates in the School of Civil Engineering upon recommendation of the Director of that school.

THE WILLIAM C. SEIDELL BOOK FUND of $1,000 was founded by Gerrit S. Miller. The income is used for the purchase of books for young men who are working their way through the School of Civil Engineering, and is paid by the Treasurer of the University upon the recommendation of the Director of the school, preference being given to underclassmen.

The Cornell Clubs of BUFFALO and ROCHESTER have each made provision for the loan of a small sum of money each year to an undergraduate student coming from the club's own neighborhood.

BUILDINGS: LABORATORIES, LIBRARIES AND OTHER EQUIPMENT

BUILDINGS

The building occupied by the School of Civil Engineering is LINCOLN HALL, a substantial brownstone structure, 200 feet long and 70 feet wide. In addition to the laboratories and museums, the building contains the working library of the School, aggregating over five thousand volumes, reading rooms, classrooms, and drafting rooms. The astronomical equipment and portions of the geodetic equipment are housed in the Fuertes Observatory, which contains all the instruments required for determining time, latitude, longitude, and azimuth. Several of the instruments are duplicates of those used by the United States Coast and Geodetic Survey. A large hydraulic laboratory is situated at the lower end of Beebe Lake in Fall Creek Gorge, near Lincoln Hall.

The Sibley School of Mechanical Engineering received its name from the late Hiram Sibley of Rochester, who between the years 1870 and 1887, gave $180,000 toward its endowment and equipment. Mr. Hiram W. Sibley has added more than $170,000 for later constructions and equipment. The SIBLEY BUILDINGS are situated at the north end of the Campus, and stand upon ground leased from the University for the purposes of the School, under an agreement with the late Hiram Sibley. There are five large buildings in the group.

The main building is 370 feet long, 50 feet wide, and three stories in height. It contains the reading room and reference library, drawing rooms, lecture rooms, offices, classrooms, and a large and well-lighted auditorium.

The Department of Experimental Engineering occupies two two-story buildings, each about 150 feet long by 40 feet wide, besides a boiler plant 30 by 40 feet, a refrigeration laboratory 30 by 40 feet, and the east basement of the main building.

RAND HALL was added to the Sibley School group (at a cost of $60,000) through the generosity of Mrs. Florence O. R. Lang. This building is a memorial to Jasper R. Rand, Addison C. Rand, and Jasper R. Rand, jr., the father, uncle, and brother of the donor. It is a three-story building, the main portion of which is 170 feet long and 50 feet wide; it contains the machine shop and pattern shop, and a portion is used for electrical laboratories.

The foundry and introductory engineering laboratory occupy a one-story building, 180 feet long and 40 feet wide.

The School of Electrical Engineering is housed in FRANKLIN HALL, but a portion of the electrical laboratory is temporarily situated on the second floor of Rand Hall.

The specialized training in Chemical Engineering, and the general instruction in chemistry for all students, are given in the BAKER LABO-

RATORY OF CHEMISTRY, which is adjacent to the engineering buildings. This large and splendidly equipped building includes, in addition to many other laboratories, classrooms and recitation rooms, a special laboratory for experimental work on unit operations and unit processes, and facilities for research in chemical engineering. An excellent technical library covering the fields of chemistry and chemical engineering is also available.

All instruction in Physics for undergraduate and graduate students is given in nearby ROCKEFELLER HALL, a large well equipped building which is used solely for work in this field, and contains the special Physics Library.

Mathematics is taught in WHITE HALL, located next to the buildings of the college proper.

LABORATORIES AND MUSEUMS

CIVIL ENGINEERING

The Civil Engineering Laboratories are housed in four distinct buildings and comprise the following:

THE CEMENT AND CONCRETE LABORATORY. This laboratory contains machines for tension tests, compression machines of from two to two hundred tons capacity, an impact machine and an eight-unit fatigue apparatus for repeated bending of concrete beams. For direct experiment with cement there is also provided a large number of tension and compression briquette molds, a water tank with capacity for the storage of three thousand briquettes, a moist cabinet with a capacity of seven hundred briquettes, and a Freas automatic electric drying oven; a Wagner turbidimeter; a moist curing room; a freezing room of 125 cu. ft. capacity with a temperature range of +70° to — 17°F.; scales, slates, and plateglass mixing tables, thermometers, permeability apparatus, several sets of apparatus for measuring linear and volume changes during setting, and apparatus for determining specific gravity, normal consistency, time of set, and constancy of volume by normal and accelerated tests; also standard sieves for determining fineness, a Ro-Tap Testing Sieve Shaker, and apparatus for determining voids in sand and stone. Knock-down forms are provided for the molding of large concrete beams and columns, and an Austin Cube Mixer is available for making concrete.

THE TESTING LABORATORY. The equipment of this laboratory includes a new 300,000-lb. Southwark Emery universal testing machine with a capacity for tension test specimens up to 14½ ft., and long columns up to 16 ft., in length; also a Riehlé 400,000-lb. testing machine with a capacity for beams and girders up to 19 inches in width and 18 feet in length, and for specimens in tension and compression up to 12 feet in length; a Riehlé 50,000-lb. testing machine; an Olsen 100,000-lb. testing machine; an Olsen 50,000-lb. testing machine, an Olsen 10,000-lb. wire testing machine; a Riehlé torsion testing machine of 60,000 inch-pounds capacity for testing rods and

shafts up to one and a half inches in diameter and six feet in length; a Riehlé 5,000-lb. transverse load testing machine for flexural tests of bars of wood and metal up to four feet in length. The equipment also includes a set of torsion clinometers reading to single minutes for use with the Riehlé torsion machine; a Henning extensometer for tension tests of metals, and two self-indicating dial extensometers with fittings which adapt them for use in testing steel or iron tension or compression specimens, and also for testing full-sized concrete beams and columns and for tests of wire. Four Berry strain gages, a Whittemore strain gage and Huggenberger tensometers are available for practical measurements of deformation of steel and concrete structures. The Martens mirror extensometer is also available.

THE MECHANICS LABORATORY. This laboratory is equipped with apparatus for qualitative and quantitative demonstration and experimentation by undergraduate students in the fundamental principles of dynamics and mechanics of materials, in conjunction with the classroom instruction in mechanics.

LABORATORY OF APPLIED ELASTICITY. There is recently installed a specially built photo-elastic apparatus providing a 12-inch diameter beam, suitable for a wide range of experimentation in advanced mechanics and structural analysis. The laboratory is also provided with electrical equipment suitable for investigations of seepage, hydraulic flow, certain stress problems, and other applications of the electrical-hydraulic, or electrical-stress, analogies based on the potential theory. A Beggs Deformeter is available for experimental analysis of statically indeterminate structures.

THE HIGHWAY LABORATORY. The laboratory is equipped with apparatus for making all the standard tests on non-bituminous and bituminous materials used in highway construction and maintenance and also for examining the properties of subgrade soils.

The section of the laboratory for testing non-bituminous materials such as gravel, rock, etc., is in the basement of Lincoln Hall. It is equipped with a Deval machine, core drill, rock saw, grinding lap, Page impact machine, ball mill, briquette molding machine, cementation testing machine, Dorry machine, rattler, and other accessories for conducting tests.

The laboratory for testing bituminous materials, bituminous mixtures, and subgrade soils is housed in a separate building. This laboratory is equipped with facilities for making the standard tests of specific gravity, consistency, ductility, softening point, total bitumen, etc., on bituminous materials and also with apparatus for the examination of bituminous mixtures determining the liquid limit, plastic limit, shrinkage determinations, wet and dry mechanical analysis, centrifuge moisture equivalent, etc., of subgrade soils.

THE HYDRAULIC LABORATORY. In addition to the usual equipment for the ordinary laboratory experiments, the unique location and construction of this laboratory render practicable investigations requir-

ing a steady gravity water supply for long periods using relatively large flows of water. The water supply is obtained from Fall Creek with a water shed of 126 square miles. Beebe Lake, a pond of about 20 acres, has been formed by the construction of a concrete dam 26 feet high with a spillway crest length of 130.5 feet. At one end of the dam there is an additional flood spillway of 141.5 feet long. A rectangular canal 420 feet long and 16 feet wide is supplied from Beebe Lake through six headgates for controlling the amount of flow. The upper portion of the canal is 17.7 feet deep and the lower portion is 10 feet deep. In this canal are two sharp crested weirs 16 feet long over which discharges as large as 400 cubic feet a second may be passed. The lower portion of the large 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. Models of dams may be built in the canal and the flow over them investigated with precision. An electrically operated car spans this canal and is used for rating current meters and Pitot tubes and for experiments that require the towing of floating or submerged objects through still or running water at various speeds. By means of a gear system the speed of the cable which moves the car, may be varied through a range from ¼ to 12 feet a second. There are also two parallel concrete flumes with water supplied from Beebe Lake independently of the large canal. These are 2 feet wide, 2½ feet deep, and 90 feet long extending downstream from a short canal 7 feet wide, 3 feet deep, and 40 feet long near the dam, to a 2,000 cubic foot concrete measuring tank. Outdoor work is usually suspended from December 1 to April 1 because of the freezing weather.

The laboratory building is built against the south cliff of Fall Creek Gorge and extends vertically about 70 feet, from the pool below Triphammer Falls to the top of the gorge. A short branch canal six feet wide is housed by the upper portion of the laboratory building and may be supplied directly from Beebe Lake by means of a 48-inch cast-iron pipe line with a short 30-inch branch at its lower end. A 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal discharges either to waste into the pool below Triphammer Falls (a sheer drop of 60 feet) or into the upper end of a steel stand-pipe 6 feet in diameter and 60 feet high. A suitable mechanism causes an instantaneous diversion of discharges as large as 60 cubic feet a second from the waste flume into the standpipe or vice versa. The 6-foot standpipe is provided at the bottom with a 36-inch discharge valve operated by hydraulic pressure. There is a float gage indicating accurately the height of the water surface in the standpipe, when used as a measuring tank. An independent 10-inch pipe line from the 30-inch pipe to the bottom of the laboratory supplies most of the pieces of apparatus used for class work and research. The 6-foot standpipe may also be used as a supply tank, water being supplied to it from either the 6-foot canal or the 10-inch pipe line. In the laboratory building there is also a concrete flume, 2 feet wide, 4 feet deep, and 25 feet long. Flows up to 11 cubic feet a second can be passed

through this and measured volumetrically. This flume is arranged conveniently for experiments on small weirs, low-head orifices, etc. There are numerous flanged connections from 4 to 12 inches in diameter for the attachment of apparatus. The hydraulic machinery equipment at present includes only types of the turbine, Pelton-Doble wheel, Fitz Overshot wheel, multi-stage centrifugal pump and hydraulic ram, all arranged for testing.

The utility of this plant has been demonstrated by calls from all parts of the country for the performance of experiments of great importance. Among these may be mentioned the valuable results obtained for the United States Deep Waterways Commission, the Michigan Lake Superior Power Company, the City of New York in connection with its water supply, and the United States Geological Survey.

HAROLD I. BELL RESEARCH FUND. In memory of her husband, Harold Ingersoll Bell, C. E., 1905, Mrs. Ellen Foster Bell in 1922 gave the University five thousand dollars to establish the Harold I. Bell Research Fund. The income of the fund is used to purchase equipment and supplies for research in the field of hydraulic engineering and related fields, under the direction of the School of Civil Engineering.

THE SOIL MECHANICS LABORATORY. In the laboratory are all the facilities for performing standard tests on soil. Here it is possible to determine the physical characteristics of soil, specific gravity, moisture content, Atterberg limits, centrifuge moisture equivalent, mechanical analysis, shear, permeability, compaction, and bearing capacity, for use in the design of foundations, dams, tunnels, subgrades for roads, and other substructures.

The laboratory is equipped with analytical balances, automatic electric drying oven, constant temperature bath, centrifuge, and other special apparatus, such as a soil dispersion machine, soil hydrometers, and liquid limit machine for special tests. A turbidimeter and a Ro-Tap Sieve Shaker are also available for use. The moist room, freezing room, and machine shop, as well as electrical apparatus suitable for investigation of seepage and flow of water under dams, are at the disposal of graduate research students.

THE SANITARY LABORATORY. This laboratory provides facilities for the physical, chemical, bacteriological, and biological analyses of water and sewage, and for the performance of such other tests as will acquaint the student with current practice as affecting the control and operation of the various types of water purification and sewage disposal plants. The equipment includes microscopes and the necessary accessories for complete bacteriological and biological examinations of water; an autoclave, a hot-air sterilizer, one 37½° and two 20°C. incubators, a chemical balance, a United States Geological Survey turbidity rod and color standards; four experimental sand filters, fitted with loss of head gauges, and providing for a total depth of sand and water of nine feet, for determining the rate and efficiency

of operation of sand filters, as well as various types of sewage nozzles. The laboratory is well equipped with such glassware, reagents, accessories, and apparatus as are needed for making the chemical analyses of water and sewage affluents.

THE FUERTES ASTRONOMICAL OBSERVATORY is situated north of Beebe Lake. It contains a transit room with four piers, a clock vault, a photographic darkroom, an office, a computing room, a classroom, and a dome for the 12-inch equatorial telescope, in addition to a comparator room and a constant temperature room for geodetic laboratory work. Besides the Irving Porter Church Telescope, a very superior 12-inch equatorial, the equipment includes a Howard mean time astronomical clock, chronometers by Negus and Nardin, four chronographs, a Troughton and Simms transit, two Fauth prismatic transits with latitude levels, a Fauth zenith telescope, an altazimuth by Troughton and Simms, spherometer, level-trier, and various meteorological instruments.

Facilities are provided for work along the various lines relating to geodesy and advanced surveying, including geodetic astronomy. The standards of length include: Invar tapes standardized at the U. S. Bureau of Standards; a steel meter bar of the International type which has been compared with the International Prototype Meter of the U. S. Bureau of Standards; a Rogers speculum metal decimeter and 4-inch scale, combined, accurately divided and compared; and a 4-meter bar for subsidiary measures. The laboratory equipment also includes a Mendenhall half-second pendulum apparatus for the determination of the acceleration of gravity—the standard type used by the U. S. Coast and Geodetic Survey; a Kew magnetometer, a dip circle, and a declinometer, for observation of terrestrial magnetism; a dividing engine by the Société Genévoise; precision thermometers by Tonnelot and Boudin standardized at the International Bureau in Paris; a small comparator for calibrating thermometers; and the usual auxiliary apparatus. A 100-foot tape comparator is located on the fourth floor of Lincoln Hall.

MECHANICIAN'S ROOM. This room is used in connection with the laboratories for the construction of special apparatus and instruments and for the maintenance of the equipment. It is well supplied with tools and special machines for the purpose, and is in charge of a mechanician.

THE MUSEUMS AND DRAWING ROOMS of the School of Civil Engineering contain the following collections: (1) The Muret collection of models in descriptive geometry and stone cutting. (2) The De-Lagrave general and special models in topography and geology. (3) The Schroeder models in descriptive geometry and stereotomy with over 50 brass and silk transformable models made in the school after the Olivier models. (4) The M. Grund collection of bridge and roof details, trusses, and masonry structures, such as right, oblique, and annular arches and domes, and several intricate models in stone cutting, supplemented by similar models by Schroeder and other

makers. (5) A model railroad bridge of 25-foot span, one-fourth natural size, and a numerous collection of models of track details. (6) The Digeon collection of movable dams, artificial harbors, and working models in hydraulic engineering. (7) Working models of water wheels, turbines, and other water engines. (8) Several large collections of European and American progress photographs of engineering work showing the progress of construction, and many other photographs, blue-prints, models, and diagrams. (9) A collection of typical geodetic and surveying instruments of historical interest including a secondary base-line apparatus made under the direction of the United States Coast and Geodetic Survey, a pair of base-bars constructed in this school, solar and magnetic compasses, levels, transits, theodolites, omnimeters, tacheometers, sextants, telemeters, altmeters, hypsometers, odometers, meteorological instruments, etc., with a large number of auxiliary and special instruments such as planimeters, pantographs, elliptographs, calculating devices, and computing machines.

The Laboratories of Mechanical Engineering

The Mechanical Engineering Laboratories and Work Shops comprise the following:

The Materials Testing Laboratory. This laboratory is equipped for tension and compression tests with an Olsen 300,000 lb. machine, a Riehlé 100,000-lb. machine, a 200,000-lb. Emery hydraulic machine, an Olsen 150,000-lb. three-screw machine, an Amsler 100,000-lb. hydraulic machine, together with several other machines varying in capacity from 10,000 to 100,000 pounds. For transverse test there is a Riehlé machine of 200,000 pounds capacity and a Fairbanks machine of 10,000 pounds capacity. There are one Olsen torsion machine of 200,000 inch-pounds capacity, two Upton-Lewis fatigue testing machines, and an Amsler-Charpy-Izod impact testing machine. The equipment includes hardness testing machines, extensometers, a cathetometer, gas and electric furnaces, tempering baths, pyrometers, and other apparatus required for the determination of the physical qualities of engineering materials under tensile, compressive, transverse, and torsional stress, and under different kinds of heat treatment.

The Photo-Elastic Laboratory. A Bausch and Lomb polariscope with 5″ diameter beam is the basis upon which this laboratory has been built up. Material for the construction of models is on hand, as well as equipment for polishing and annealing. A 2,000-lb. Olsen Universal hydraulic testing machine is used for loading the models. Both white light and monochromatic light sources are available. Stress distributions in models up to 12″ in length or breadth can be determined.

The Steam Laboratory. In this laboratory there is a 150-HP triple expansion Allis-Corliss engine so fitted up that it may be oper-

ated as a simple, compound, or triple expansion engine, condensing or non-condensing. There are also several smaller engines, including a Russell, a Harris-Corliss, a Payne, a Fitchburg uniflow, and a Troy steam engine. There are three surface condensers and one jet condenser which may be connected with these engines as desired. There are two 35-kw. horizontal Curtis turbines, and a Lee turbine driving a Goulds centrifugal pump. A two-stage Worthington air compressor driven by a Uniflow engine and one airbrake pump, together with meters, nozzles, and other instruments, may be used for routine tests. This part of the laboratory also has several fans that can be arranged and equipped for testing. The apparatus and instruments used for engine testing comprise about eighty indicators of different types, about seventy-five steam gauges, a number of calorimeters for determination of the quality of steam, speed counters, tachometers, planimeters, etc., besides a number of dynamometers of various kinds. The boiler section of this laboratory has one 150-HP Babcock and Wilcox water-tube boiler of the marine type, one 100-HP Babcock and Wilcox water-tube boiler of the standard type, both of which are fitted with internal superheaters, and an 80-HP Heine water-tube boiler. The auxiliary apparatus consists of a Cochrane open heater, a Wainwright closed heater, water softener, steam pumps, traps, injectors, etc. A full set of scales, measuring tanks, gauges, flue gas apparatus, separating and throttling calorimeters, pyrometers, etc., complete the boiler equipment.

The Gas Engine Laboratory. The equipment in this laboratory is chosen with a view to providing a great variety of types as to fuel used, governing, etc. It includes an 8-HP Fairbanks gasoline engine, a 6-HP Ingeco oil engine, a 6-HP and a 15-HP Hornsby-Akroyd oil engine, a 30-HP Westinghouse gas engine, a 25-kw. General Electric Co. gas motor set, and a 45-HP Diesel engine. High speed engines are represented by a variety of auto and marine engines. The testing equipment includes high speed indicators. Dynamometers are represented by a 150-HP Sprague Electric, a 60-HP Diehl Electric, a 150-HP General Electric, a Wheeler hydraulic, good for 100-HP at 4000 r.p.m., and a second Wheeler dynamometer, good for 300-HP at 2500 r.p.m.

The Hydraulic Laboratory. This laboratory contains the following machines and apparatus: a 6-inch single-stage DeLaval centrifugal pump; a 2½-inch two-stage Worthington centrifugal pump, a 16-inch Goulds centrifugal pump direct connected to a variable speed motor; a 12-inch Doble water wheel; a 15-inch S. Morgan Smith turbine with Lombard governor; a complete test stand for research and testing of pumps in capacities up to 1000 G.P.M. and 230 ft. head at speeds up to 4000 r.p.m., including an electric dynamometer of 13-HP rating with independent motor-generator power supply and control, a 3-inch motor-driven centrifugal booster pump and 1½-inch motor-driven centrifugal priming pump, 2-inch, 3-inch and 4-inch calibrated Venturi tubes; Toledo Precision platform

scales with tank for the collection and weighing of water in amounts up to 6500 lbs.; sets of weir boxes with various types of weirs and nozzles for the determination of coefficients of discharge; various types of water meters and other apparatus for measuring the flow of water, such as Pitot tubes, Venturi meters, current meters, etc.

THE OIL TESTING LABORATORY. This laboratory contains a Cornell oil-testing machine, a Thurston standard railway-testing machine. The rest of the equipment consists of several viscosimeters of different types, flash and burning test apparatus, chillpoint apparatus, together with the necessary hydrometers and thermometers.

THE REFRIGERATION LABORATORY. For the study of refrigeration the mechanical laboratory possesses a 2-ton York absorption machine and a very complete York refrigerating compression plant having a capacity of 15 tons of ice.

THE CEMENT LABORATORY. This laboratory contains the ordinary apparatus for the testing of cement and concrete.

THE FUEL TESTING LABORATORY. This laboratory contains a complete equipment of fuel calorimeters and other apparatus needed for the determination of the composition and calorific value of fuel, whether gaseous, liquid, or solid.

THE BELT TESTING LABORATORY. This laboratory contains a belt testing machine which consists of two 75-HP electric dynamometers capable of operating at any speed up to 1000 r.p.m. and of carrying pulleys up to 36 inches in diameter. The belt tension power transmitted by the belt, and the slip of the belt may be observed. Belts can be tested in widths up to 10 inches and the pulley center distance may be varied from 4½ feet to 20 feet.

THE INTRODUCTORY ENGINEERING LABORATORY contains the necessary equipment to demonstrate the principal operations in the forge shop, forging (hand and machine), welding, soldering, brazing, etc. The equipment also includes numerous examples of common engineering appliances such as valves, traps, gauges, etc., and an example of simple steam engine, a gas engine, and a steam pump. There is also a complete equipment to teach the principles of oxy-acetylene welding and cutting; electric arc welding, and atomic hydrogen arc welding.

AERONAUTICAL EQUIPMENT. Laboratory and field work in aeronautics is conducted with the cooperation of the management of the Ithaca airport. The college has laboratory facilities for calibration of aeronautical instruments in connection with flight tests run at the Ithaca airport. Most of the publications of the National Advisory Committee for Aeronautics are available in the library.

THE WORK SHOPS IN MECHANICAL ENGINEERING

The Work Shops of the Sibley School of Mechanical Engineering comprise the following units:

THE FOUNDRY occupies floor space of about 4,800 square feet, and has an equipment for the production of iron and composition castings. The methods of producing duplicate work are demonstrated by molding machines of different types selected to illustrate the production of castings of various kinds at lowest labor cost.

THE PATTERN SHOP occupies the top floor of Rand Hall with floor space of 8,440 square feet. The work given the students in this department includes the use of hand and power operated tools under instructors who are skilled in the trade of pattern making.

THE MACHINE SHOP is located on the ground floor of Rand Hall with the same floor area as the pattern shop. It is equipped with an electric traveling crane and representative modern machine tools selected with a view to demonstrating manufacturing methods. A part of the work-shop equipment is installed to illustrate the latest practice in production with specialized labor-saving machinery. The students are not expected to become skilled operators of the machines of this class, but to acquire a general knowledge of their possibilities in the kinds of work to which they are adapted. The equipment is arranged in groups, each under the charge of an instructor who has made a special study of the machinery in his group.

THE LABORATORIES OF ELECTRICAL ENGINEERING

The equipment of the laboratories of the School of Electrical Engineering is distributed as follows:

THE LECTURE ROOM EQUIPMENT. The main lecture room is on the first floor of Franklin Hall. Provision is made here for a large number of experimental demonstrations which accompany many of the earlier lectures in electrical principles and applications.

Direct and alternating current services from the University Gorge Plant, together with a direct current service from the dynamo laboratory in Franklin Hall, are available at a four panel switchboard in the lecture room. A more flexible power supply of 3 kw. capacity is provided by a three-unit motor-generator set comprising an induction motor, an alternator, and a compound dc generator all cabled to the switchboard for connection to the control and load panels in any manner desired.

The usual indicating instruments for dc and ac current, voltage, and power, and for synchronizing are mounted on the switchboard and arranged for any desired connection.

All of the switchboard services and equipment are made available to the lecture demonstration table through a multi-conductor cable. The numerous pieces of small apparatus for use on this table are housed in an adjacent preparation room. These include an oscillograph, machine models, special demonstration equipment originated in the school, illumination apparatus, etc.

ELECTRICAL MACHINERY LABORATORIES. A great variety of direct and alternating-current machines are available, so selected as to

afford at least one machine of every type ordinarily encountered in practice. Most of these represent modern construction and are of such size and design as to give typical performance, but at the same time provision is made for great flexibility of operation. For example, in five of the synchronous machines the coil terminals are brought out to an external connecting board. One 15-kva synchronous machine is provided with a phase-wound rotor and a squirrel-cage rotor, either of which may be readily used to replace the synchronous rotor. A modern type of synchronous converter is arranged for direct or inverted operation, either single-phase, two-phase, or three-phase, with metering and control boards which permit very rapid change of operating conditions. There are three types of commutating alternating-current motors, four types of fractional-horsepower alternating-current motors, and a large number of direct-current machines.

Typical examples of automatic starters for alternating and direct current motors are provided, including time-element, counter-e.m.f., and series lock-out types, in addition to drum controllers and a complete Sprague multiple-unit railway control system.

The non-rotating apparatus also includes constant-potential transformers of standard and special construction, constant-current transformers, induction regulators, storage batteries and a small mercury-arc rectifier.

THE ELECTRONIC LABORATORY contains various types of high vacuum thermionic devices, gas conduction devices, photo-electric cells, mercury tubes, and a modern 6-phase steel case mercury rectifier with grid control and complete vacuum apparatus, which may also be operated as an inverter.

The facilities for testing are well-planned and very complete. For machine testing, there are numerous Prony brakes, and electric dynamometer, and a special apparatus for determining the complete characteristics of fractional-horsepower motors. The magnetic testing apparatus includes a Fahy permeameter, an Epstein apparatus and a large motor-generator set comprising two sine-wave generators and a third-harmonic generator on the same shaft, with provision for adjusting phase displacement and for measuring form factor. The dielectric testing apparatus includes an 80,000-volt testing transformer together with full-wave rectifying equipment and an electrostatic voltmeter. Among the general pieces of test equipment are a very complete assortment of meters and three oscillographs.

THE STANDARDIZING LABORATORY includes standard precision ammeters and voltmeters, a Silsbee current-transformer test set, and primary standards of voltage and resistance with the necessary potentiometers and auxiliary equipment arranged for convenient checking of secondary standards and of other meters.

THE ELECTRICAL COMMUNICATION LABORATORY. This laboratory is well equipped with apparatus to illustrate present day methods of electrical communication. The wire telegraph section includes various types of commercial apparatus illustrative of simple, duplex,

quadruplex, and repeater circuits. The telephone section includes representative telephone equipment of various types. A complete machine switching exchange is installed in the laboratory. The radio section comprises various transmitting and receiving sets including a complete commercial radio broadcasting equipment. Laboratory standards of inductance, capacity and frequency are available for precision tests and measurements.

The University owns and operates, under the supervision of the Department of Electrical Communications, Broadcasting Station WESG which has the modern 1000 watt, crystal controlled 100% modulated broadcast transmitter housed in a special building near the Northern edge of the Campus. Two 165 ft. steel towers support the antenna.

The studios are centrally located on the Campus in a building exclusively devoted to them, and numerous University programs originate at this point.

The equipment of the transmitting station and the studios are used in regular instruction and available for special tests and research.

THE LABORATORIES OF CHEMICAL ENGINEERING. The laboratory for the study of unit operations is housed in the Baker Laboratory of Chemistry and is provided with semi-plant scale equipment for the study of heat transfer, fluid flow, fractional distillation, gas absorption, evaporation, filtration, drying, crushing and grinding, and various other unit operations in chemical engineering. Other laboratories are also available for specialized and research work in chemical engineering.

LIBRARIES: GENERAL AND DEPARTMENTAL

The Cornell University Library comprises about 877,000 volumes, being one of the largest collections of its kind in the country. Most of the books are in a general library building.

For convenience of reference, the University Library maintains SCHOOL LIBRARIES in Lincoln Hall for the School of Civil Engineering, in Sibley Dome for the School of Mechanical Engineering, and in Franklin Hall for the School of Electrical Engineering. These libraries are under the supervision of the authorities of the several schools. They contain the standard reference and text books and the current files of the important engineering periodicals. In addition, many of the departments of the college have their own special working and reference libraries.

Of special importance is the KUICHLING MEMORIAL LIBRARY, of the School of Civil Engineering, a collection of about fifteen hundred books and pamphlets on hydraulic and municipal engineering, formerly the professional library of the late Emil Kuichling, A.B., C.E., of Rochester, N. Y. It was given to the school in 1919 by Mrs. Sarah L. Kuichling, with an endowment of one thousand dollars, the income of which is to be used to extend the collection and to maintain it as a separate library.

Through the generosity of former students in the School of Civil Engineering, the Irving Porter Church Fund was established in 1917 for book purchases for the School's Library.

The library in Franklin Hall for the School of Electrical Engineering is known as the ALEXANDER GRAY MEMORIAL LIBRARY. The nucleus of the library was the personal library of the late Alexander Gray, for some years Professor of Electrical Engineering at Cornell University and executive head of the School of Electrical Engineering. The McGraw Hill Book Company bought this collection and gave it to Cornell University for the use of the School of Electrical Engineering.

THE LIBRARY OF THE DEPARTMENT OF CHEMISTRY is in Baker Laboratory and is immediately available to students in the courses in Chemical Engineering. The Chemical Library is unusually well provided with books and journals covering the fields of chemistry and chemical engineering.

THE LIBRARY OF THE DEPARTMENT OF PHYSICS is located in Rockefeller Hall where all instruction and research in physics are conducted.

COURSES OF STUDY IN THE COLLEGE

THE REGULAR FOUR-YEAR COURSES

As stated already in the preceding discussion, regular four-year courses are offered in the schools of the college, leading to the degrees of Civil Engineer, Mechanical Engineer, and Electrical Engineer. In addition these schools offer four-year courses leading to the degree of Bachelor of Science in Administrative Engineering.

The first year of all the courses is basically the same so that no student need make his choice of Civil Engineering, Mechanical Engineering, Electrical Engineering, or Administrative Engineering until near the end of the first year of residence. The curriculum of the first year is given on page 49 under the head of The Freshman Year.

The last three years of each regular four-year course are spent by the student under the direct supervision of one of the three schools. Further on in this Announcement there will be found, under the appropriate head, a particular statement of the curriculum of the last three years in each school.

In the last year of each course, certain options or electives are offered, so that each student may have a certain amount of freedom in placing the main emphasis of his work upon branches of the profession in which he may be most interested. These options and electives are clearly defined in the announcement of each school, on subsequent pages.

FIVE AND SIX-YEAR COURSES

As already mentioned on page 14 of this Announcement, arrangements may be made for five-year courses combining engineering training with the equivalent of one year of studies designed to broaden the education. These courses lead to the same degree as the four-year regular courses, i.e., C.E., M.E., or E.E., as the case may be.

There is also a five-year course in Chemical Engineering leading to the degree of B.Chem., at the end of four years and to the degree of Chemical Engineer at the end of the fifth year.

In addition six-year courses may be arranged for in any one of the three schools, leading to two degrees, A.B., at the end of four years, and either C.E., M.E., or E.E., at the end of six years.

THE REQUIREMENTS FOR GRADUATION

The degree of Civil Engineer, Mechanical Engineer, Electrical Engineer, Bachelor of Science in Administrative Engineering, or Chemical Engineer, is conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have

satisfied the University requirements in Military Training (or Physical Training), in Hygiene and Preventive Medicine, and in the payment of tuition and fees.

2. If admitted to the four-year course, he must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects, including elective hours, prescribed in the four-year curriculum as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

TWO DEGREES IN ONE YEAR. In case a person has satisfied the requirements for any baccalaureate degree, he shall not be recommended for any other baccalaureate degree until he shall have completed at least one year of further residence and of work acceptable to the Faculty on whose recommendation the second baccalaureate degree is to be conferred.

CHANGES IN REQUIREMENTS

As engineering is constantly expanding and advancing, the College of Engineering reserves the right to modify at any time its courses and curricula, alter the requirements for admission and graduation, and change the degrees awarded; and such changes shall apply to both prospective and matriculated students at such time as the college may determine.

THE FRESHMAN YEAR

There is fundamentally a single schedule of studies for all students in the freshman year of the College of Engineering. The prescribed schedule is given below. In it the numbers of the courses refer to the lists of courses printed on this and the next three pages. Certain courses are for all freshmen, while others are for freshmen in the school indicated.

SCHEDULE OF STUDIES

	Hours	
	1st Term	*2nd Term*
Analytical Geometry and Calculus 5a, 5b	5	5
Physics 11, 12	4	4
Chemistry 106a, b	3	3
Drawing 200, 201 (C.E.)	3	3
Descriptive Geometry and Drawing 120, 121 (M.E., E.E.)	3	3
Elementary Surveying 110 (C.E.)	3 or 0	0 or 3
Elementary Surveying 111 (M.E., E.E.)	2 or 0	0 or 2
Woodwork 102 (M.E., E.E.)	0 or 1	1 or 0
Introducing Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours each term (C.E.)	20 or 18	17 or 19
Total number of hours each term (M.E., E.E.)	19	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

For the schedules of the sophomore, junior, and senior years in Civil Engineering, Mechanical Engineering, Electrical Engineering, or Administrative Engineering, consult the announcement of the appropriate school in following pages.

THE COURSES OF INSTRUCTION, FRESHMAN YEAR

The following courses of instruction are those prescribed for all students in the freshman year of the four-year course leading to the degree of Civil Engineer, Mechanical Engineer, Electrical Engineer, or Bachelor of Science in Administrative Engineering. The courses in Mathematics, Physics, and Chemistry are given in the College of Arts and Sciences; the other courses in the list, except Hygiene, are given in the College of Engineering.

MATHEMATICS

5a. **Analytical Geometry and Calculus.** First term. Credit five hours. Repeated in second term.

5b. **Analytical Geometry and Calculus.** Second term. Credit five hours. Given also in first term.

Course 5a or 5b may not without special permission, be taken simultaneously with any of the other courses in Mathematics. Courses prerequisite to 5a or 5b are Solid Geometry and Trigonometry.

PHYSICS

11. **General Physics.** Required of Freshman Engineering students. First term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. Entrance physics is desirable but not required.

Two lectures, two recitations and one laboratory period a week as assigned, covering the subjects of mechanics, wave motion, sound and light.

Rockefeller Hall. Assistant Professor GRANTHAM and instructors.

12. **General Physics.** Required of Freshman Engineering students. Second term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. It is recommended, though not required, that Physics 11 precede this course.

Two lectures, two recitations and one laboratory period a week as assigned, covering the subjects of electricity and heat.

Rockefeller Hall. Assistant Professor GRANTHAM and instructors.

CHEMISTRY

Entrance credit in chemistry does not carry with it University credit in Courses 106a or 106b. If a student entering the University from a preparatory school desires credit for these Courses, he must pass an examination set by the Department of Chemistry. This examination is held in Ithaca on the same day in September as the entrance examination. University credit in Courses 106a and 106b that is obtained by passing this examination does not carry with it entrance credit in Chemistry.

106a. **General Chemistry.** First term. Credit three hours.

One lecture, one recitation, and one laboratory a week as assigned.

Baker Laboratory. Assistant Professor LAUBENGAYER, Mr. FERGUSON, and assistants.

106b. **General Chemistry.** Second term. Credit three hours. Prerequisite Chemistry 106a.

One lecture, one recitation, and one laboratory a week as assigned.

Baker Laboratory. Assistant Professor LAUBENGAYER, Mr. FERGUSON, and assistants.

DRAWING, SURVEYING, SHOPWORK, INTRODUCTORY LABORATORY AND INTRODUCTORY LECTURES

102. **Woodshop.** Freshmen. One hour either term as assigned. Wood working; the use of hand and machine tools for wood working followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third floor.*

103. **Introductory Engineering Laboratory.** Freshmen. One hour either term as assigned. Elementary laboratory work and study of the various materials, processes and machines commonly used in engineering work. Demonstrations, followed usually by practice in forging, welding, hardening, and tempering, drop forging, metallizing and brazing, oxy-acetylene cutting and welding, atomic hydrogen, and electric welding. Also study of pipe and pipe fittings, soil pipe and fittings, threaded fastenings, bearings, instruments of measurement, steam engine, gasoline engine, electric motors and steam pump. Assistant Professor MORDOFF and Messrs. HODGES and HEAD.

110. **Elementary Surveying.** Freshmen. (Primarily for C.E. students.) Either term as assigned. Credit three hours. Use of steel tape, level and transit; fundamental surveying methods; measurement of lines, angles, and differences of elevation; land surveying, areas and plotting. Recitations, field work, computations, and mapping. Text-book: Breed and Hosmer's *Elementary Surveying.* First term, one recitation and two field or computation periods a week; Second term, three recitations a week for the first six weeks and three field or computation periods a week for the remainder of the term. Professor UNDERWOOD and Assistant Professor LAWRENCE. *Lincoln Hall.*

111. **Elementary Surveying** (M.E. and E.E. students). Freshmen. Either term as assigned. Credit two hours. Use of steel tape, level and transit; funda-

mental surveying methods, measurement of lines, angles and differences of elevations; land surveying. Recitations, field work and computations. Textbook: Breed and Hosmer's *Elementary Surveying*. First term, two recitations or two field or computation periods a week. Second term, two recitations a week during the first half of the term, and two field or computation periods a week during the remainder of the term. Professor UNDERWOOD and Assistant Professor LAWRENCE, Mr. SPRY. *Lincoln Hall.*

120. **Descriptive Geometry** (M.E. and E.E. students). First term. Prerequisite to course 121. One recitation and 2 two and one-half hour drawing periods a week. Instruction and drill in the use of drawing room equipment, lettering and the following essentials of descriptive geometry: the description of points, lines, planes and solids; the description of in-space relations of points, lines, planes and solids, including intersections and tangents; the graphic computation of linear and angular measurements; the development of surfaces. Professor TOWNSEND, Assistant Professor CLEARY, and Instructors. *East Sibley.*

121. **Mechanical Working Drawing** (M.E. and E.E. students). Second term. Prerequisite course 120. One recitation and 2 two and one-half hour drawing periods a week. This course includes: the purposes of working drawings; the principles of planning drawings to meet their purposes; execution of planning sketches, drawings, tracings, bills of material, drawing lists, etc. Professor TOWNSEND, Assistant Professor CLEARY, and Instructors. *East Sibley.*

125. **Drawing.** This course is given in the College of Engineering, but is designed only for students registered as candidates for the degrees of Bachelor of Chemistry and the degree in Chemical Engineering. First term. Credit three hours. One recitation and two two and one-half hour drawing periods a week. Lettering, machine sketching, working drawings including conventions, tracing, isometric projection, etc. Professor TOWNSEND and Instructors. *East Sibley.*

130. **Introductory Lectures.** Freshmen. Credit one hour. One lecture a week. This course of lectures is designed to introduce the first-year men to the various fields of engineering, and to demonstrate to them some of the simpler and more general methods of engineering construction. It is the purpose of the lectures to awaken the interest of the freshmen in their chosen profession through the aid of vivid description, of stimulating biography, and of personal experience. *Lecture room to be assigned in the fall.*

200. **Drawing** (C.E. students). First term. Credit three hours. Use of instruments, free-hand lettering, titles, geometrical problems, simple projections, tracing. Professor PARSON and Assistant Professor PERRY.

201. **Drawing** (C.E. students). Second term. Credit three hours. Projections and intersections of solids, practical problems, orthographic projection with sections, use of different scales, scale drawings, conventional signs, isometric drawing, line shading, topographic signs for mapping. Professor PARSON and Assistant Professor PERRY.

HYGIENE

REQUIRED COURSES

1. **Hygiene.** First term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Assistant Professors GOULD, SHOWACRE, YORK, and Doctors HOOD, ROBINSON, and TEAGARDEN.

Sections for women: Assistant Professor EVANS, Doctors CUYKENDALL and STELLE.

2. **Hygiene.** Second term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Assistant Professors GOULD, SHOWACRE, YORK, and Doctors HOOD, ROBINSON, and TEAGARDEN.

Sections for women: Assistant Professor EVANS, Doctors CUYKENDALL and STELLE.

ELECTIVE COURSES FOR ALL STUDENTS

3. **Health Supervision of School Children.** Second term. Credit two hours. Assistant Professor GOULD. T Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. (Not given in 1936.)

A practical course of lectures and demonstrations designed to familiarize the student with the facts and methods necessary for making an effective health supervision of school children. Prerequisites suggested but not demanded: Human Physiology and Anatomy. Open to sophomores, juniors, and seniors.

4. **Advanced First Aid.** First and second term. Credit one hour. Assistant Professor SHOWACRE. First term: Anatomy lecture room, *Stimson*, F 9. Second term: S 9, Anatomy lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

This course will include a discussion and practical demonstration of the main methods at hand for preventing accidents and for giving emergency treatment.

5. **Industrial Hygiene.** First term. Credit one hour. Assistant Professor GOULD. Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

Factory sanitation, ventilation, and illumination; occupational poisoning and disease; factory legislation; accident prevention; fatigue in industry; preventive medicine in the industries.

6. **School Hygiene.** Professor YOUNG. See Physical Education 24.

7. **Rural Hygiene.** Second term. Credit one hour. Professor SMILEY. W 12. Anatomy lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2. Not given in 1935 or 1936.

A general consideration of the health problems peculiar to rural areas with the presentation of practical schemes for the solution of these problems as far as possible.

8. **Mental Hygiene.** First term. Repeated in second term. Credit two hours. Section 1, Histology lecture room, *Stimson*, M F 11; Section 2, Histology lecture room, *Stimson*, W F 2. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2. Doctors W. H. YORK and RUTH STELLE.

A study of the factors involved in the growth and maintenance of mental health: i. e., satisfactory human relationships, attitudes, and behavior. Discussion of the causes and mechanisms underlying the more common personality deviations.

SCHOOL OF CIVIL ENGINEERING

OUTLINE OF THE INSTRUCTION

The object of the instruction is to impart knowledge of fundamental principles of the design and behavior of structures and works met in Civil Engineering. Emphasis is placed upon engineering as an applied science rather than as a vocational technique.

The instruction in Mathematics, Chemistry, Physics, Geology, Economics, Psychology, English, and the languages is given in the College of Arts and Sciences; and all other regular subjects in the course are of an engineering nature and are given in the School of Civil Engineering, or in the Schools of Mechanical Engineering or Electrical Engineering.

The following is a brief outline of the scope and purposes of instruction in various departments of the School of Civil Engineering:

1. Surveying

An important branch of Civil Engineering is the making of surveys for the accurate location of properties, for the purpose of mapping, and for the control of engineering works. Instruction is given in this department in the use of surveying instruments, in precise leveling and measuring, and in making topographic, hydrographic, subterranean and geodetic surveys. The student is taught the elements of field astronomy, and makes astronomical observations in relation to survey control. Instruction is given in the principles and present practices in photographic and aerial surveying.

An important feature of instruction in this department is the work done by all students in the School at the Summer Survey Camp near Cayuta Lake, New York. Field practice is here given in triangulation and precise leveling and their control. Railroad and highway location surveying is also conducted by the students. They become familiar with field organization, and hold the various positions in field and office parties.

2. Mechanics of Materials

In this department classroom and laboratory instruction is given to the student in the principles of mechanics as the fundamental basis for the design of engineering structures and works. An important feature of instruction in this department is the work done by the student in the laboratory, where he obtains experience in dynamical actions and in the behavior of structural members under load. Demonstration and verification of the behaviors studied in the classroom are here developed.

Opportunity is afforded the advanced student in mechanics for analytical and experimental work in the theory of elasticity, in photoelasticity, in the application of analogies and the use of models as they apply to engineering analysis and design.

3. Materials of Construction

The purpose of the work in this department is to acquaint the student with the processes of manufacture of the materials of construction, and the properties of these materials which are important in their behavior in engineering structures. In the laboratory the student is afforded opportunity for experience in the actual behavior of materials under load and other service conditions. It is not the purpose of this instruction to develop laboratory technicians, but rather to provide the student with physical experience and concepts of the behavior of materials of engineering.

4. Hydraulic Engineering

The work in this department begins with the fundamental behavior of fluids and continues into the design and operation of hydraulic works. In the Hydraulic Laboratory the student is instructed in the principles of hydraulic flow and measurement. The advanced student is afforded opportunity for study in hydrodynamics, experimental study in channel flow, pipe lines, weirs, spillways, and other hydraulic units.

In Water Power Engineering the student is given instruction in the methods of developing hydraulic power, the principles underlying the design and use of hydraulic machines, and in hydroelectric development.

Instruction is given to the student in the development of public water supplies and the principles of water purification. Instruction is also afforded the student in reclamation, canalization, and river and harbor development.

5. Municipal and Sanitary Engineering

The object of the instruction in this department is to provide the student with the principles underlying sewer systems, the treatment of sewage, water supply and distribution, purification of water and the operation of sanitary works. Fundamental instruction in classroom and laboratory is given in sanitary biology underlying the biological processes utilized in the purification of water and the treatment of sewage.

6. Transportation Engineering

The work in this department relates to the location, construction, operation, maintenance, and economics of various agencies of transportation. Instruction begins in the economic location and construction of railways and highways. It continues with study covering maintenance-of-way and the operation and management of railroads and highways.

A feature of the work in highway engineering is the laboratory instruction giving students experience in the study and testing of soils of highway subgrades, and in the testing of materials used in road construction.

7. Structural Engineering

In this department the student receives instruction in the design of bridges, buildings, and other structures of timber, masonry, concrete, steel, and other materials. Instruction is also offered in more advanced forms of bridge and building design and in the principles underlying their analysis. The student is also given instruction in the principles and methods involved in foundation work for bridges, buildings, and other land and waterfront structures.

8. Regional and City Planning

Instruction in Regional Planning is given by the Colleges of Engineering and Architecture in cooperation. The work does not recognize Regional or Town Planning as a separate profession, and hence no attempt is made to give the student technical proficiency in planning, nor even any large array of factual information. The courses deal in a broad way with the adaptation of man's environment to suit his needs and desires. A study is made of past and possible future achievement in the field of planned and controlled developments of public and private properties as the necessary basis for better living.

Emphasis is placed on the fact that historically and logically, the problems presented by large scale planning are so difficult that no one professional group is competent to comprehend them, much less to solve them. It is shown that actual achievement must finally rest on the united efforts of groups composed of people of diverse interests and widely varying training. The courses offered are therefore open to upperclassmen and graduates in all colleges of the University.

9. Administrative Engineering in the School of Civil Engineering

The large number of Civil Engineering graduates who hold executive administrative positions is evidence of the usefulness of such a training for these positions. Engineering methods are finding increased application in problems of executive management. This is due in part to the increasing scientific development underlying the operation of works and processes, and in part to the nature of the training of the engineer in fact gathering and analytical study.

In order to strengthen the instruction in the economic, financial, legal, and functional aspects of business without at the same time sacrificing the fundamental instruction of civil engineering in its various branches, the School of Civil Engineering offers a four-year course in Administrative Engineering leading to the degree of B.S. in Administrative Engineering.

The opportunities in the field of administration for one trained as a civil engineer have been rapidly increasing in recent years. Railroad and public utility operation and management, highway ad-

ministration, the broad field of construction, the operation and maintenance of public works, transit systems, river and harbor facilities, power developments, reclamation and conservation works, city and regional planning, and city management, offer large and rapidly growing fields of administrative service for the civil engineer.

This training would also be useful in such business-engineering fields as sales engineering, purchasing, efficiency engineering, promotion, appraisal and valuation work, statistical and economic studies as related to construction, and the work of municipal, state, and federal officials.

Engineering Research

The instructing staffs, laboratories, libraries, and other facilities of the various departments of the College of Engineering and those of the other departments of the University are available for graduate and undergraduate students desiring to pursue original study and research in engineering and allied fields. (For description of the laboratories, libraries, and other facilities in Engineering, see pages 34–46 of this pamphlet. For discussion of graduate research in Engineering, see the Announcement of the Engineering Division of the Graduate School, beginning on p. 131 following.)

Undergraduates who have shown the requisite proficiency and have available the necessary time may have opportunity to conduct special investigations under expert guidance. Such special work may consist of an analytical study or discussion of data, reports and other engineering information already available, or it may be devoted to a design or construction or both of technical importance, or it may be an original investigation—analytical or experimental or both. In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a thesis.

A limited number of seniors who have shown special ability for investigation may substitute research for some of the usual senior electives. See course 297.

Arrangements for research and thesis should be made with the Director of the School and the department concerned, preferably during the junior year.

Opportunities for Professional Development

During the year non-resident lecturers are heard by the students on technical and professional subjects. The Ithaca Section of the American Society of Civil Engineers meets frequently and the students have an opportunity to participate in these meetings. There is also a Student Chapter of the American Society of Civil Engineers operated by the students themselves. The *Cornell Engineer*, a technical journal appearing monthly through the school year, is managed and edited by students in the College.

COURSES LEADING TO THE DEGREE OF CIVIL ENGINEER

The curricula offered by the School of Civil Engineering leading to the degree of Civil Engineer are planned to provide fundamental instruction necessary for the practice of the profession. They all contain training in those subjects which the Faculty considers essential. Great latitude is given to provide for liberalization in the regular course, while a series of optional curricula are offered as a guide to those who have the desire to add further to their fundamental preparation in any of the several branches of civil engineering. All of these technical optional curricula have a common background of technical courses paralleling those of the regular course; so that a student electing to follow one of the technical options will be as well prepared in the other branches of civil engineering as he would had he taken the regular course.

With the single exception of the Sanitary Engineering Option, it will be found that a student may defer electing to follow one of the options until the beginning of the Junior Year. Even in the case of the Sanitary Engineering Option, it would be possible to make up the two courses in Zoology and Chemistry, after beginning the Junior Year, provided the student's record is sufficiently high to justify the additional load. The same sequence of dependent courses must be followed.

Students, desiring to specialize in a field requiring it, may, subject to the approval of their class adviser, defer certain courses of the junior year not fundamental or prerequisite to the senior work until the senior year in order to take elective or required courses of the senior year in the junior year. A student may not, however, anticipate the work of the curriculum by more than one year.

1. THE REGULAR FOUR-YEAR COURSE

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220	5	0
Mechanics Laboratory 220A	2	0
Mechanics 221	0	4
Mechanics Laboratory 221A	0	1
Engineering Construction 264	3 or 0	0 or 3
English 23	0 or 3	3 or 0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Introduction to Economics 3	3	0
Materials 225	0	3
Materials Laboratory 226	0	3
Hydraulics 240	4	0
Municipal Sanitation 252	0	4
Engineering Management 293	3	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Concrete Construction 280	0 or 3	3 or 0
Foundations 281	3 or 0	0 or 3
Total number of hours each term	17	16

SENIOR YEAR

Heat-Power Engineering 3P43	3	0
Essentials of Electrical Engineering 417	0	4
Engineering Problems 223	0	2
Water Supply 230	0	3
Highway Engineering 265	3	0
Engineering Law 290	3	0
Elective*	9	9
Total number of hours each term	18	18

*Of the elective hours, at least six must be taken in the School of Civil Engineering. The elective courses taken outside the School of Civil Engineering must be selected from among those not open to freshmen, unless the course selected has the special approval of the class adviser.

Not more than four hours credit in Advanced Military Science and Tactics will be accepted toward meeting the requirements for the C.E. degree.

2. ADMINISTRATIVE OPTION

To meet the needs of those students who, while primarily interested in Civil Engineering, still wish to get a more thorough training in Business Management and Administrative Engineering courses, the following option leading to the degree of Civil Engineer is offered:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Public Speaking 1	3 or 0	0 or 3
Economics 3	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 23	0 or 3	3 or 0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Elementary Accounting 3A31	3	0
Corporation Finance 3A34	0	3
Materials 225	3	0
Materials Lab. 226	3	0
Concrete 280	3	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Hydraulics 240	0	4
Engineering Management 293	0	3
Engineering Geology 501	0	3
Total number of hours each term	16	16

SENIOR YEAR

Money or Banking, Economics 11	0	3
Cost Accounting 293-B	0	3
Engineering Law 290	3	0
Municipal Sanitation 252	4	0
Engineering Problems 223	2	0
Water Supply 230	3	0
Highway Engineering 265	0	3
Heat Power 3P43	0	3
Electrical Engineering 417	4	0
Foundations 281	0	3
Electives*	3	3
Total number of hours each term	19	18

*Any of the following courses may be taken profitably as an elective: Industrial Combinations, Ec. 32; Public Utilities, Ec. 33; Transportation, 269; Valuation Engineering, C.E. 295; Municipal Government, C.E. 256.

3. SANITARY ENGINEERING OPTION

To meet the needs of those students who desire to strengthen their training for work in Sanitary Engineering, by the addition of courses in Zoology, Biology, Bacteriology, Chemistry and Physics, the following four-year course leading to the degree of Civil Engineer is offered:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Engineering Geology 501	0	3
Zoology	2	0
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Chemistry	0	3
English 23	0	3
Engineering Construction 264	3	0
Economics 3	3	0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Physics of Soil Phenomena 431	3	0
Soil Mechanics 287	0	3
Materials 225	3	0
Materials Laboratory 226	0	3
Hydraulics 240	4	0
Municipal Sanitation 252	0	4
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Concrete Construction 280	0	3
Bacteriology	3	0
Total number of hours each term	17	16

SENIOR YEAR

Prime Movers	0	3
Public Speaking 1	3	0
Water Supply 230	3	0
Highway Engineering 265	0	3
Engineering Law 290	0	3
Sewage Works 254	3	0
Sanitary Biology 251	3	0
Treatment of Wastes 255	3	0
Water Purification 253	0	3
Public Health	0	3
Ventilation of Sewage Works	0	3
Electives	3	0
Total number of hours each term	18	18

4. STRUCTURAL ENGINEERING OPTION

To meet the needs of those students who wish to prepare more thoroughly for Structural Engineering, by the addition of Mathematics, Physics, Soil Mechanics, Advanced Mechanics and Advanced Structural Theory and Practice, the following four-year course leading to the degree of Civil Engineer is offered:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Engineering Geology 501	0	3
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
English 23	0	3
Engineering Construction 264	3	0
Public Speaking 1	3	0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Economics 3	0	3
Materials 225	3	0
Materials Laboratory 226	3	0
Hydraulics 240	0	4
Advanced Mechanics 222	0	3
Stress Analysis and Structural Design 270	4	0
Structural Design	0	3
Concrete Construction 280	3	0
Physics of Soil Phenomena 431	3	0
Soil Mechanics 287	0	3
Total number of hours each term	16	16

SENIOR YEAR

Prime Movers	0	3
Municipal Sanitation 252	4	0
Water Supply 230	0	3
Highway Engineering 265	0	3
Engineering Law 290	3	0
Advanced Structural Analysis 272	3	0
Fixed Arches 283	3	0
Engineering Mathematics 224A	3	0
Highway Bridges (274 or 284)	0	3
Concrete Design 280	3	0
Foundations 281	0	3
Elective	0	3
Total number of hours each term	19	18

5. HYDRAULIC ENGINEERING OPTION

To meet the needs of those students who desire more thorough preparation in Hydraulic Power Engineering, Hydraulic Construction, Hydraulic Conservation or Irrigation, and Experimental Hydraulics, the following four-year course leading to the degree of Civil Engineer is offered:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 23	0 or 3	3 or 0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Hydraulics 240	4	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Municipal Sanitation 252	0	4
Economics 3	0	3
Materials 225	3	0
Materials Laboratory 226	3	0
Concrete Construction 280	0	3
Physics of Soil Phenomena 431	3	0
Soil Mechanics 287	0	3
Total number of hours each term	17	16

SENIOR YEAR

Heat Power Engineering 3P43	3	0
Essentials of Electrical Engineering 417	0	4
Water Supply 230	3	0
Engineering Law 290	3	0
Highway Engineering 265	0	3
Foundations 281	0	3
Hydraulic Measurements 242	3	0
Hydraulic Construction 231	0	3
Hydraulic Group Options*	3	3
Electives	3	3
Total number of hours each term	18	19

*From Courses Water Power 232, Hydraulic Engineering 233, Conservancy and Reclamation Problems 234, Engineering Mathematics 224-A, Hydrodynamics, Physics 600, Advanced Hydraulics 241, Hydraulic Engineering Design 291(c), Hydraulics Research 297(c), Thesis 298.

6. TRANSPORTATION ENGINEERING

This Option, leading to the degree of Civil Engineer, is offered for those students who desire to prepare more thoroughly for Highway or Railroad Engineering through a further study of the technical economic principles underlying them:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 23	0 or 3	3 or 0
Total number of hours either term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Economics 3	3	0
Materials 225	0	3
Materials Laboratory 226	0	3
Hydraulics 240	4	0
Structural Analysis and Design 270, 271	4	3
Concrete Construction 280	0	3
Physics of Soil Phenomena 431	3	0
Soil Mechanics 287	0	3
Route Location	0	3
Engineering Management 293	3	0
Total number of hours either term	17	18

SENIOR YEAR

Prime Movers	0	3
Engineering Problems 223	0	2
Engineering Law 290	3	0
Transportation 269	3	0
Engineering Design 291(e) or 291(g)	3	0
Valuation Engineering 295	0	3
Highway Engineering 265	3	0
Highway Laboratory 266 *or* Railroad Maintenance of Way 261	3	0
Advanced Highway Engineering 267 *or* Railroad Operation and Management	0	3
Municipal Sanitation 252-A	3	0
Water Supply 230	0	3
Electives	0	3
Total number of hours each term	18	17

7. GEODETIC ENGINEERING

To those students who desire further preparation in Geodesy and Advanced Surveying the following four-year curriculum leading to the degree of Civil Engineer is offered:

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 203	2	0
Descriptive Geometry 204	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 23	0 or 3	3 or 0
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Economics 3	3	0
Materials 225	0	3
Materials Laboratory 226	0	3
Hydraulics 240	4	0
Municipal Sanitation	0	4
Engineering Management 293	3	0
Structural Analysis and Design 270, 271	4	3
Concrete Construction 280	0	3
Mapping 214	2	0
Topographic Surveying 214-A	1	0
Total number of hours each term	17	16

SENIOR YEAR

Heat Power Engineering 3P43	3	0
Essentials of Electrical Engineering 417	0	4
Engineering Problems 223	0	2
Water Supply 230	0	3
Highway Engineering 265	3	0
Engineering Law 290	3	0
Adjustment of Observations 215, 216	3	0
Geodesy and Geodetic Laboratory 218	3	0
Photographic and Aerial Surveying 219	0	3
Foundations 281	0	3
Elective	3	3
Total number of hours each term	18	18

A Six-Year Course Leading to the Degrees of A.B. and C.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Civil Engineering before beginning his fifth year. By attending two Summer Sessions, this combined course may be completed in five years. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Civil Engineering.

A Four-Year Course in Administrative Engineering Leading to the Degree of B.S. in A.E. With Special Reference to Civil Engineering

The requirements for admission to this Course are the same as for the regular four-year C.E. Course; see page 22.

FRESHMAN YEAR

See schedule on page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Economics 3	3	0
Public Speaking 1	0	3
Business and Industrial Management 3A23	0	4
Mechanics 220, 221	5	4
Engineering Construction 264	3	0
English 23	3	0
Engineering Geology 501	0	3
Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Drawing 202, 203	1	2
Total number of hours each term	18	19
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Economics 11, Money and Banking	3	0
Elementary Accounting 3A31	3	0
Corporation Finance 3A34	0	3
Engineering Management 293A	0	3
Psychology 16	0	3
Economics 41, Labor Conditions and Problems	3	0
Materials 225	3	0
Materials Laboratory 226A	2	0
Hydraulics 240A	0	3
Structural Analysis 270A	2	0
Structural Design 271	0	3
Concrete Construction 280	3	0
Foundations 281	0	3
Total number of hours each term	18	17

SENIOR YEAR	Hours 1st Term	2nd Term
Engineering Law 290	3	0
Adv. Engineering Law 290A	0	3
Transportation 269	0	3
Valuation Engineering 295	0	3
Cost Accounting 293B	0	3
Engineering Problems 223	2	0
Municipal Sanitation 252A	3	0
Water Supply 230	3	0
Highway Engineering 265	3	0
Power and Prime Movers	0	3
Electives	3	3
Total number of hours each term	17	18

A Five-Year Course Leading to the Degrees of C.E. and B.S. in A.E.

It is possible so to arrange the work of a five-year course that the C.E. degree may be obtained at the end of the first four years and the B.S. in A.E. degree at the end of the fifth year. Declaration of intention to take the five-year C.E.-A.E. curriculum should be made at the beginning of the second year.

DESCRIPTION OF THE COURSES OF INSTRUCTION

The courses in the following list are designed for sophomores, juniors, and seniors. Those courses which are designed for freshmen are described under the head THE FRESHMAN YEAR, page 49. The following courses in Geology, Economics, English, Physics, Psychology, and Public Speaking are given in the College of Arts and Sciences.

GEOLOGY

501. **Engineering Geology.** Required of Sophomores in Civil Engineering. Either term as assigned. Credit three hours. Registration by special permission. Lectures and laboratory work. The practical application of geologic principles and the occurrence of such economic materials as are of importance to engineering students, the whole subject being treated with reference to their needs. *McGraw Hall.* Professor RIES.

ECONOMICS

3. **Introduction to Economics.** Repeated in second term. Credit three hours, A survey of the existing economic order, its more salient and basic characteristics, and its operation. Assistant Professor O'LEARY.

11. **Money and Banking.** Repeated in second term. Credit three hours. Prerequisite, Economics 1 or its equivalent. Professor REED. *Goldwin Smith* C. A study of the history and the theory of money and banking.

41. **Labor Conditions and Problems.** First term. Credit three hours. Prerequisite, Economics 1 or its equivalent. Assistant Professor MONTGOMERY. M W F 9. *Goldwin Smith* 256.

An introduction to the field of Labor Economics and a survey of the more basic labor problems growing out of modern economic arrangements.

3A34. **Corporation Finance.** Second term. Credit three hours. Prerequisite course 3A31.

A study of the financial problems of the business corporation from the points of view of the management, the investor, and the public. Assistant Professor O'LEARY.

ENGLISH

23. **Composition and Readings in Science.** Either term. Credit three hours. For second-year students in the School of Civil Engineering. Writing from experience and from prose models of scientists and engineers to develop clearness and exactness in observation and expression. Mr. WILSON.

PHYSICS

431. **Physics of Soil Phenomena.** First term. Credit three hours. Prerequisite, Physics 11, and 12 and course work covering Calculus and Mechanics. Two lectures and one laboratory or problem period a week. Professor MURDOCK and Dr. BARNES. *Rockefeller.*

Surface phenomena at fluid-fluid and fluid-solid interfaces; viscous flow in porous materials; theory of solutions, osomitic pressure, electrolytes, colloids, gels; capillary potential and hysteresis in finely divided material. Primarily designed for students of Civil Engineering.

PSYCHOLOGY

16. **Applications of Psychology.** Second term. Credit three hours. Assistant Professor JENKINS. *Goldwin Smith* A.

A critical review of the attempts to apply psychological facts and methods to the solution of technological problems.

PUBLIC SPEAKING

1. **Public Speaking.** Either term. Credit three hours. *Goldwin Smith* 24. Designed to give the student the fundamentals of speech preparation and to help him acquire a simple, direct manner of speaking. Original speeches and interpretation of selections. Professor DRUMMOND.

MECHANICAL ENGINEERING

3A23. **Business and Industrial Management.** Second term. Credit four hours. Required of all sophomores in Administrative Engineering. Four lecture-discussion periods a week with regularly assigned problems.

This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business and industrial ownership, together with the functions of finance, control, machine production, personnel and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study, wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Professor BANGS.

3A31. **Accounting for Engineers.** Second term, required of A.E. sophomores. Credit three hours. Two recitations and one 2½-hour computing period a week. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; budgetary control; modern mechanical methods of performing the accounting function. Mr. MILLARD and others.

3P43. **Heat-Power Engineering.** Required of all seniors in Civil Engineering. For a description of this course see page 84 of this Announcement.

ELECTRICAL ENGINEERING

417. **Essentials of Electrical Engineering.** Either term. Required of all seniors in Civil Engineering. For description of this course see page 127 of this Announcement.

ASTRONOMY

182. **The Elements of Field Astronomy.** Either term. Credit two hours. Prerequisites, Astronomy 180, and Mathematics 3 or Surveying 110. Required of students in Civil Engineering. For hours and rooms see Schedule of Courses, Sections and Rooms for School of Civil Engineering. Professor BOOTHROYD and Mr. PENDLETON.

186. **Geodetic Astronomy.** Throughout the year. Credit three hours. Prerequisites, Astronomy 182, Astronomy 181, or Advanced Surveying 212 and Mathematics 4a and 4b or equivalents. This course is given in alternate years. Professor BOOTHROYD.

DESCRIPTIVE GEOMETRY AND DRAWING

200 and 201. **Drawing.** Freshmen. Credit three hours each term. See page 51.

202. **Drawing.** Sophomores in Administrative Engineering. First term. Credit one hour. A study of the representation lines, planes, surfaces, and solids, with practical applications. Professor PARSON.

203. **Drawing.** Sophomores. First term C.E. students; second term Administrative Engineering students.

Credit two hours. Lettering, with practice in forming letters and combining them into appropriate titles; projections and intersections of practical problems. Practice with water colors in rendering of flat or curved surfaces, and in the use of crayon, rendering in sepia, as applied to stone and concrete bridges. Professor PARSON.

204. **Descriptive Geometry.** Sophomores. Either term. Credit three hours. Instruction and drill in the fundamental conceptions of descriptive geometry

including orthographic projection and representation of the point, line, and plane. A study of the sections, developments, and intersections of surfaces and solids with applications in practical problems. Assistant Professor JENKINS.

205. **Advanced Drawing.** Elective. Juniors and seniors. Second term. Credit three hours. Perspective drawings, rendered in pencil, ink, and washes, of architectural buildings (exterior and interior), concrete bridges, dams, and other engineering works; building details of window frames, doors, cornices, molding, stairs, and other simple details, to give the student some insight into detailing parts of plans, and to familiarize him with reading working drawings; engineering drawings, rendered in crayon and color, to enable the student to supplement ordinary working drawings with artistic representations so portrayed as to be readily intelligible to non-technical committees, etc. Professor PARSON.

SURVEYING

110. **Elementary Surveying.** Freshmen. Either term. Credit three hours. See page 50.

211. **Advanced Surveying.** Sophomores. First term. Credit three hours. Prerequisite course 110. City and mine surveying; surveys of the United States Public Lands; rectangular coordinate systems for cities and states; earth volumes. Topographic, hydrographic, and geodetic surveying; transit and stadia and plane table surveys; sextant; soundings; triangulation; base lines; precise and trigonometric leveling; elements of photographic surveying; map projections. Lectures, recitations, and problems, three class periods a week. Professor UNDERWOOD and Assistant Professor LAWRENCE.

212. **Advanced Surveying.** For students in Landscape Architecture. Second term. Credit three hours. Prerequisite course 110. Topographic surveying; transit and stadia methods; plane table; triangulation; circular curves, vertical curves; profile leveling; cross-sectioning; precise taping; photographic surveying; earthwork computations. Recitations and field work. Textbook: Breed and Hosmer's *Elementary Surveying*, Vol. I. Assistant Professor LAWRENCE.

213. **Summer Survey: Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores. (Attendance for five weeks is required for 213 and 260-A, four weeks for 213 and one week for 260-A.) Credit four hours. Date of beginning to be announced in second term. Prerequisite course 212. Practical experience in surveying under field conditions. An extensive topographic survey with the transit and stadia and the plane table, and a hydrographic survey of a portion of Cayuta Lake are executed, and field maps are made. Triangulation and precise leveling control the topographic and hydrographic work. A base line is measured with invar tapes. Solar observations for azimuth and time are made and results computed. Each student takes part in all branches of the work. Field and office work six days a week. Professors UNDERWOOD and BOOTHROYD, Assistant Professors LAWRENCE, PERRY, THATCHER, and Mr. SPRY.

214. **Mapping.** Elective. Upperclassmen. First term. Credit two hours. The construction of a final topographic map of the area covered by the field work of Course 213 during the preceding summer. The field sheets are combined for this purpose, reduced in scale from 1:4800 to 1:12000, and reproduced, using the triangulation system as a base for the work. Lectures and drawing. Professor UNDERWOOD.

214-A. **Topographic Surveying.** Primarily for students taking the Geodetic Engineering Option; elective for others. Prerequisite courses 211 and 213. First term. Credit one hour. Methods of making topographic surveys for mapping to a large scale. The use of the plane table in such surveys. Solutions of the three-point problem; two-point problem; location of details by direction and distance. Field work and mapping. One field or drawing period a week. Professor UNDERWOOD.

215. **Problems in the Adjustment of Observations.** Elective. Upperclassmen. Second term. Credit one hour. Prerequisite course 213. A series of examples in the adjustment of typical surveying work such as leveling, direct measurement of

lines and angles, and simple triangulation figures, using the method of least squares. Lectures and problems. Professor UNDERWOOD.

216. **Least Squares: Adjustment of Observations.** Elective. Second term. Credit two hours. Prerequisites, Calculus and Physics. Lectures and recitations. The course is designed for students who have experimental investigations in view. Applications are made to problems in physics, astronomy, mechanics, hydraulics, surveying, etc., with some attention given to the derivation of empirical formulae. Two hours a week, as may be arranged. Professor UNDERWOOD.

217. **Advanced Topographic Surveying.** Elective. Upperclassmen. Second term. Credit two hours. Prerequisite course 213. Economics of surveying methods. Surveys for special purposes such as extensive construction work; storage and distribution of water for irrigation; earthwork on a large scale; lines of communication; topographic reconnaissance, etc.; photographic surveying. Lectures, recitations, and assigned readings. Two hours a week. Professor UNDERWOOD.

218. **Geodesy and Geodetic Laboratory.** Elective. Upperclassmen. First term. Credit three hours. Prerequisite courses 182 and 212. A course for the consideration of special problems in geodetic work. Precise leveling; deflection of the plumb line; figure of the earth; use and investigation of geodetic instruments and apparatus such as circles, levels, micrometer microscopes, standards of length, thermometers, pendulums, magnetic apparatus, etc. Subject to arrangement to meet the special needs of students. Lectures, reading, discussions, and laboratory work. Three periods a week. Professor BOOTHROYD.

219. **Photographic and Aerial Surveying.** Elective. Upperclassmen. Second term. Credit three hours. Prerequisite, Advanced Surveying, Course 212 or Course 211-A. The principles of photographic surveying; surveys with camera stations on the ground, including stereoscopic methods; aerial surveys and the making of maps from such surveys; ground control. Recitations, lectures, and collateral reading. Three hours a week. Professor UNDERWOOD.

MECHANICS OF ENGINEERING

220. **Mechanics of Engineering.** Sophomores. First term. Credit five hours. Repeated in one section, second term. Prerequisite course, Mathematics 5b. (See Course 220-A below.) Statics of a material point and of rigid bodies and structures by algebraic and by graphic methods of analysis; chains and cords; centers of gravity; movements of inertia; kinetics and dynamics of a material particle; centrifugal and centripetal forces; dynamics of collections of material particles forming rigid bodies; pendulums; friction, work, power, measurement of power; the general theorem of work and energy applied to collections of rigid members forming machines; impact, impulse and momentum. Five recitations a week. Emphasis is placed upon the theory as well as upon the use of consistent units and correct numerical work. Facility in the use of the slide rule is essential. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

220-A. **Mechanics Laboratory.** Sophomores. First term. Credit two hours. One two and one-half hour period in the laboratory together with a write-up period of equal length outside. Courses 220 and 220-A are closely correlated and must be taken concurrently. This course consists of experiments (both qualitative and quantitative) designed to illustrate the principles of mechanics covered in Course 220. In general, the experiments are performed by the students themselves, and a complete, well-arranged report on each experiment is required of each student. Instruction in the use of the slide-rule and of the planimeter is included in the work. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

221. **Mechanics of Engineering.** Sophomores. Second term. Credit four hours. Continuation of Mechanics 220. Prerequisite course, Mechanics 220. Mechanics of materials including stress and strain, tension, shearing, compression, torsion, flexure; elastic curves; safe loads; columns; flexure of beams by semi-graphic treatment. Review problems showing application of principles in Engi-

neering Design. Four recitations a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

221-A. **Mechanics Laboratory.** Credit one hour. One two-and-one-half hour period a week. Experiments designed to illustrate the principles of mechanics studied in Course 221. Courses 221 and 221-A are closely correlated and must be taken concurrently. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

222. **Advanced Mechanics.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite courses 220 and 221. Following a brief general review of fundamental topics in Mechanics of Materials, this course covers: induced stresses; torsion; unsymmetrical bending; torsion of prisms of non-circular section; hoops; flat plates; localized stresses; theory of least work; internal work and its derivatives. Recitations, three hours a week. Professors GEORGE and RETTGER.

223. **Engineering Problems.** Seniors. Either term. Credit two hours. Prerequisite courses 220, 221 and 240. The object of this course is to provide a review involving additional practice in using the principles and methods of applied mechanics. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports. Five hours a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

224-A. **Engineering Mathematics.** Primarily for graduate students. Prerequisite, Mathematics 5b. First term. Credit three hours. An elementary course in ordinary differential equations with applications to engineering problems. Hyperbolic functions, trigonometry, advanced calculus and advanced algebra are dealt with in so far as this is necessary for a clear understanding of the processes of differential equations. The purpose of this course is to lay the foundation for course 224-B. Professor RETTGER.

224-B. **Advanced Engineering Mathematics.** Second term. Credit three hours. Special emphasis is given to partial differential equations. Laplace's equation is derived and is applied to engineering problems. Vector analysis and complex variable in engineering problems. Professor RETTGER.

228. **Theory of Elasticity.** Primarily for graduate students. Second term. Credit, four hours. Prerequisite, 224-A. Theories of elastic breakdown. Fundamental relations of stress and strain; Airy stress function. Problems in two-dimensional and three-dimensional stress and strain. Analogies and their application to solutions of engineering problems in elasticity. Professors HOLLISTER and RETTGER.

229. **Experimental Elasticity.** Primarily for graduate students. Second term. Credit dependent upon approved work done. To be preceded or accompanied by Course 228. Experimental study in applications of the theory of elasticity to engineering problems. Investigations of stress concentrations and distributions by (a) photo-elastic analysis; (b) model analysis based upon the membrane, electrical, slab, or other analogies; (c) model tests. Professor HOLLISTER.

MATERIALS OF CONSTRUCTION

225. **Materials of Construction.** Juniors. Either term. Credit three hours. Prerequisite course 221. The materials studied are: Lime, cement, stone, brick, sand, timber, ores, cast iron, wrought iron, steel, and some of the minor metals and alloys. The chemical and physical properties, uses, methods of manufacture, methods of testing, and unit stresses of each material are considered, particular emphasis being laid on the points of importance to engineers. Three recitations a week. Textbook: Mill's *Materials of Construction*. Professor SCOFIELD and Mr. PENDLETON.

226. **Materials Laboratory.** Juniors. Either term. Credit three hours. Prerequisite course 221 and must be taken with or preceded by 280. Experimental determination of the properties of materials by mechanical tests. Study of testing

machines (their theory, construction, and manipulation); calibration of testing machines and apparatus; commercial tests of iron and steel; tensile, compressive, torsional, shearing, and flexure tests of metal and various woods with stress-strain observations; tests of cement, concrete aggregate, concrete, plain and reinforced, and of road material and paving brick. The course is planned to supplement Course 225 with its study of the properties of materials by the actual handling of the materials and by observations of their behavior under stress. Laboratory work five hours a week. Professor SCOFIELD and Mr. PENDLETON.

226-A. **Materials Laboratory.** Given especially for Juniors in Administrative Engineering. Either term. Credit two hours. Prerequisite Course 221 and must be taken with or preceded by Course 280. A brief course in the study of material testing technique and the properties of the more common materials of construction. Professor SCOFIELD and Mr. PENDLETON.

227. **Testing of Materials.** (Laboratory.) First term. Credit one hour. Given especially for students in the College of Architecture. A brief course in laboratory methods comprising test of beams and columns in steel, wood, and concrete. Professor SCOFIELD.

HYDRAULIC ENGINEERING

230. **Water Supply.** Seniors. Either term. Credit three hours. Prerequisite course 240. Three recitations a week from assigned texts and the working of assigned problems. About half of the term is devoted to the methods of making the preliminary investigations for a hydraulic development involving the use of a stream or the ground water; general hydrology; water resources of a basin; methods of systematic stream gaging; stream characteristics; working up data; use of mass curves in storage studies; percolating waters; probable dependable draft; flow into wells, etc. The second half of the term is devoted to a review of the methods of developing public water supplies from the several sources; typical structures; a study of the working conditions and fundamental data for designing conduits; distributing reservoirs; and a network of street mains; particular attention being given to the requirements for fire protection and the economics of pumped supplies. In the problems applications of the text are made to particular localities, the topographic maps of cities and drainage basins forming the bases of the problems. Students contemplating extensive election of courses in hydraulics should arrange to take this course the first term. Courses, 231, 232, and 233 are elaborations of details in this course. Professor SEERY.

231. **Hydraulic Construction.** Elective. Seniors and graduates. Second term. Credit three hours. This is a computing and designing course dealing with problems of water storage and the design and construction of dams by means of lengthy problems to be solved by graphical and analytical methods, and involving the economics of water storage at a given site, the design of a high masonry dam by Wegmann's Method and the tests for safety and stability of design, and the design of a weir dam of reinforced concrete and the analysis of stresses and stability. Professor SEERY.

232. **Water Power.** Elective. Seniors and graduates. Either term. Credit three hours. Three lectures and recitations a week and the working of three lengthy problems during the term. The subject matter of the course is to be found in the text used, Mead's *Water Power Engineering*, and covers the technique of hydraulic turbines, the analysis of test data, study of the adaption of turbine types to working conditions, unsteady flow and surging in long conduits, governing, and the analysis of the power available at a low head millsite. Professor SEERY.

233. **Hydraulic Engineering.** Elective. Seniors and graduates. Credit three hours. First term. Lectures, recitations and abstracting of references relating to soil technology and theory of percolating water, recent developments in the design and construction of earthen dams and levees; theory of design of gravity and arch masonry dams and distribution of stresses in such structures; spillway design; preparation of dam sites; construction methods and plants. Professor SEERY.

234. **Conservancy and Reclamation Problems.** Elective. Seniors and graduates. Credit three hours. Second term. Lectures, recitations and abstracting of references relating to flood flow estimates; planning for and designing of flood protection structures, irrigation and drainage works. The Miami Conservancy work will be the chief source of material for the course. Professor SEERY.

236. **Water Power and Pumping Plants.** Elective. Seniors and graduates. Second term. Three hours credit. This is a computing and designing course devoted to the problems of designing and detailing power and pumping plants. Prerequisites, courses 230 and 232. Professor SEERY.

THEORETICAL AND EXPERIMENTAL HYDRAULICS

240. **Hydraulics.** Juniors. First term. One section second term. Credit four hours. Prerequisite courses 220 and 221. Three recitations and one laboratory period a week; about one-quarter of the recitation periods are utilized for demonstration lectures. Hydrostatic pressure; manometers; strength of pipes; stability of dams; immersion and flotation; flow of liquids through orifices, nozzles, Venturi meters, and pipes, and over weirs; time required to empty tanks and reservoirs; simple, compound, branching and looping pipes; elementary power calculations in common pumping and fire protection problems; flow of water in open channels; pressure on stationary solids due to deviated flow. Elementary consideration of modern water wheels. Textbook: Schoder and Dawson's *Hydraulics*. Professors SCHODER and WALKER.

240-A. **Hydraulics.** Juniors in Administrative Engineering in Civil Engineering. Second term. Credit three hours. Prerequisite courses 220 and 221. Three recitations a week. About one-quarter of the recitation periods are utilized for experimental demonstrations. The topics covered are the same as stated under course 240, but there is no laboratory work. Professor SCHODER.

241. **Advanced Hydraulics.** Elective for seniors and graduates. Second term. Credit three hours. Prerequisite course 240. Lectures, recitations, and problems. Topics selected from the following list are taken up, subject to changes to suit group requirements: Stability of flotation; barometric levelling; flow over weirs and dams, free and submerged; backwater and non-uniform flow in open channels; the hydraulic jump; water hammer; surges in pipes and canals; viscous flow of fluids and flow of air in pipes; hydraulic similitude and flow in models; some introductory elements of hydrodynamics; impulse wheels and turbines; centrifugal pumps. Professor SCHODER.

242. **Hydraulic Measurements.** Elective for seniors and graduates. First term. Credit three hours. Prerequisite course 240. Three periods a week in laboratory or computing room. Experimental studies involving usually (as time permits): current meters and floats in canal or river; Pitot tubes in pipes; water meters; weirs; the hydraulic jump; special features of orifices, nozzles, Venturi meters, pipes; model studies; such other occasional experimental measurements as opportunity offers in the laboratory or in the neighborhood of Ithaca; the determination of efficiency, capacity, and characteristics of hydraulic machinery by tests. Professor SCHODER.

MUNICIPAL AND SANITARY ENGINEERING

250. **Sanitary Biology.** Elective. Juniors and seniors. Second term. Credit three hours. The course is designed to familiarize the student with current standard practice in the bacteriological control of water and sewage treatment plants. The use of the microscope; preparation of media; bacteriological analyses of water, sewage, sewage effluents and sewage sludge; efficiency of disinfectants; and that part of the science of bacteriology related to sanitary engineering. Textbook: Buchanan's *Household Bacteriology*. One recitation and two laboratory periods a week. Professor WALKER.

251. **Sanitary Biology.** Elective. Juniors and seniors. First term. Credit two hours. The collection and microscopical examination of the various forms of algae most prevalent in water supplies; the methods of their identification and control; and a study of the biological forms most prevalent in sewage wastes and sludges. Lectures, notes, and various references. One laboratory period a week. Professor WALKER.

252. **Municipal Sanitation.** Juniors. Second term. Credit four hours. Prerequisite course 240. Three recitations and one computing period a week. Sewer design and construction, and sewage disposal. Problems illustrating the matter taken up in the recitations such as problems on sewage flow, both domestic and storm water; hydraulic problems; construction problems dealing with various details of disposal plants. Textbook: Babbitt's *Sewerage and Sewage Disposal.* Four sections. Professors OGDEN and WALKER.

252-A. **Municipal Sanitation.** Required of seniors in Administrative Engineering and Transportation Engineering Option. Credit three hours. A shorter course covering a field similar to that of 252. Professors OGDEN and WALKER.

253. **Purification and Control of Water Supplies.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 230. Examination of water (physical, chemical, and bacteriological); normal quality of surface and subterranean waters, with effects of storage; communicable diseases and water supplies; epidemics of typhoid fever and cholera with studies of etiology, etc.; purification of water, sedimentation, and coagulation; slow sand filtration (theory, construction and operation, with examples); rapid sand filtration (theory, construction, and operation, with examples); miscellaneous purification processes (aeration, softening, iron removal, sterilization, distillation, and purification by chemicals). Professors OGDEN and WALKER.

254. **Sewerage Works.** Electives. Seniors and graduates. First term. Credit three hours. Prerequisite course 252. Three hours a week for fifteen weeks, divided between lectures and recitations. The work is upon the construction and operation of sewers and sewage disposal works, illustrated by lantern slides and by reference to recent descriptions of sewage-disposal plants in the current literature. There are, generally speaking, three recitations or one week's work on each of the following topics: disposal by dilution (salt and fresh water); chemical precipitation; broad irrigation, with special reference to institutions; natural and artificial filtration beds; sedimentation and septic tanks; Imhoff tanks; contact beds; sprinkling filters; and activated sludge. It is intended to differentiate this course from the junior work by making the latter chiefly a discussion of principles involved, while the senior course is a detailed investigation of the methods of construction with the reasons involved. Textbook: Metcalf and Eddy's *Sewage Disposal.* Professor OGDEN.

255. **Treatment of Wastes.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 252. The treatment of municipal and industrial wastes such as from garbage plants, tanneries, slaughter-houses, mines, canning factories, sugar factories, dye plants, pulp mills, creameries, cheese factories, milk bottling stations, and condensaries is considered.

Flow or process charts for each industry are used to show the general character, and composition of the wastes; and methods of treatment applicable, including results of experimental work, are considered. Professor WALKER.

256. **Municipal Engineering.** Elective. Seniors and graduates. First term. Credit three hours. A study of the relationships that exist between the practising municipal engineer and the various state and city commissions and other organizations with which he comes in contact. Financing of municipal operations including bond issues and sinking funds; special assessments; the limitations and restrictions placed by State Departments on municipal enterprises; town planning and public utilities; municipal housekeeping. Lectures, reports, and readings. Professor OGDEN.

257. **Purification of Water.** Elective. Graduates. Credit three hours. Specific problems in water purification; control of watersheds; effect of sedimentation on waters of different compositions; treatment of waters for particular require-

ments, such as removal of hardness, sediment, bacteria, etc. A report on some existing water system will be required from each student. Professor OGDEN.

258. **Conference on Present Methods of Sewage Disposal.** Elective. Graduates. Credit three hours. A critical study of the construction and operation of plants now in existence. Inspections and reports. Professor OGDEN.

259. **A Laboratory Course for Graduates.** Devoted to some special problem of sewage or water, such as the operation of a water-filtration plant, a sewage-disposal plant, the purification of trade wastes, the value of disinfection, etc. Professors OGDEN and WALKER.

TRANSPORTATION ENGINEERING

260-A. **Location Surveying.** Juniors. See Course 213. One week during summer vacation, opening date to be announced. Credit one hour. Each section is required to make complete preliminary and location surveys for a line two or three miles long. In this work the section is divided into level, transit, topography, and cross-section parties, as the different phases of the work are encountered. Finally structure and right of way surveys are made. The assignments of the men are changed every day so that each student receives practice in the various kinds of field work. Professor BARNES, Assistant Professors PERRY and THATCHER, and Mr. SPRY.

260-B. **Route Surveying and Drawing.** Juniors. Second term. Credit three hours. One recitation and two field or drawing periods a week. Prerequisite courses 213 and 260-A. The recitations cover the theory of simple, transition, and vertical curves, and earthwork computations; with applications to practical problems for purposes of illustration. The field periods take up about two-thirds of the term and are devoted to computing, laying out and checking simple, transition, and vertical curves. Each section is divided into parties of three so that each student obtains more individual instruction, more practice in handling instruments, and a more intimate knowledge of the problems than he would in larger parties. The drawing periods take up the remaining third of the term and in them each student makes a pencil map of the preliminary line surveyed by his section in 260-A and prepares a detailed "paper location" report based on these data. A tracing and profile of the final location as run in the field is then required, also a computation of part of the earthwork. Professors BARNES and CONWELL, Assistant Professors PERRY, CRANDALL, and THATCHER.

261. **Railroad Maintenance of Way.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 260-B. The subjects treated are track materials (with special reference to the section, method of manufacture and composition of steel rails, to the economics of tie preservation and the use of metal ties, and to the effect of quality of ballast upon maintenance); machine and other methods of grading for second track; drainage; track laying by both machine and hand methods; ballasting and bringing new track to line and grade; turnouts and switches; derailing switches; side tracks and yard tracks; sorting and terminal yards; track maintenance; track tools, work trains; action of car wheels on curves; widening of gage; double tracking; separation of grades; and improvement in grades and alinement. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

262. **Railroad Operation and Management.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 260-B. Under organization the following subjects are treated: general principles underlying organization and the effect of each on efficiency; principal departments of railway service with a brief outline of the work of each; departmental and divisional systems of organization, with examples on various roads and discussion of adaptability of each. The duties of officers and the work of the different departments are taken up in considerable detail. The most important laws affecting railroads are given in discussing the work of the legal department. Freight traffic, freight houses, classification yards, car service rules, accounting, etc., are among the topics considered under operation. Signaling and interlocking and train rules are also considered. Lec-

tures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

263. **Railroad Location.** Elective. Seniors and graduates. Second term. Credit three hours. A detailed study is made of the economic principles governing the location of new railroads, both steam and electric, and the revision or relocation of existing lines to make them most efficient as transportation machines. Some of the topics treated are estimation of revenue, expenses and rates and steam and electric locomotive performance and train operation; gradients, distance and curvature; line and grade revisions; grade crossing elimination and additional facilities; location surveys and estimates. Lectures and recitations with problems involving investigations of projects, revisions and comparisons of alternate locations. Three hours a week. Professor BARNES.

264. **Engineering Construction.** Sophomores. Either term. Credit three hours. A fundamental course designed to acquaint the student with the financial and economic principles underlying human enterprises, both public and private; and with the agencies, money, men, materials and machines, utilized in carrying out construction projects, and their correlation and control. About one-third of the term is devoted to such topics as the history of engineering and the rôle of the civil engineer in the progress of civilization, cooperation with other professions, day labor and contract methods of control, types of contracts, elements of cost including depreciation and overhead, life and economic selection of structures, planning and plant layouts including the plotting and use of the Mass Diagram. The other two-thirds of the term are devoted to the methods and processes of construction with special attention to the equipment available and its adaptability to various kinds of work. Problems and reports on references to periodical literature are required of all students. Professors BARNES and CONWELL and Assistant Professors PERRY, CRANDALL, and THATCHER.

265. **Highway Engineering.** Seniors and graduates. Either term. Credit three hours. Prerequisite courses 260-A and 260-B. The course consists of lectures and recitations considering the economics of location, modern tendencies and methods of design, economic selection of routes and types of surfaces, subgrade soils, drainage, finance, and the technique of construction and maintenance of flexible and rigid types of pavements. In addition to the class work a problem is assigned which requires a complete redesign for modern traffic conditions of an old highway. Professor CONWELL and Assistant Professor THATCHER.

266. **Highway Laboratory.** Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite course 265 or may be taken concurrently with course 265. Subgrade soils are sampled and their properties examined in the laboratory. Tests are also made of various soils used with bituminous materials to determine their suitability for use in highway work; sheet asphalt and other mixtures are designed and examined for stability, etc. Professor CONWELL and Assistant Professor THATCHER.

267. **Advanced Highway Engineering.** Elective. Seniors and graduate students. Second term. Credit three hours. Prerequisite course 265. This course is conducted as a seminar. Meetings are held once each week during an afternoon or evening. The topics for assignment and discussion include the economics of highway engineering, design, construction, and maintenance of highways, the latest research programs and reports, labor and plant organization for various kinds of highway contracts with especial emphasis on the economics of contracting, highway finance, legislation, regulation, etc. Professor CONWELL.

268. **Advanced Highway Laboratory.** Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite courses 265 and 266. Testing of non-bituminous and bituminous highway materials and a study of their characteristics; testing of aggregates, soils, bituminous concrete, sheet asphalt, and asphalt paving block mixtures; study of specifications. Special investigations and tests are made to determine the properties of various combinations of materials and the effects of modifications in design. Two laboratory periods a week. Professor CONWELL and Assistant Professor THATCHER.

269. **Transportation.** Second term. Required of seniors in Administrative Engineering and may be elected by other qualified seniors, and graduates. A course covering travel and transport agencies with special reference to their facilities, ownership, financing, regulation and coordination. A brief review of the development of transportation throughout the world is used as a background for an intensive study of the present situation in the various countries and comparison of the policies and practices in use. Particular attention is given to the various proposals designed to promote more efficient use of the various transportation agencies in the United States by better coordination, pooling of facilities, etc., and economic studies are made of some of the new projects which are under discussion. Professors BARNES and CONWELL.

STRUCTURAL ENGINEERING

270. **Stress Analysis and Structural Design.** Juniors. Either term. Credit four hours. Prerequisite courses 220 and 221.

Stress Analysis. Graphic Analysis of simple and cantilever beams, roof trusses, and framed bents. Determination of position of moving concentrated loads for maximum shears and moments in beams and deck girders. Also for through girders and maximum floor beam reactions for same. Stresses due to dead load, live load, impact, and wind load in the principal types of simple trusses employed in modern construction. Stiff web systems and counter bracing. Three-hinged roof and bridge arches. Practical problems in actual stress computation throughout the course. Textbook: Urquhart and O'Rourke's *Stresses in Simple Structures.* Three recitations a week.

Structural Design. Graphic analysis of stresses in a timber truss. Design of truss members and joint details. Computations, systematically arranged in the form of reports, and working drawings. Textbook: Jacoby and Davis' *Timber Design and Construction.* Computation and drawing, two and one-half hours a week. Professors URQUHART and O'ROURKE, Assistant Professor BURROWS and Mr. PENDLETON.

270-A. **Structural Analysis.** Juniors in Administrative Engineering. First term. Credit two hours. Prerequisite courses 220 and 221. Graphic analysis of simple and cantilever beams, roof trusses, three-hinged roof arches, and framed bents. Analysis of stresses in through and deck girder bridges, due to dead and moving concentrated loads. Textbook: Urquhart and O'Rourke's *Stresses in Simple Structures.* Two recitations a week. Professors URQUHART and O'ROURKE and Assistant Professor BURROWS.

271. **Structural Design.** Juniors. Either term. Credit three hours. Prerequisite course 270 or 270-A. An elementary course in Steel Design. Complete designs and detail drawings of the steel skeleton of a small building, including trusses, and of a through plate girder bridge. Textbook: Urquhart and O'Rourke's *Design of Steel Structures.* Three computation or drawing periods a week. Professors URQUHART and O'ROURKE, and Assistant Professor BURROWS.

272. **Advanced Structural Analysis.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 270. Stress analysis of continuous beams, framed bents and rigid frames. Horizontal as well as vertical loading considered. Redundant structures including the braced two-hinged arch. Displacement diagrams for trusses and arches and analytical computation of deflections of such structures. Three recitations a week. Professors URQUHART and O'ROURKE.

273. **Steel Buildings.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 220, 221, and 271. This course comprises the design of the steel framework for buildings of the prevailing type used in power house or shop construction. Dead, snow, and wind stress diagrams are drawn for the roof trusses. Provision is made for an electric crane moving the full length of the building and the stresses in the framework due to the movement of the crane are determined. The effect of the wind and the eccentric load due to the crane girder are considered in the design of the columns. Textbook: Ketchum's *Steel Mill Buildings.* Reports and drawings. Three two-hour periods a week. Assistant Professor BURROWS.

274. **Bridge Design.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 271. Computations and drawings for the complete design of a railroad bridge of six or seven panels or a heavy highway bridge. The computations to determine the stresses and sections of all members, pins, pinplates, splices, deflection, camber, and other details as well as of connecting rivets are to be written up in the form of systematically arranged reports. The drawings consist of general detail plans showing the location of all rivets as well as the composition and relation of all members and connections. The final report is to give a full list of shapes and plates, and a classified analysis of weight for the span. Textbook: Urquhart and O'Rourke's *Design of Steel Structures*. Computation and drawing, three two-hour periods a week. Assistant Professor BURROWS.

275. **Investigation of Existing Bridges.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 271. Inspection of existing structures for the determination of sizes and conditions of plates and shapes. After full data have been obtained in the field, computations will be made to determine either the unit stresses under a specified load, or the safe load or rating according to standard specifications. Assistant Professor BURROWS.

280. **Concrete Construction.** Juniors. Either term. Credit three hours. Prerequisite courses 220 and 221. (Preferably taken concurrently with or preceded by course 225). Properties of plain concrete, elementary theory of reinforced concrete as applied to rectangular beams, slabs, T-beams, beams reinforced for compression, columns and footings. Shear, diagonal tension, and direct stress combined with flexure. Computations in the forms of reports on the design of a typical beam and girder floor panel and of a retaining wall. Detail sketches of sections and reinforcement required. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professors URQUHART and O'ROURKE, and Mr. PENDLETON.

281. **Foundations.** Juniors. Either term. Credit three hours. Prerequisite courses 220 and 221. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons; pneumatic caissons for bridges and buildings, caisson sinking, and physiological effects of compressed air; pier foundations in open wells; freezing process; hydraulic caissons; ordinary bridge piers; cylinders and pivot-piers; bridge abutments; spread footings for building foundations; underpinning buildings; subterranean explorations; unit loads. Textbook: Jacoby and Davis's *Foundations of Bridges and Buildings*. Recitations, collateral reading in engineering periodicals, and illustrated reports. Three hours a week. Professors URQUHART and O'ROURKE.

282. **Reinforced Concrete Building Design.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 280. Design of a reinforced concrete flat-slab building and investigation of various other types of floor systems for commercial buildings. Complete detail design for one building, including stairway, elevator shafts, penthouses, etc. Working drawings and steel schedules. Seven and one-half hours a week. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professors URQUHART and O'ROURKE, and Mr. PENDLETON.

283. **Fixed Arches.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 270, 271 and 280. Theory of the curved beam; the closed ring; the fixed arch. Influence lines for arches of various forms. Selection of curvature of axis for various loadings. Effect of temperature and rib-shortening. Effect of plastic flow on stresses in a reinforced concrete arch. Design of a reinforced concrete arch and its abutments. Lectures, recitations, and computations. Six hours a week. Professors URQUHART and O'ROURKE.

284. **Highway Bridges.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 280. Design of short span bridges and their abutments. Comparison of the economy of steel and reinforced concrete superstructures for bridges of this type. Reports and drawing. Professor O'ROURKE.

285. **Reinforced Concrete Design.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 280. Theory and design of gravity,

cantilever, and counterfort retaining walls. Design of footings: single and multiple columns of reinforced concrete, I-beam grillages. Design of bins and tanks, subsurface and supported on towers. Reports and sketches. Three two-hour periods a week. Professors URQUHART and O'ROURKE.

286. **Building Construction.** Elective. Juniors, seniors, and graduates. Second term. Credit three hours. Lectures and quizzes. The general plan includes one lecture each week by a practicing engineer or architect well known in his particular field. This is followed by a supplementary lecture by a member of the University staff.

In 1933–34, the field covered included lectures on: The Field of the Consulting Engineer; the Conception and Execution of a Building Project; The Financial Plan in Building Operations; Fire Protection; Testing Materials; Building Codes; Licensing; Concrete and Reinforced Concrete; Foundations; Steel Frame Buildings and Their Erection; Welding; Exterior and Interior Finish; Synchronizing Operations; Maintenance and Remodeling; The State Building Program. Professor URQUHART and others. (Not given in 1934–35.)

287. **Applied Soil Mechanics.** Second term. Credit three hours. Prerequisite course, Physics 431.

A comprehensive study of the properties of soil, presenting a conception of its behavior as an engineering material. Theory of soil classification, soil structure, pressure distribution, compressibility, cohesion, elasticity, plasticity, and permeability. Practical problems on pile foundations and earthwork engineering. Laboratory tests for identification of soils; mechanical analysis, determination of water content, specific gravity, density, permeability, etc. Tests for physical properties of soils. Professors HOLLISTER and O'ROURKE, and Assistant Professor JENKINS.

ADMINISTRATIVE ENGINEERING

290. **Engineering Law.** Seniors. Juniors admitted only by special permission. Also open to seniors in Architecture, Mechanical and Electrical Engineering, Chemistry, and other seniors submitting acceptable qualifications. Either term. Credit three hours. Essentials of contracts and contract principles; agency, tort and independent contractor; use and conveyance of lands and waters, including irrigation law, real estate documents, boundary lines, eminent domain and title searches; corporations, partnerships and other contracts of association; sales and transportation contracts; negotiable instruments; bankruptcy, mechanics liens, patents, trademarks, copyrights, courts, wills, and laws of insurance. The course culminates with the preparation of a set of contract documents for an assigned construction job, including advertisement, form of proposal, information to bidders, agreement form, and general conditions with clauses covering payments, time limit, arbitration, extras, liquidated damages and abandonment of contract. Tucker's *Contracts in Engineering* is used as a text, supplemented liberally from other sources. Lectures and recitations three hours a week. Professor BARNES, Assistant Professors CRANDALL, PERRY, and THATCHER.

290-A. **Advanced Engineering Law.** Second term. Credit three hours. Required of seniors in Administrative Engineering and open to others who have completed course 290 of which this course is largely an extension. Some additional topics treated are municipal laws and ordinances, labor laws under various jurisdictions, reclamation and other laws concerned with the development of natural resources and compensation and insurance laws. Actual cases will be used for illustrating the above and also some of the topics treated in course 290. Professor BARNES and Assistant Professors PERRY, CRANDALL, and THATCHER.

293. **Engineering Management.** Seniors. Either term. Credit three hours. Also open to qualified seniors from other departments. This course is devoted mainly to the management of construction work but also treats briefly of such larger problems as economics of plant location and economic selection of plant, or structure, to fulfill a given purpose. Management is treated under its two main heads,—planning and operation. Under planning are such subjects as the selection of methods of procedure which will result in maximum economy, the plan-

ning of a thoroughly coordinated organization of men and machines to carry out these methods and the scheduling and estimating of the work in accordance with the adopted plans. Under operation are selecting, training and maintaining labor forces including pay systems, accident prevention, welfare work, etc., purchasing, operation and maintenance of equipment and keeping the records essential to the management for comparing results with schedules, i.e., cost keeping. Bookkeeping is recognized also as an essential tool of management and the fundamentals of double entry bookkeeping are given, together with the use of control accounts, financial statements and budgets. Blanks and forms for cost keeping for actual or assumed jobs are required and each student also works out problems in bookkeeping. Professor BARNES and Assistant Professor CRANDALL.

293-A. **Engineering Management.** Juniors in Administrative Engineering, juniors in administrative engineering option and others who have had accounting. First term. Prerequisite, an elementary course in accounting. Covers the same ground as course 293 except that bookkeeping is omitted and more attention is given to management proper, especially to personnel and labor relations. Professor BARNES.

293-B. **Cost Accounting.** Second term. Credit three hours. Required of seniors in Administrative Engineering and open to others who have had an elementary course in accounting. A general course in cost accounting on engineering construction and operations involving estimating, bidding, planning and scheduling, control of job costs and effect of financing, time of construction and methods on costs. Professor BARNES and Assistant Professor CRANDALL.

295. **Valuation Engineering.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite courses 264 and 290 or taken concurrently with 290. Lectures, recitations, and reports. Theory and practice of valuation or appraisal for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, mergers or joint ownership, taxation and assessment, issuance of securities, bank loans, insurance, uniform system of accounting and improved management. Topics considered include scientific systems of real estate assessment, federal railroad valuation, rate disputes, court rulings, computation of actual rates for gas, telephone, electrical supply and street railways, valuation of land, mines, water power, factories, railroads, toll bridges, buildings, and all kinds of property both tangible and intangible. Detailed examples of forms and methods with outline of typical valuation reports. Assistant Professor CRANDALL.

See also page 85 for additional courses in Administrative Engineering.

REGIONAL AND CITY PLANNING

710. **Principles of Regional and City Planning.** Throughout the year. Credit two hours each term. Registration limited to 50. Open to graduates and upperclassmen in all colleges of the University. Professor CLARKE. The history of planning with a review of influences which affected the development of cities from ancient to modern times. A general view of the theory and accepted practices of large-scale planning including a study of the legal and economic phases. Lectures, assigned reading, and examinations. Occasional lectures will be given by members of other faculties and by outside lecturers selected because of their special experience and skill in certain phases of planning. Students wishing to register for this course should register with Professor CLARKE at the College of Architecture on registration day. M W 12. *White* 28.

711. **Seminar in Regional and City Planning.** Throughout the year. Credit one hour each term. Professor CLARKE. Investigation of assigned topics on particular aspects of the subject with emphasis on regional planning. Registration limited. Open to students in all colleges of the University, by permission. This course should accompany or follow course 710. By appointment. *White.*

713. **Seminar in Parkway, Freeway, and Highway Planning.** Second term. Credit two hours. Professor CLARKE. Specific problems relating to the design of the modern parkway, freeway, and highway with study of examples. Registration limited. Open to upperclassmen and graduates in the Colleges of Architecture and Engineering. By appointment. *White.*

GENERAL COURSES

291. **Engineering Design.** Elective. Seniors. Credit three or more hours. The student may make complete designs in one of the following sub-divisions, subject to approval. Hours to be arranged.

(a) **General Civil Engineering.** Either term. Problems in practical design may be taken in any department, the work to be supervised by the department concerned in cooperation with the Department of Structural Engineering in regard to structural features.

(c) **Hydraulic Engineering.** Second term. Prerequisite course 240. For best results Hydraulic Design should be preceded by Course 230, but the two may be taken concurrently. The purpose of the course is to go more into detail in selected phases of hydraulic engineering and is not to duplicate in large part work regularly given in the scheduled courses in hydraulic and structural engineering. Professor SEERY.

(d) **Sanitary Engineering.** First term. This course must be preceded by or taken at the same time as Course 254, and may not be elected otherwise. The following problems indicate the scope of the work: (1) Computations, design, and detail drawings for the wooden forms needed for brick or concrete sewers of various diameters and forms of cross sections. (2) Computations, design, and detail drawings for a pile foundation to support sewers from three to ten feet in diameter. (3) Design and detail drawing for patterns of cast-iron manhole covers. (4) Computations, designs, and detail drawings for flap valve as outlet of settling tank, the design involving a lifting device. (5) Design and detail drawings of a sewage screen, involving a device for raising screen for cleaning. (6) Computations, designs, and a detail drawing for an inverted siphon for sewage flow; the problem involves a flushing gate and overflow as well as manholes. (7) Design of disposal plant for a small community as an asylum or school. Professor OGDEN.

(e) **Railroad Engineering.** Either term. The problems are those encountered in the location and construction of railroads, and include the following subjects: Economic location of railroads; culverts; bridges; retaining walls; tunnel and subway design; small depot buildings; freight houses; water supply and coaling plants; icing stations; turntables and engine-houses; gravel washing plants; track layouts with details of signals and interlocking; yard and terminal design, etc. Bills of material and estimates of cost are usually required. The field is so broad that the interest of the student is given consideration in assigning problems. Professor BARNES and Assistant Professor PERRY.

(f) **Structural Engineering.** Second term. Course 271 is required as general preparation for engineering design in bridges and buildings. Course 272 is required in preparation for designs relating to draw, cantilever, suspension, and metallic arch bridges. Course 280 is similarly required for designs of bridges and buildings in reinforced concrete. Professor URQUHART and Assistant Professor BURROWS.

(g) **Highway Engineering.** Second term. The problems are those encountered in the location and construction of highways and include the following: Economic location; selection and design of different types of highway surfaces for various traffic conditions; culverts, bridges, retaining walls, and other highway structures. Bills of materials and estimates of cost are usually required, also plant layouts and methods of executing work. Professor CONWELL and Assistant Professor THATCHER.

297. **Engineering Research.** Elective. Seniors and graduates. Credit three or more hours. Research may be taken in one of the following subdivisions or two or more departments may cooperate in the assignment of special problems. Hours to be arranged.

(a) **Geodetic Astronomy.** Second term. Prerequisite courses 184 and 216. Investigations of instrumental errors; variation of latitude and azimuth; any and all questions relating to work of the highest precision connected with astronomical problems and geodetic operations. The field is so broad that the interest of the

student is given consideration as to the actual research undertaken. Professor BOOTHROYD.

(b) **Engineering Materials.** Either or both terms. Credit one hour for forty hours of actual work. A project may be started during the junior year for completion in the senior year. Prerequisite courses 225 and 226 or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction. The aim of the course is to secure results by proper investigational methods which are of the caliber and scope deemed essential for publication. Professor SCOFIELD.

(c) **Hydraulics.** Either term. Prerequisite course 240 or its equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is often desirable and is permissible for two students to work together on the same investigation. Written reports are required but the text need not be typewritten in thesis style. These reports are kept by the department. In most cases it is necessary to arrange a definite schedule for work in the laboratory to avoid conflicts. Professor SCHODER.

(d) **Sanitary Engineering.** Either term. Prerequisites for work in this field will depend upon the particular problem to be pursued, but in general will include work in water analysis, bacteriology, and courses in Hydraulics and Sanitary Engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, prerequisites and other questions relating to contemplated research in this field will be arranged by conference. Professors OGDEN and WALKER.

(e) **Railroad Engineering.** Either term. Special problems in the economics of location, construction, maintenance and operation of railroads, comparison of transportation agencies, traffic studies and economics of various systems of transport. Professor BARNES.

(f) **Structural Engineering.** Second term. Students wishing to pursue one particular branch of bridge engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction or theoretical work with a view to simplifying present methods of design or proposing new methods. Professor URQUHART.

(g) **Highway Engineering.** Either term. The laboratory for testing and investigating bituminous materials is available for research, and other materials may be tested in the laboratories in Lincoln Hall. Special problems in location and design and in economic selection of types of surfaces give opportunity for a wide variety of research. Professor CONWELL.

298. **Thesis.** Elective. Seniors. Credit three hours. The thesis is intended to demonstrate the ability of the student for independent investigation, or his ability to apply the fundamental principles acquired in his course to the study of some special problem related to civil engineering. The latest date for filing the subject with the Director of the School is October 15 for the first term, and January 15 for the second term. The plan of work is to be submitted to the professor having charge of the subject, to whom also regular reports are to be made showing the progress of the investigation. The latest date for presenting the complete thesis is June 1. A pamphlet containing instructions in regard to theses in Civil Engineering is available and should be consulted by students registered for this course.

SPECIAL AND GRADUATE COURSES

All the elective courses are suitable for graduate and advanced students, and may be taken by them in the regular classes. Other special courses will be arranged to suit the requirements of graduate students. These courses are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom, and working either independently or in conjunction with others taking the same course.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and provide as much experience in engineering practice in the fields of mechanical engineering as can be well imparted in a school.

The instruction in Mathematics, Chemistry, Physics, and English is given in the College of Arts and Sciences. All other regular subjects in the course are of an engineering nature and are taught in the Sibley School of Mechanical Engineering in the following departments of instruction: (1) Mechanics of Engineering, (2) Machine Design, (3) Heat-Power Engineering, (4) Experimental Engineering, (5) Industrial Engineering, (6) Administrative Engineering, (7) Automotive Engineering, (8) Aeronautical Engineering, (9) Hydraulic Power Plant Engineering, (10) Metallurgical Engineering, and (11) Mechanic Arts; or else in the School of Electrical Engineering or the School of Civil Engineering.

The following is a brief outline of the scope and purposes of instruction in the various departments of the School of Mechanical Engineering.

1. Mechanics of Engineering

In this department instruction is given in theoretical and applied mechanics, hydraulics, fluid mechanics, and applied mathematics beginning with a course for sophomores in the fundamental principles of statics, kinetics, strength of materials and hydraulics. An effort is made to teach students to think rather than to memorize. With this in view the free-body method is used in the solution of problems involving forces, and students are required to work from fundamental definitions and principles rather than from formulas.

For seniors elective courses on hydraulic power plants are offered. While the theory of turbines is outlined, stress is laid upon the practical side of the subject, the object being to make the course of definite value for those expecting to take up hydroelectric work. The laboratory instruction in hydraulics is given in the Department of Experimental Engineering.

2. Machine Design

In this department, instruction is given in empirical design, kinematics, and machine design, to sophomores and juniors in mechanical, electrical, and administrative engineering. Instruction in machine design is also given to seniors in chemical engineering. The department also offers elective courses open to sophomores, juniors, seniors, and graduates.

Instruction is given by means of recitations and work over the drawing board. First, a study is made of the common machine parts

and their uses and the empirical proportioning and assembling of such parts. The study of kinematics is then taken up and applied to the solution of cam, gear, linkage, instant center, velocity, and acceleration problems. These courses are followed by recitations and drawing room courses in general machine design. The theory and principles developed are applied to the solution of many short problems and to the design of complete machines in the drawing room. Only such machines as lend themselves to rational analysis to the greatest degree are selected. The calculations are regarded as an important part of the work and the student's design is criticized from the standpoint of appearance, cost, convenience and economy of shop operations, lubrication, accessibility, ease of assembly, economy of upkeep, etc.

3. Heat-Power Engineering

Instruction in this department is given to all juniors and seniors in Mechanical Engineering, juniors in Electrical and Administrative Engineering, and seniors in Civil Engineering, with the object of training them to solve problems involving the theory, design, performance, selection, and economics of steam, internal combustion and other heat engines, refrigerating machines, gas compressors, and related auxiliary equipment, considered both separately and in combination in power plants.

This instruction in fundamentals begins with lectures and recitations on the elements of heat-power engineering, including the study of the thermodynamic properties and processes of gases, vapors, and mixtures; ideal and actual gas and vapor cycles; air compressors; internal combustion engines; and steam engines. This is followed by a study of steam turbines, fuels, combustion, heat transmission, flow of gases and vapors, furnaces, steam generating units, draft apparatus, condensers and other heat exchangers, refrigeration, the utilization of waste heat, and other related topics.

Two senior options are offered by this department, one in Steam Power Plants, and the other in Fluid Flow, Heat Transmission, Refrigeration, and Air Conditioning. Elective courses are also offered on steam turbines, power plant economics, steam generating equipment, internal combustion engines, and graphical computations.

4. Mechanical Experimental Engineering (mechanical laboratory)

Instruction in this department begins in the sophomore year with the study of materials of engineering, their manufacture, properties, and uses.

Throughout the junior and senior years the student receives instruction in the very completely equipped mechanical laboratories (described on page 40), not only to familiarize him with the various types of testing apparatus and to give him skill in their use, but to teach him the best methods of research. Briefly, the courses include:

the use of computing machines; the testing of engineering materials, with determination of influences of composition and heat treatment; the calibration and use of indicators, gauges, thermometers, dynamometers, etc.; tests of lubricants; fuel calorimetry; steam calorimetry; valve setting; tests of boilers, steam engines, turbines, pumps, heaters, condensers, injectors, and other steam apparatus; tests of fans, air compressors and refrigerating machines; tests of external and internal combustion gas and oil engines; and tests of hydraulic machinery.

5. Industrial Engineering

In the junior year all students in Mechanical and Electrical Engineering receive instruction in industrial history and the present principles and tendencies of industrial engineering.

For seniors in Administrative Engineering and seniors in Mechanical Engineering who elect the Industrial Option more advanced work is provided. The principles governing manufacturing methods are studied and a layout made for a modern manufacturing industry. Methods of production and material control are studied, as well as organization and methods of expense distribution. The subject of time and motion study is presented, including micro-motion study and the principles of motion economy. The department conducts a micro-motion laboratory equipped with the necessary motion-picture equipment.

The course in Industrial Relations includes a consideration of the human problems of management such as organized labor, labor legislation, employee health, wage payment, employee selection, etc.

The subject of cost-accounting is treated in coordination with the above subjects including principles and practise of standard, process and order costs.

6. Administrative Engineering

It is recognized that the four functions of business and industry are Marketing (including selling and advertising), Production, Finance, and Accounting. Accordingly, a basic course in Business and Industrial Management is given in the sophomore year to orient the student in commercial thinking. This course is paralleled by one in basic economics. Upon these two courses are built a series of carefully coordinated courses in English, Technical Writing, Accounting, Cost Accounting, Corporation Finance, Public Speaking, Industrial Relations, Statistics, Business Law, Industrial Engineering, Production Management and Marketing. To supply the even closer contact with the outside world, a series of special lectures is given by business leaders who appear weekly before the senior classes.

The freshman year is the same as that given to all engineering students. During the next two years all students are required to take a balanced group of technical and economic courses. In the senior year a certain degree of specialization is permissible in either mechanical or electrical engineering.

About 68% of the course content, as given to the students in the M.E. and E.E. schools, is devoted to regular engineering subjects. This gives the course a substantial ground work in fundamental engineering; a prime requisite for the principles of scientific management so ably pioneered by Mr. Frederick W. Taylor. These principles have spread to almost every phase of human endeavor but their background is still engineering. The remaining 32% of the course is made up of subjects devoted to business and economics especially designed to fit the needs of modern industry.

7. Automotive Engineering

Since Automotive Engineering is merely a branch of the general field of mechanical engineering and is dependent on the basic preparation covered in the first three years of the regular curriculum, the special instruction of the Automotive Option is deferred until the senior year. This special work covers the wide variety of theoretical and practical problems in design and operation which are of great importance in the industry; applies the fundamental principles that have been studied in the previous years; reviews the topics that are usually covered by books on the subject; and makes a special study of current developments. The instruction is given by means of lectures and computing courses. The lectures may be elected by seniors in other options. Provision is made also for conducting experimental investigations in this field.

8. Aeronautical Engineering

The College does not offer a complete four-year course in Aeronautical Engineering, for the main reason that, under the Guggenheim Foundation, there are at the present time six or eight schools of engineering in the country offering such courses and the number of graduates annually turned out is more than sufficient to supply the field. In accordance with the recommendation of the Foundation, therefore, this College is offering a few courses in Aeronautics, beginning with the junior year and including an option in such work in the senior year. This amount of training in Aeronautics is believed to be sufficient to constitute a good foundation upon which to base advanced work in the same field in any one of the schools offering complete curricula in Aeronautics.

9. Hydraulic Power Plant Engineering

The work of the water-power engineer includes a combination of civil, mechanical, and electrical engineering. Hence the special courses offered in this field are designed to cover all those topics which are essential to an intelligent co-operation among all classes of engineers, whether engaged in the design, construction, or operation of water-power developments or in the transmission and distribution of the energy. The work of the option in this field is confined

to the senior year. It gives special emphasis to the financial and economic phases, including the elements of design and construction which affect economical operation. Included in the option is a course in electrical engineering which covers the electrical power plant, transmission, and distribution. The object of the instruction is to present a complete picture of the problem, from the water in the stream to the sale of energy to the ultimate consumer. Arrangements are made, as opportunities occur, for inspection trips to water-power plants under construction or completed, and students in this option have the privilege of joining in any such trip if they wish to do so. Those students who can spend five years are urged to combine this option with the course in electrical engineering; elective courses in the Department of Heat-Power Engineering ought also to be included because the present-day power system usually includes thermal plants. In the five-year period the M.E. and the E.E. degree may both be obtained. For the details of this combination the student should consult the Directors of the Schools of Mechanical and Electrical Engineering as early as possible, preferably before beginning the second year.

10. Metallurgical Engineering

As the iron and steel and other metal producing or fabricating industries employ a larger percentage of graduates in mechanical engineering than other industries do, a metallurgical option is offered for students interested in this field of engineering. The courses in the option do not, however, constitute a complete curriculum in Metallurgy, for such a curriculum would require greater specialization in Physical Chemistry, Metallography, and Metallurgy than can be included in a course primarily devoted to mechanical engineering. The option does, however, give the student a good start in this branch. The special work begins in the junior year with a course in Introductory Metallurgy. This is followed in the senior year by courses in Physical Chemistry, Analytical Chemistry, Applied Metallography, Chemistry of Solids, and Furnace Metallurgy. Seniors in 1936–37 may take all of the special work of the option in that year.

11. Mechanic Arts

The object of the instruction in this department is not only to familiarize the student with modern shop operations and processes, and with the workability of materials used in engineering construction but more particularly to give him instruction in the principles of manufacturing and duplication of parts, and in the selection and arrangement of shop equipment.

The work of the freshman year in the shops is given in a laboratory course and in the wood shop. The laboratory course is designed to familiarize the student with current engineering terms and common engineering appliances. This course also includes some work in the

forge shop illustrating the principal forge shop operations, like welding, hot working, gas and electric welding.

Instruction in wood-working is given with the object not only of familiarizing the student with wood-working tools and machines and their use, but more especially to teach him pattern and core-box making. Instruction is also given in large pattern work and sweep-work.

In the sophomore year the student receives instruction in the foundry in molding, core making, mixing of metals, operation of cupola, the uses of moulding machines, etc., with consideration given to the methods and appliances for sweep-work, large work, and production in quantities.

In the junior year the principles of manufacturing are taught, supplemented by work of an illustrative character in the machine shop, where carefully graded instruction is given in the use of measuring instruments, hand tools, and machine tools, including semi-automatic and automatic machines, and in the use of jigs and special fixtures for manufacturing in large quantities. The administration of this shop in particular is intended to illustrate as far as possible approved methods of shop management and operation, and to give the students a general idea of time keeping, piece work, premium plan, and other wage systems. The instruction is given to a great extent in connection with the construction of commercial machines.

Engineering Research

The instructing staffs, laboratories, libraries, and other facilities of the various departments of the College of Engineering and those of the other departments of the University are available for graduate and undergraduate students desiring to pursue original study and research in engineering and allied fields. (For description of the laboratories, libraries, and other facilities in Engineering, see pages 34–46 of this pamphlet. For discussion of graduate research in engineering, see the Announcement of the Engineering Division of the Graduate School, beginning on p. 131 following.)

Undergraduates who have shown the requisite proficiency and have available the necessary time may have opportunity to conduct special investigations under expert guidance. Such special work may consist of an analytical study or discussion of data, reports and other engineering information already available, or it may be devoted to a design or construction or both of technical importance, or it may be an original investigation—analytical or experimental or both. When occasion offers, qualified students may assist in commercial tests, made at the University or elsewhere, of materials, prime movers, machines, power plants, air conditioning equipment, etc. In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a Thesis.

A limited number of seniors who have shown special ability for investigation may substitute Research (or Thesis) for some of the usual senior electives or for courses in an option.

Arrangements for Research or Thesis should be made with the Director of the school and the department concerned, preferably during the junior year.

Non-Resident Lecturers

Supplementing the regular class room instruction, lectures are delivered from time to time by non-resident specialists in the profession on various subjects relating to the many branches of mechanical engineering. Seniors are required to attend these lectures. The student may also attend the many public scientific lectures given in other departments of the University by non-resident lecturers.

Inspection Trips

At appropriate times during their course the students in the various groups are taken on supervised inspection trips for the purpose of studying commercial, industrial, and engineering applications of the principles inculcated in the classroom, and of inspiring them in their work through affording them opportunities to observe typical engineering projects in the actual processes of development, and important ones that have been completed and are carrying out the functions for which they were planned.

COURSES LEADING TO THE DEGREE OF MECHANICAL ENGINEER

I. THE REGULAR FOUR-YEAR COURSE

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop, laboratory, computing room, or drawing room count as one hour of credit, and each recitation hour assumes about two hours of outside preparation.

The curricula offered by the Sibley School of Mechanical Engineering, leading to the degree of Mechanical Engineer, all contain the fundamental studies in Mathematics, Physics, Chemistry, Mechanics, Kinematics and Machine Design, and Thermodynamics, considered essential to the basic training for this degree. Recognizing, however, that students in the later years of the course may have developed a special interest in some particular field of Mechanical Engineering, a certain degree of specialization is introduced in those years. It is clearly kept in mind that there is not a great deal of time for such special work, and that the emphasis must be kept on fundamentals. Hence not more than from 8 to 12 hours of work may be devoted to such optional work.

With the exception of the options in Aeronautical Engineering (Option E) and Metallurgical Engineering (Option G) the curricula of the various options are the same for the first three years, the specialization taking place only in the senior year. Hence a choice of option can be deferred until the beginning of the fourth year unless the choice is to be Option E or G, in which case the decision

should be made before starting the third year. The following pages show the curricula of the various options. The special courses peculiar to each option are printed in **boldface** type.

Option A. Power-Plant Engineering

The object of the special courses in this option is to acquaint the student with load-curves and their characteristics, station factors, power-plant economics, and the cost of plants and of their component parts and output; the principles of the economic selection and operation of the power-plant machinery with respect to character of the loading, the cost of factors, and the local conditions involved; the design of steam power plant equipment with regard to these considerations and the structural requirements; plant location and layout; and similar topics. The special work in this option is confined to the senior year and is taught by lectures supplemented by a computing and layout course.

For schedule for the Freshman Year, see page 49.

Sophomore Year

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

Junior Year

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	20

Senior Year

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Steam Power Plants Lectures 3P44, 3P45	2	2
Computing and Design 3P46, 3P47	2	2
Power Plant Economics 3P50	2	0
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	1 or 4	5 or 2
Total number of hours each term	19	19

Option B. Heat Engineering

(Fluid Flow, Heat Transmission, Refrigeration, and Air Conditioning)

The purpose of the special work in this option is to train men in the fundamentals required in solving problems encountered in the rapidly expanding fields of air conditioning, refrigeration, and the industrial utilization of heat. Extended instruction in the basic principles of fluid flow, heat transfer, properties of mixtures, and refrigeration will be given during the first term of the senior year. In the second term important applications of these principles in air conditioning for the purpose of improving human comfort and for the control of the properties of hygroscopic materials during manufacturing processes will be given.

For schedule for the Freshman Year, see page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	20

SENIOR YEAR

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heat Engineering 3P57, 3P58	4	4
Refrigeration 3P49	2	0
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	4	5
Total number of hours each term	19	19

Option C. Industrial Engineering

This option is intended for those who wish to enter the commercial side of engineering or who are particularly interested in industrial organization and administration. In the special senior courses in this option the following topics are discussed: Modern time-keeping and cost-finding systems; methods of planning work and insuring production; time and motion studies; purchasing; problems in administration, plant locating; heating; lighting; powering; safety engineering; fire protection and similar subjects. In the drafting and designing courses the graphical work includes the application of these fundamental principles to planning industrial enterprises. Students expecting to elect this option are advised to read for preparation as much industrial history and kindred subjects as possible.

For schedule for the Freshman Year, see page 49.

Sophomore Year

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

Junior Year

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	20

Senior Year

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Industrial Engineering 3I43, 3I44	**3**	**3**
Industrial Relations 3I46	**2**	**0**
Cost Accounting 3I47	**0**	**2**
Industrial Engineering 3I48	**0**	**2**
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	2 or 4	2 or 0
Total number of hours each term	19 or 18	19 or 20

Option D. Automotive Engineering

The specialization in this option is confined to the senior year and begins in the first term with study of the broad purposes of the automotive vehicle taken as a whole; the main functions; steering, driving, braking, suspension; power for operation; power transmission; the specific structures and their detailed actions. The second term deals with the power plant theory, design, and operation; nature of working fluid; preparation for and control of combustion; power conversion; efficiencies and mechanism of the engine. There are two lectures and two computing periods a week. The latter are usually devoted to analytical work, but sometimes to drawing, laboratory, or demonstration.

For schedule for the Freshman Year, see page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	20

SENIOR YEAR

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Motor Car Construction Lectures 3X45, 3X46	2	2
Motor Car Construction Computations 3X47, 3X48	2	2
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	3 or 6	5 or 2
Total number of hours each term	19	19

Option E. Aeronautical Engineering

Students who are interested in aeronautical work may find a limited amount of specialization in aeronautics desirable in the senior year. For this option, the student must have elected an introductory course in aerodynamics in the junior year, and should preferably have had some instruction in practical flying. Flight training is not offered by the University, but can be obtained at the Ithaca Airport, within two miles of the Cornell campus. The student is introduced to practical engineering work by problems in the design and construction of airplanes. The study of aeronautic power plants is undertaken with the automotive group.

For schedule for the Freshman Year, see page 49.

Sophomore Year

	Hours 1st Term	Hours 2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

Junior Year

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Aerodynamics 3M35	0	2
Total number of hours each term	18	20

Senior Year

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Motor Car Construction 3X46	0	2
Internal Combustion Engines 3P51	2	0
Airplane Design Recitations 3M36	2	0
Airplane Design Computations 3M45, 3M46	2	2
Industrial Organization 3I31	2	0
Heating, Ventilating, and Refrigeration 3X44	0	3
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	2 or 0	0 or 2
Total number of hours each term	19 or 17	17 or 19

Option F. Hydraulic Power Plant Engineering

The aim of the special courses in this option is to cover all topics essential to an intelligent cooperation between engineers engaged in either the design, construction, or operation of water power developments or in the transmission of energy. Special consideration is given to financial and economic phases and to the elements of design and construction affecting economical operation. The special instruction is given in the senior year by lectures, supplemented by work in computing periods. A course covering electrical power plants and transmission and distribution is also included.

For schedule for the Freshman Year, see page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations, 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	20

SENIOR YEAR

Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Hydraulic Power Plant Lectures 3M41, 3M42	2	2
Hydraulic Power Plant Computations 3M43, 3M44	2	2
Electric Power Plant Design 441	3	0
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 97)	0 or 2	5 or 3
Total number of hours each term	19 or 18	19 or 20

Option G. Metallurgical Engineering

This option of studies does not represent a complete curriculum in Metallurgy, because that would require a much wider specialization in Physical Chemistry, Metallography, and Metallurgy than is here included. The option is intended to give to students who are interested in the metallurgical field, mainly iron and steel, some training which will enable them to get a start along this line.

For schedule for the Freshman Year, see page 49.

Sophomore Year

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Strength of Materials 3M22b	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21	3	0
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Accounting 3A31	0	3
Total number of hours each term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Military Drill.

Junior Year

Heat-Power 3P31, 3P32	3	3
E.E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Applied Mathematics 3M32	3	0
Fluid Mechanics 3M33	0	4
Machine Shop 3S31	3	0
Introductory Metallography, Chem. 545	**2**	**0**
Total number of hours each term	20	18

Senior Year

Heat-Power 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Industrial Organization 3I31	2	0
Physical Chemistry 405	**3**	**3**
Physical Chemistry Laboratory 410	**0**	**3**
Analytical Chemistry 201	**4**	**0**
Applied Metallography 3X52	**0**	**2**
Chemistry of Solids 435	**2**	**0**
Furnace Metallurgy, Chem. 750	**0**	**3**
Total number of hours each term	20	20

Note.—Work under this Option may be begun by seniors in the Fall of 1936-37. Under this arrangement the work of the first three years is the same as that for Option A. The Senior Year is made up of the following courses:

SENIOR YEAR, 1936–37

	Hours 1st Term	2nd Term
Heat-Power 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Physical Chemistry 405	3	3
Physical Chemistry Laboratory 410	0	3
Analytical Chemistry 201	4	0
Introductory Metallography, Chem. 545	2	0
Applied Metallography 3X52	0	2
Chemistry of Solids, Chem. 435	2	0
Furnace Metallurgy, Chem. 750	0	3
Total number of hours each term	20	20

Option H. Elective Group of Studies or Thesis

In exceptional cases only, seniors who have made excellent records and can show a real need for specializing in Physics, Chemistry, Mathematics, or advanced work in Engineering, or in a field related thereto, may petition to be allowed to devote to such specialization the hours assigned to the group courses and electives in the other options.

Also, under this option, a limited number of well qualified seniors may, upon petitioning, be allowed to substitute for either the special or the elective courses of one of the other options an investigation or research of importance and of broad educational value in Mechanical Engineering or in a field related thereto. The results of the investigation are to be embodied in a Thesis or Essay submitted in the manner and form required of graduate students.

A student desiring to take the special work under the provisions of this option must submit to the Director of the School and to the department principally concerned, a definite plan of the proposed work. The plan, which should be submitted in the Junior year, must have definite objective and must state in detail the reasons for desiring the special work.

ELECTIVE SUBJECTS IN THE SCHOOL OF MECHANICAL ENGINEERING

	Hours 1st Term	2nd Term
Mechanical Technology 3D51 (not open to seniors)	0 or 3	3 or 0
Advanced Kinematics and Kinetics 3D52	0	3
Materials Handling 3D53	0	2
Motor Car Construction 3X45, 3X46	2	2
Ordnance Problems 3M53 (one hour a term for two years)	1	1
Hydraulic Power Plants 3M41, 3M42	2	2
Aerodynamics 3M51	2 or 0	0 or 2
Photoelasticity 3M55	0	3
Steam Power Plants 3P44, 3P45	2	2
Fluid Flow, Heat Transmission, and Air Conditioning 3P48	2	0
Refrigeration, 3P49	2	0
Power Plant Economics 3P50	0	2
Steam Turbine 3P51	0	2
Internal Combustion Engines 3P52	2	0
Steam Boilers and Boiler Plants 3P53	2	0
Graphical Computations and Representations 3P55	0	2
Experimental Engineering Research 3X51	1 to 3	1 to 3
Applied Metallography 3X52	2	0
Industrial Relations 3I46	2 or 0	0 or 2
Corporation Finance 3A34	0	3
A. S. M. E. Credit 3G51	0	1
Cornell Engineer Credit 3G52	0 or 2	2 or 0

FOR GRADUATES AND ADVANCED STUDENTS

Experimental Engineering Research 3X51	As assigned	
Special Hydraulic Power Plant Problems 3M52	2 to 5	2 to 5
Advanced Industrial Engineering 3I51	1 to 3	1 to 3
Advanced Heat-Power Engineering 3P60	1 to 5	1 to 5
Business and Industrial Research 3A51	As assigned	

ELECTIVE SUBJECTS IN OTHER SCHOOLS AND COLLEGES

Advanced Hydraulics 241	0	3
Hydraulic Measurements 242	3	0
Foundations 281	0 or 3	3 or 0
Engineering Law 290	0 or 3	3 or 0
Electrical Power Plants 441	3	0
Elements of Elect. Ry. Practice 461	2	0
Industrial Applications and Control 462	0	2
Transmission and Distribution 464	0	3
Illumination 466	0	2
Elementary Differential Equations 41	0 or 3	3 or 0
Patents 488	1	0
Advanced Calculus 42	3	3
Introductory Qualitative Analysis 210	0 or 3	3 or 0
Introductory Quantitative Analysis 225	0 or 3	3 or 0
Introductory Physical Chemistry (Lect.) 405	3	3
Introductory Physical Chemistry (Lab.) 410	3	3
Introductory Chem. Microscopy (Lect. and Lab.) 530	0 or 3	3 or 0
Metallography 545	2	0
Gas and Fuel Analysis 250	0 or 4	4 or 0
Physics courses dependent upon prerequisites (Consult the Department)		
Introductory Geology 100	3 or 0	0 or 3
Engineering Geology 501	4 or 0	0 or 4
Money and Banking 11	3 or 0	0 or 3
Industrial Hygiene 5	1	0
Public Speaking 1a	3 or 0	0 or 3

For other subjects such as Languages, History, Philosophy, Psychology, Government, Astronomy, Biology, Botany, Archaeology, Music, see the announcements of the colleges concerned.

2. A FIVE-YEAR COURSE LEADING TO THE DEGREE OF MECHANICAL ENGINEER

A five-year course leading to the Degree of Mechanical Engineer may be arranged. In general this curriculum includes all the work of one of the regular four-year courses, outlined on the preceding pages, with the addition of the equivalent of one year's work in studies, generally in the Arts and Sciences, designed to broaden the student's training.

There is no definite curriculum laid down for this course, since much depends upon the student's special interests, but the following curriculum suggests a possible arrangement. The Group Lectures and Design Courses provided for in the fifth year of the course are to be chosen from one of the options of the regular four-year course. The entrance requirements are the same as for the regular four-year course.

YEAR I

See Freshman Year, page 49.

YEAR II

See Sophomore Year, Option A, page 90.

YEAR III

	Hours 1st Term	2d Term
Heat-Power Engineering 3P31, 3P32	3	3
Mechanical Laboratory 3X31, 3X32	4	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Machine Shop 3S31	0	3
Applied Mathematics 3M32	3	0
Electives	6	5
Total number of hours each term	18	19

YEAR IV

Electrical Engineering 415, 416	3	3
Industrial Organization 3I31	2	0
Mechanical Laboratory 3X41, 3X42	4	4
Heat-Power Engineering 3P41, 3P42	3	3
Fluid Mechanics 3M33	0	4
Electives	6	4
Total number of hours each term	18	18

YEAR V

Group Lectures	2	2
Group Design	2	2
Electrical Engineering 435, 436	2	2
Heating, Ventilating and Refrigeration 3X44	3 or 0	0 or 3
Non-resident Lectures 3G41	0	1
Electives	10 or 13	12 or 9
Total number of hours each term	19	19

3. A FIVE-YEAR COURSE LEADING TO THE DEGREES OF MECHANICAL ENGINEER AND ELECTRICAL ENGINEER

In various fields of practice and investigation the mechanical engineer often has use for a more extensive training in electrical engineering than can be included in a regular four-year course in mechanical engineering; similarly, the electrical engineer may desire to have had more instruction in heat-power engineering, hydraulic-power engineering, mechanics, experimental engineering, and other phases of mechanical engineering than can be given in a four-year electrical engineering course. To meet these broader requirements it may be possible to rearrange the required work in the respective four-year curricula in mechanical and electrical engineering so that both the M.E. and E.E. degrees may be obtained in a five-year period of study. The necessary readjustment of work for obtaining the two degrees must be made with the Directors of the Schools of Mechanical Engineering and Electrical Engineering before the beginning of the student's second year.

4. A SIX-YEAR COURSE LEADING TO THE DEGREES OF A.B. AND M.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Mechanical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the Sibley School of Mechanical Engineering and to the Dean of the College of Arts and Sciences.

A FOUR-YEAR COURSE IN ADMINISTRATIVE ENGINEERING, LEADING TO THE DEGREE OF B.S. IN A.E., WITH SPECIAL REFERENCE TO MECHANICAL ENGINEERING

The keynote of this curriculum is the coordination of technical, economic, and business courses. The special work in non-technical subjects begins in the sophomore year and continues in increasing amount through the junior and senior years. In the last year a certain degree of specialization is permissible in either Mechanical or Electrical Engineering.

For schedule for the FRESHMAN YEAR, see page 49.

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Hydraulics 3M23	0	2
Kinematics, Recitations 3D25	3	0
Empirical and Kinematic Drawing 3D26	2	0
Materials of Engineering 3X21, 3X22	3	3
Pattern Shop 3S21	0	1
Foundry 3S22	1	0
Machine Shop 3S32	0	2
English 21	0 or 3	3 or 0
Technical Writing 3A33	2 or 0	0 or 2
Economic Organization 3A21	3	0
Business and Industrial Management 3A23	0	4
Graphical Computations 3P55	0	2
Total number of hours each term	19 or 20	20 or 19

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Heat-Power 3P33, 3P34	3	3
Machine Design, Recitations 3D34	2	0
Machine Design, Drawing 3D35	0	2
Mechanical Laboratory 3X33, 3X32	3	3
Electrical Engineering 405, 406	4	4
Accounting 3A31, 3A32	3	3
Business Statistics and Forecasts 3A41	0 or 3	3 or 0
Money and Banking, Economics 11	3 or 0	0 or 3
Total number of hours each term	18	18

SENIOR YEAR		
Industrial Engineering 3I43, 3I44	3	3
Industrial Relations 3I46	2	0
Cost Accounting 3I47	0	2
Corporation Finance 3A34	0	3
Engineering Business Law 3A43, 3A46	3	3
Industrial Marketing 3A44	3	0
Public Speaking 1	3 or 0	0 or 3
Mechanical Laboratory 3X41, 3X42	4	4
Non-resident Lectures 3G41	0	1
Electives	1 or 4	3 or 0
Total number of hours each term	19	19

A FIVE-YEAR COURSE LEADING TO THE DEGREES OF B.CHEM. AND CHEMICAL ENGINEER

Under this arrangement the student registers both in the College of Arts and Sciences (Department of Chemistry) and in the College of Engineering. The requirements for admission are those set by the College of Arts and Sciences for the B.Chem. degree, and are the same as those set for Engineering, with the exception that 3 units of one foreign language are mandatory (instead of 3 units in one language or 2 units in each of two languages) and in addition one unit of high school Chemistry is required.

The curriculum is outlined below. The student receives the degree of B.Chem. at the end of the fourth year and the degree of Chemical Engineer at the end of the fifth.

For description of the courses in Engineering contained in the curriculum, see pages following. There will be found also a brief description of the courses in Chemistry. For a more detailed description of these courses see the Announcement of the Department of Chemistry.

	Hours	
YEAR I	*1st Term*	*2nd Term*
Introductory Inorganic Chemistry (Chem. 110)	3	2
Inorganic Chemistry Laboratory (Chem. 115)	3	0
Introductory Qualitative Analysis (Chem. 203)	0	5
Analytic Geometry, Calculus (Math. 5a, 5b)	5	5
Introductory Experimental Physics (Physics 11, 12)	4	4
English (English 1)	3	3
Total number of hours each term	18	19
YEAR II		
Introductory Organic Chemistry (Chem. 305)	3	3
Organic Chemistry Laboratory (Chem. 310)	3	3
Introductory Quantitative Analysis (Chem. 220)	3	0
Quantitative Analysis Laboratory (Chem. 221)	3	0
Gas and Fuel Analysis (Chem. 250)	0	3
General Physics (Physics 21, 22)	3	3
Drawing (Drawing 125)	0	3
German (German 1b)	3	3
Total number of hours each term	18	18

In addition to these courses, sophomores are required to take Military Drill.

YEAR III

	Hours 1st Term	2d Term
Introductory Physical Chemistry (Chem. 405)	3	3
Physical Chemistry Laboratory (Chem. 410)	3	3
Introductory Chemical Microscopy (Chem. 530)	0	3
Elementary Mineralogy (Geology 311)	3	0
Mechanics (3M21)	5	0
Strength of Materials (3M22a)	0	3
Hydraulics (3M23)	0	2
Materials of Engineering (3X21, 3X22)	3	3
Total number of hours each term	17	17

YEAR IV

Unit Operations of Chemical Engineering (Chem. 705)	3	3
Chemical Engineering Laboratory (Chem. 710)	2	2
Advanced Inorganic Chemistry (Chem. 130)	3	3
Advanced Physical Chemistry (Chem. 420)	3	0
Advanced Quantitative Analysis (Chem. 230)	0	3
Special Topics in Chemistry (Chem. 910)	1	0
Heat-Power Engineering (3P33, 3P34)	3	3
Mechanical Laboratory (3X33, 3X32)	3	3
Total number of hours each term	18	17

YEAR V

Electrical Engineering Lectures (405, 406)	4	4
Machine Design (3D34, 3D36)	3	0
Mechanical Laboratory (3X43)	2	0
Industrial Organization (3I31)	2	0
Introduction to Economics (Economics 3)	0	3
Chemical Plant Design (Chem. 730)	3	3
Electives (hours each term variable)	3	7
Total number of hours each term	17	17

DESCRIPTION OF COURSES

COURSES FOR FRESHMEN

The courses for freshmen in Engineering are described on pages 49 to 52.

COURSES FOR SOPHOMORES, JUNIORS, AND SENIORS

I. COURSES GIVEN IN OTHER SCHOOLS AND COLLEGES

In the following list of prescribed courses, those in Chemical Engineering, Economics, English, and Physics are taught in the College of Arts and Sciences, and those in Electrical Engineering are given in the School of Electrical Engineering.

CHEMISTRY

(Required of Chemical Engineers or of Students taking Option G in M.E. page 96.)

Chemistry 110. Introductory Inorganic Chemistry. Throughout the year. Credit three hours first term, two hours second term. Prerequisite, entrance credit in chemistry, or course 101.

Lectures: Assistant Professor LAUBENGAYER. First term, T Th S 11; second term, T Th 11. *Baker* 107.

Chemistry 115. Introductory Inorganic Chemistry. Recitations and laboratory practice. First term. Credit three hours. Must be taken with the first term of Chemistry 110. Deposit, $20. Assistant Professor LAUBENGAYER and assistants.

Recitations: one hour a week, to be arranged.

Laboratory: W 1:40–4. S 8–10:30. *Baker* 50.

Chemistry 130. Advanced Inorganic Chemistry. Throughout the year. Credit three hours a term. Prerequisite or parallel courses, Chemistry 405 and 410. Assistant Professor LAUBENGAYER. M W F 11. *Baker* 107.

Lectures. The chemical elements are discussed in the order in which they occur in the Periodic Table of Mendeléeff, with special attention to the group properties of the elements and to the relations of the groups to one another. The rare elements are treated in as great detail as are the more common elements.

Chemistry 201. Introductory Analytical Chemistry. Repeated in the second term. Credit four hours. Prerequisite, Chemistry 101 and 105. Deposit, $20. Primarily for students majoring in the biological sciences. Professor NICHOLS, Dr. MORSE, and assistants. Lectures: T Th 10. *Baker* 177.

Laboratory sections: W F 1:40–4; S 8–1. *Baker* 252.

A study of the fundamental principles of qualitative and quantitative analysis. Laboratory practice in gravimetric and volumetric quantitative methods.

Chemistry 203. Introductory Qualitative Analysis. Second term. Credit five hours. Prerequisite, one term of Chemistry 110 or special permission. Deposit, $30. Must be taken with the second term of Chemistry 110. Required of candidates for the degree of Bachelor of Chemistry. Dr. BURFORD and assistants.

Lecture or recitation: M 9. *Baker* 177. One other recitation, to be arranged.

Laboratory: M W F 1:40–4. *Baker* 50.

Chemistry 220. Introductory Quantitative Analysis. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 203, or 205 and 206. Must be taken with Course 221. Professor NICHOLS, Mr. ————, and assistants.

Lectures: T Th 9. *Baker* 207.

Recitations: one hour a week, to be arranged.

A study of the fundamental principles of gravimetric and volumetric analysis with practice in stoichiometry.

Students in science are advised, and candidates for the degree of Bachelor of Chemistry are required, to take this course together with Course 221 instead of Course 225.

Chemistry 221. Introductory Quantitative Analysis. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 203, or 205 and 206. Must be taken with Course 220. Deposit, $20. Professor NICHOLS, Mr. ————, and assistants.

Laboratory sections: F 1:40–4, S 8–1; T Th 10–12:30, Th 1:40–4 (first term only). *Baker* 252.

Laboratory practice in the preparation and standardization of various volumetric solutions and the analysis of a variety of substances by volumetric and gravimetric methods.

Students in science are advised, and candidates for the degree of Bachelor of Chemistry are required, to take this course together with Course 220 instead of Course 225.

Chemistry 230. Advanced Quantitative Analysis. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 220 and 221 or special permission. Deposit, $20. Professor NICHOLS, Mr. ————, and assistants. Recitation: one hour a week, to be arranged. Laboratory periods; first term. T Th 1:40–4; T Th 8–12:30; second term, T Th 1:40–4; T Th 8–12:30; S 8–1. *Baker* 294.

Students will be assigned to a combination of laboratory periods that will total seven and one-half hours a week.

The calibration of weights and volumetric apparatus; the analysis of ferrous and non-ferrous alloys, silicates and organic substances by various gravimetric, volumetric, and combustion methods.

Chemistry 250. Gas and Fuel Analysis. Second term. Credit three hours. Prerequisite, Chemistry 220 and 221. Deposit, $10. Professor NICHOLS and assistants. Lectures: F 10. *Baker* 207.

Laboratory sections: M W 1:40–4; T or Th 10–12:30, 1:40–4; S 8–1. *Baker* 282.

The complete analysis of coal gas, flue gas, and air, the determination of the heating power of gaseous, liquid, and solid fuels; the analysis of coal; standard methods of testing various petroleum and coal-tar products; the analysis of various substances by methods involving the use of different types of gas evolution apparatus. Problems are assigned which afford practice in the calculation and interpretation of results.

Chemistry 305. Introductory Organic Chemistry. Throughout the year. Credit six hours on completion of the course. Prerequisite, Qualitative Analysis. Open to those who are taking Course 220. Professor JOHNSON and Dr. BRUCE. M W F 9. *Baker* 200.

Lectures and written reviews. The more important compounds of carbon, their occurrence, methods of preparation, relations and uses.

Chemistry 310. Introductory Organic Chemistry. Throughout the year. Credit three hours a term. Prerequisite or parallel course, Chemistry 305. Deposit, $35. Professor JOHNSON, Dr. BRUCE, and assistants. Laboratory sections: T Th 10–12:30, Th 1:40–4, S 8–1. *Baker* 250.

Laboratory practice and oral reviews. The student prepares a large number of typical compounds of carbon and familiarizes himself with their properties, reactions, and relations.

Chemistry 405. Introductory Physical Chemistry. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 305, Mathematics 5a and 5b and Physics 11 and 12 (or their substantial equivalent). Professor BRIGGS and assistants. Lectures, M W F 9. *Baker* 7.

A systematic presentation of modern physical chemistry. The topics include: the properties of gases, liquids, and solids; physical and chemical equilibrium in homogeneous and heterogeneous systems; the Mass Law, theorem of Le Chatelier, and the Phase Rule; thermochemistry and elementary thermodynamics; the theory of solutions; ionic equilibria and the concept of activity; chemical kinetics and catalysis; photochemistry; written problems in physical chemistry.

Chemistry 410. Introductory Physical Chemistry. Throughout the year. Laboratory and recitations. Credit three hours a term. Prerequisite or parallel course, Chemistry 405. Deposit, $20. Professor BRIGGS, Mr. ————, and

assistants. Laboratory sections: M T 1:40–4; Th F 1:40–4; and S 8–1. *Baker* 1. Recitations, to be arranged.

Qualitative and quantitative experiments illustrating the principles of physical chemistry and practice in performing typical physico-chemical measurements. Recitations on the general principles of physical chemistry, based upon the lectures given in Course 405.

Chemistry 420. Advanced Physical Chemistry. First term. Credit three hours. Prerequisite, Chemistry 405. Required of candidates for the degree of Bachelor of Chemistry. Assistant Professor KIRKWOOD. Lectures and recitations, M W F 12. *Baker* 7.

Exposition of the principles of physical chemistry from the mathematical standpoint, with emphasis on the solution of simple problems.

Chemistry 435. Chemistry of Solids. First term. Credit two or three hours. Prerequisite or parallel courses, Chemistry 405, and Chemistry 530 or 545 or special permission. Hours to be arranged. Professor MASON, Assistant Professor KIRKWOOD, and ————.

A general discussion of the formation and growth of metallic and chemical crystals, their physical and chemical behavior, and the relationships between lattice structure and chemical constitution. In the last third of the course, the physical chemistry of crystal lattices is covered in some detail.

Chemistry 530. Introductory Chemical Microscopy. Repeated in the second term. Credit three hours. Prerequisite, Chemistry 210 and 225 (or 205, 206, 220, and 221) and Physics 21 and 22, or by special permission. Fee, $5. Professor MASON and assistants.

Lecture: M 10. *Baker* 377.

Laboratory sections: M T 1:40–4; T Th 9–11:30. *Baker* 478.

Lectures and laboratory practice. The use of the microscope and its accessories; microscopic methods as applied to chemical and technological investigations: micrometry; the examination of crystalline compounds and industrial materials; recognition of textile and paper fibers, etc. The application of microscopic methods of quantitative analysis.

Chemistry 545. Introductory Metallography. First term. Credit two hours. Prerequisite or parallel course, Chemistry 405, or special permission. Fee, $5. Professor MASON and assistant. Th F 1:40–4; additional sections if warranted. *Baker* 384.

Laboratory practise, conferences, and reports. An introduction to the principles and methods involved in the study of the structure of metals. The relation of microscopical appearances to thermal history and mechanical properties. Preparation of specimens for macroscopic and microscopic study. Metallographic microscopics and their use.

Chemistry 550. Advanced Metallography. Second term. Credit variable. Prerequisite, Chemistry 545, and consent of the instructor. Fee variable. Professor MASON. Hours to be arranged. *Baker* 384.

Laboratory practise and reports. The work may be selected in accordance with the interests of the student, from topics such as heat treatment and structures of various ferrous or non-ferrous alloys, special methods of polishing, etching, and photomicrography, or minor research problems.

Chemistry 705. Unit operations of Chemical Engineering. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 405. Professor RHODES. Lectures, M W F 10. *Baker* 177.

A critical discussion of the important unit operations of chemical engineering: fluid flow, heat transfer, evaporation, distillation, filtration, gas absorption, crushing and grinding, etc. In these lectures particular emphasis is placed on the development of the fundamental theory upon which the various unit operations are based.

Chemistry 710. Unit Operations Laboratory. Throughout the year. Credit two hours a term. Prerequisite, Chemistry 405. Fee variable. Professor RHODES, Dr. WINDING, and assistants. Laboratory period, day and hour to be arranged. *Baker* B-78. Conference period, Th 11. *Baker* 207.

The study, in the laboratory, on a semi-plant scale, of the important unit operations of chemical engineering.

Chemistry 715. Unit Processes. Second term. Credit three hours. Prerequisite or parallel course, Chemistry 705. Professor RHODES. Lectures, M W F 11. *Baker* 177.

A discussion of the important typical unit processes of chemical engineering, as, for example, nitration, sulphonation, esterification, caustic fusion, chlori nation, etc.

Chemistry 725. The Chemistry of Fuels. First term. Credit three hours. Prerequisite or parallel course, Chemistry 705. Professor RHODES. Lectures. M W F 11. *Baker* 177.

The chemistry of coal, coke, petroleum, tars, and the fuel gases.

Chemistry 730. Chemical Plant Design. Throughout the year. Credit three hours a term. Prerequisite, Chemistry 705. Professor RHODES and Dr. WINDING. Conference and two laboratory periods, to be arranged.

Practice in the calculation and design of chemical plants.

Chemistry 735. Plant Inspections. Second term. Credit one hour. Prerequisite or parallel course, Chemistry 705.

Visits to plants typical of the various chemical industries. Conferences and reports. A trip during the spring vacation will be a feature of this course.

Chemistry 740. Chemical Engineering Computations. Throughout the year. Credit two hours a term. Prerequisite or parallel course, Chemistry 705. Dr. WINDING. Day and hour to be arranged.

Conferences and lectures. Problems in stoichiometric relationships, material balances and reaction rates, fluid flow and heat transfer, distillation, evaporation and drying, humidification and air conditioning, and filtration.

Chemistry 750. Furnace Metallurgy. Second term. Credit three hours. Lectures, hour to be arranged.

A discussion of the reactions involved in the smelting of ores and the furnace refining of metals. The discussion is accompanied by problems dealing with the various subjects discussed. Professor RHODES.

Chemistry 795. Research for Seniors. Either term. Credit two or more hours a term. Professor RHODES and Dr. WINDING.

Chemistry 910. Special Topics in Chemistry. First term. Credit one hour. Required of candidates for the degree of Bachelor of Chemistry. T 11. *Baker* 207.

The use of chemical literature; methods of research; administration of chemical laboratories; patent law; and other special topics.

ELECTRICAL ENGINEERING

Electrical Engineering 405, 406. Fundamentals of Electrical Engineering. Required of juniors in Administrative Engineering. Throughout the year. Credit four hours a term. Two lectures, a computing period and a laboratory period each week.

First Term: D. C. Electric and Magnetic Circuits; Study and Tests of D. C. Motors, Generators and Control Equipment; Simple A. C. Circuits.

Second Term: A. C. Circuits, Measurements and Machinery; Industrial Applications; Distribution and Rates. A study of fundamental electrical principles and machinery and the application of electrical equipment in industry. Professor R. F. CHAMBERLAIN, Assistant Professor B. K. NORTHROP, and Mr. SOHON.

Electrical Engineering 415, 416. Principles of Electrical Engineering. Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21, 22; Mechanics 3M21. Two lectures and a recitation-computing period a week. First term: Electric and magnetic circuits, and direct-current machinery. Second term: Alternating-current circuits and machinery. A study of the fundamental electrical principles and their practical application to commercial electrical circuits and machinery, with a view primarily towards enabling the student to choose intelligently the

proper type of electrical equipment for various service requirements met with in ordinary engineering practice. Assistant Professor STRONG and Messrs. MESERVE, BRISTOL, and RAMADANOFF.

Electrical Engineering 435, 436. Electrical Laboratory for M.E. Seniors. Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 21, 22, Mechanics 3M21, and E.E. 415, 416. Similar in scope to 431, 432. Professor CHAMBERLAIN and Mr. WOOD.

ENGLISH AND PUBLIC SPEAKING

English 21. First or second term. Credit three hours a term. Required of all sophomores in Administrative Engineering. A course in composition with readings mainly from contemporary English and American literature. Professor R. P. SIBLEY. M W F 12.

Public Speaking 1. Repeated in second term. Credit three hours. Required of Seniors in Administrative Engineering. Professor WICHELNS, Assistant Professors MUCHMORE and WAGNER, Mr. STINE, and Mr. ———. First term: M W F 9, 10, 11, 12; T Th S 9, 10, 11. Second term: M W F 9, 10, 11, 12; T Th S 9, 10.

Planned to give the fundamentals of speech preparation and to develop simple and direct speaking. Study of principles, and constant practice: readings on public questions; conferences; drills.

Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Assistant Professor THOMAS before registering for course 1.

PHYSICS

Physics 21. General Physics. Required of candidates for the degree of M.E. or E.E. First term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Two class-room periods a week and one laboratory period on alternate weeks. Laboratory work covering selected topics in electricity and magnetism. Assistant Professors GRANTHAM and COLLINS and instructors.

Physics 22. General Physics. Required of candidates for the degree of M.E. or E.E. Second term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Physics 21 desirable, but not required. Two class-room periods a week and one laboratory period on alternate weeks. Theory, problems and laboratory work covering such selected topics as thermionics, photoelectricity, photometry, kinetic theory, radiation, polarized light, and diffraction. Assistant Professors GRANTHAM and COLLINS and instructors.

For elective courses in other schools and colleges of the University, see page 103, and the special announcements of the schools and colleges.

II. COURSES GIVEN IN THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

These courses are listed alphabetically according to Department letters.

ADMINISTRATIVE ENGINEERING (A)

3A21. **Economic Organization.** Lectures, collateral reading, and discussion periods. First term. Credit three hours.

A study of the form and functioning of the arrangements by which men work together in economic production, and apportion the resulting product. Professor GARRETT.

3A23. **Business and Industrial Management.** Second term. Credit four hours. Required of all Sophomores in Administrative Engineering. Four lecture-discussion periods a week with regularly assigned problems. Prerequisite 3A21.

This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business and industrial ownership, together with the functions of finance, control, machine production, personnel and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study,

wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Professor BANGS.

3A31. **Accounting for Engineers.** Required of all A.E. and M.E. juniors. Given first term for A.E. and second term for M.E. juniors. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A21 or its equivalent. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; budgetary control; modern mechanical methods of performing the accounting function. Mr. MILLARD and others.

3A32. **Accounting for Engineers.** Second term. Required of all juniors in Administrative Engineering. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A31. Continues the work of first term 3A31, covering the extension of proprietorship; bond and stock issues and valuation; negotiable instruments; consolidations; mergers and holding companies; good will; depreciation; reserves; sinking funds; actuarial science; flexible budget; controversial accounting subjects; consolidated statements; statement analysis. Assistant Professor HANSELMAN.

3A33. **Technical Writing.** First or second term as assigned. Two recitations a week. Credit two hours. Required of all sophomores in Administrative Engineering. A study of the forms of written expression with emphasis on those most frequently used in engineering and business. The writing of short reports, editorials, news articles, technical magazine articles, simple advertisements, and book reviews. Composition of business letters, such as credit, inquiry, quotation, order, collection, adjustment and sales letters, with examples of internal correspondence of a corporation. Professor BANGS and Mr. LOBERG.

3A34. **Corporation Finance.** Second term. Credit three hours. Required of all seniors in Administrative Engineering, elective for upperclassmen in Mechanical Engineering. Prerequisite courses 3A21 and 3A31.

A study of the financial problems of the business corporation from the points of view of the management, the investor, and the public. Assistant Professor O'LEARY.

3A41. **Business Statistics and Forecasts.** First or second term. Three recitations a week. Credit three hours. Required of all juniors in Administrative Engineering. Prerequisite course 3A21. In 1036–37, first term only.

Elements of the technique of statistical analysis. The collection, preparation, and use of business statistics. The sources of information. Business indices and business barometers. Professor GARRETT.

3A43, 3A46. **Engineering Business Law.** Throughout the year. Credit three hours a term. Required of all seniors in Administrative Engineering. A study of the fundamental legal principles which relate to the usual business transactions with emphasis on the laws of contracts, agency, negotiable instruments, sales, and corporations, and on employers' liability and workmen's compensation. By the use of adequate case material the student is aided in his application of the general legal principles to specific situations. Assistant Professor HANSELMAN.

3A44. **Industrial Marketing.** First term. Required of all seniors in Administrative Engineering. Credit three hours. Two recitations and one lecture a week Prerequisite courses 3A21, 3A23, and 3A41. A study of the field of industrial marketing using the case method of instruction. The scope of the course includes product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Professor BANGS and Mr. LOBERG.

3A45. **Industrial Marketing.** Elective. Second term. Credit two hours. One recitation and one 2½ hour laboratory period a week. Prerequisite course 3A44. The application of the principles of marketing to specific problems. Each student will develop a complete market study and analysis for given industrial products. Professor BANGS and Mr. LOBERG.

3A51. **Business and Industrial Research.** Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a very limited number of

seniors and graduate students who have shown by training and aptitude their ability to carry on original investigations in business and industrial subjects. Professors BANGS and GARRETT, and Messrs. HANSELMAN, MILLARD, and LOBERG.

AERONAUTICAL ENGINEERING

(For courses in this subject see under Mechanics, (M) page 113.)

AUTOMOTIVE ENGINEERING

(See courses listed under Experimental Mechanical Engineering, (X), page 118.)

DRAWING AND DESCRIPTIVE GEOMETRY

(See under courses offered to Freshmen, page 50.)

MACHINE DESIGN (D)

3D21. **Kinematics Recitations.** Sophomores in Mechanical Engineering. First term. Credit two hours. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two recitations a week throughout the term on the theory of motion; the transmission of motion; the instant center method of determining linear and angular velocities; vector method of determining linear and angular velocities and accelerations; cams; rolling curves and friction gearing; etc. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D23. **Empirical and Kinematic Drawing.** Sophomores in Mechanical Engineering. First term. Credit two hours. Must be taken with course 3D21. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term, about twelve periods being devoted to empirical design and the remaining eighteen to drawing board applications of the theory and principles of course 3D21. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D24. **Kinematics, Recitations and Drawing.** Sophomores in Mechanical Engineering. Second term. Credit three hours. Prerequisite course 3D21. About twenty-five recitation periods and twenty drawing periods, for which two recitation and two drawing periods a week must be provided in the student's schedule. Recitation and drawing board work dealing with gears; gear cutting; linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D25. **Kinematics, Recitations.** Sophomores in Electrical and Administrative Engineering. First term. (Make-up section, second term). Credit three hours. Prerequisite courses 120 and 121 and Mathematics 5a and 5b. Three recitations a week throughout the term on the theory of motion; the transmission of motion; the instant center method of determining linear and angular velocities; cams; rolling curves and friction gearing; gears; gear cutting; linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D26. **Empirical and Kinematic Drawing.** Sophomores in Electrical and Administrative Engineering. First term. Credit two hours. Must be taken with course 3D25. Prerequisite Drawing courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term, about eight periods being devoted to empirical design and the remaining twenty-two to drawing board applications of the theory and principles of course 3D25. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D31. **Machine Design, Recitations.** Juniors in Mechanical Engineering. First term. Credit two hours. Prerequisite courses 3D21, 3D23, 3D24, 3X21, 3X22, 3M21 and 3M22a and b. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as suitability of materials, safety, lubrication, construction, etc. Professor ALBERT and Assistant Professor GARNER.

3D32. **Machine Design, Recitations.** Juniors in Mechanical Engineering. Second term. Credit two hours. Prerequisite course 3D31. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as suitability of materials, safety, lubrication, construction, etc. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY, MORRIS, and KNIGHT.

3D33. **Machine Design, Drawing.** Juniors in Mechanical Engineering. Second term. Credit three hours. Must be taken with course 3D32. Prerequisite course 3D31. Three drawing periods a week throughout the term. The student for the first time undertakes the design of a complete machine and makes all the necessary calculations and drawings. Orderly, systematic calculations are insisted upon and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the machine. The last third of the term is devoted to a dynamical problem. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY, MORRIS, and KNIGHT.

3D34. **Machine Design, Recitations.** Juniors in Electrical and Administrative Engineering and Seniors in Chemical Engineering. First term (Make-up section, second term.) Credit two hours. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M21, and 3M22a for Electrical and Administrative Engineers and 125, 3X21, 3X22, 3M21, and 3M22a for Chemical Engineers. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as lubrication, safety, suitability of materials, construction, etc. Professor ALBERT and Assistant Professor GARNER.

3D35. **Machine Design, Drawing.** Given the second term to Junior Electrical and to Junior Administrative Engineers. Credit two hours. Must be taken with course 3D34 or in the term following. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M21, and 3M22. Two drawing periods a week throughout the term. The student for the first time undertakes the design of a complete machine and makes all the necessary calculations and drawings. Orderly systematic calculations are insisted upon, and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the machine. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY and KNIGHT.

3D36. **Machine Design, Drawing.** Seniors in Chemical Engineering. Second term. Credit one hour. Prerequisite courses 125, 3X21, 3X22, 3M21, 3M22, and 3D34. One three-hour drawing period a week throughout the term. The work of the term includes a problem illustrative of the design of pressure vessels and the design of a single-cylinder, plunger pump fitted with a flywheel. Orderly systematic calculations are insisted upon, and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the pump. Professor ALBERT or Assistant Professor GARNER.

3D51. **Mechanical Technology as Related to Design.** An elective for sophomores and juniors in engineering. Second term. Credit three hours. Three one hour periods a week; thirty-five recitation and discussion periods, six lectures, and four written examinations a term. The purpose of the course is to show how the various mechanical processes are related to design and production. The course is based on textbooks, dealing principally with measuring and the processes of fashioning metals by machining, cutting, grinding, shearing, punching, drawing, rolling, hammering, pressing, moulding, etc. Each period is devoted to an oral quiz and informal discussion of the day's assignment, with occasional lectures on the general and particular relations of mechanical processes to design work. Professor ALBERT.

3D52. **Advanced Kinematics and Kinetics.** An elective for juniors, seniors, and graduates. Second term. Credit three hours. Prerequisite courses 3D21, 3D23, and 3D24, or 3D25 and 3D26. About twenty-four lecture and discussion periods and about twenty-one three-hour drawing periods during the term, for which two one-hour and two three-hour periods a week must be provided in the student's schedule. Graphical and semi-graphical treatment of linear and angular

velocities and accelerations and of the resulting forces, stresses, and strains due to the form and mass of the moving parts of mechanisms and machines. Vibration and critical speeds and the theoretical basis and use of balancing machines for securing static and running balance of machine parts will be treated so far as time permits. Professor ALBERT or Professor ROGERS.

3D53. **Materials Handling.** An elective for juniors, seniors, and graduates. Second term. Credit two hours. Prerequisite courses 3D21, 3D22, and 3D24, or 3D25 and 3D26. Two lectures a week throughout the term. Treatment and analysis of the known methods of handling different kinds of materials and of the principles and considerations involved in a proper choice of the method of handling any given kind of material. Professor ————.

EXPERIMENTAL MECHANICAL ENGINEERING

(See courses listed under letter X on page 118.)

GENERAL COURSES (G)

3G52. **Cornell Engineer Credit.** Undergraduate members of the *Cornell Engineer* Board may receive not to exceed two hours of University credit in each term of their senior year (i.e. a maximum credit of four hours) for work satisfactorily done for *The Cornell Engineer*, provided they are elected to the Board during or before their sophomore year, and continue active members to the end of the term in which credit is desired.

3G41. **Non-resident Lectures.** Required for graduation of all seniors in Mechanical and Administrative Engineering. These lectures are given at some hour in the day specially set aside in the senior schedules. Seniors may also be required to attend certain of the non-resident lectures given in E.E. 491. Notices of the lectures will be posted on the bulletin board of the Sibley School of Mechanical Engineering. A notebook showing a résumé of each lecture attended (not more than one page for each lecture) must be handed in at the Director's office during block week at the end of the second term.

3G51. **A.S.M.E., Student Branch.** Members of the junior and senior classes in Mechanical Engineering may obtain one hour elective credit in one, or both years, by joining the Student Branch of the American Society of Mechanical Engineers, and by attending all of the Branch Meetings during the year. Application for membership should be made at the Director's office in October of each year, or to Professor F. O. ELLENWOOD, Honorary Chairman of the Student Branch.

HEAT-POWER ENGINEERING

(See the courses listed under the letter P on page 114.)

HYDRAULIC POWER ENGINEERING

(See courses listed under letter M on page 114.)

INDUSTRIAL ENGINEERING (I)

3I31. **Industrial Organization.** Required of all juniors in Mechanical and in Electrical Engineering. Either term. Credit two hours. Open only to upperclassmen except by special arrangement. A course of lectures on modern industrial tendencies and the principles that underlie modern methods of production. The treatment includes not only the reasons for our changed methods of production but also discussion of the principal features of such industrial factors as factory legislation, factory welfare work, and modern methods of administration. Professor ————.

3I43, 3I44. **Industrial Engineering.** One lecture and five hours of laboratory each week throughout the year. Credit three hours each term. Required of all Administrative Engineers, and of Mechanical Engineers electing the Industrial Option. The laboratory work consists of a study of modern production and ma-

terials handling equipment, plant location, plant layout, time and motion study, production and materials control, plant organization, cost estimates, methods of overhead, distribution, etc. Much of this study is built around a case problem which concerns, in a specific and detailed manner, the location and layout of a factory for the production of automobile transmissions. Special emphasis is placed upon the economic factors involved in all industrial problems. The lectures cover the major features of modern industry as well as specific problems concerning the laboratory work. Professor LEE, and Messrs. ROY and VANDERBILT.

3I46. **Industrial Relations.** Two lectures or recitations a week during either term. Credit two hours. Prerequisite course 3I31, or 3A23. A discussion of the more important problems which arise from the relation of employer and employee under present conditions of industry. Such features are considered as the effect of organized labor, employment methods, methods of wage payment, committee systems, industrial education and personnel service activities in general. Professor LEE.

3I47. **Cost Accounting.** Second term. Credit two hours. Required of all students in Administrative Engineering and of Mechanical Engineering seniors electing the Industrial Engineering Option. One recitation or lecture and one two and one-half hour computing period. Prerequisite, course 3A31. A detailed study of manufacturing cost systems dealing with order costs, process costs, and standard costs. Professor LEE, and Messrs. ROY and VANDERBILT.

3I48. **Industrial Engineering.** Two recitation and discussion periods a week during the second term. Credit two hours. Prerequisite courses 3I43, and 3A31 or its equivalent. A consideration of problems in industrial organization and administration including budgetary control, control of materials and production; and a study of the economic and human factors involved in manufacturing. The case method of presentation is frequently used. Professor LEE and Messrs. ROY and VANDERBILT.

3I51. **Advanced Industrial Engineering.** Open to graduates and seniors who have completed the equivalent of 3I43 and 3I44. Professor LEE and Mr. ROY.

MACHINE DESIGN (D)

(See courses under letter D beginning on p. 109.)

MECHANICS OF ENGINEERING (M)

3M21. **Theoretical and Applied Mechanics.** Sophomores. First term. Credit five hours. Four recitations and one examination a week. Prerequisite courses, Mathematics 5a and 5b. Motion of a Particle: displacement, velocity, acceleration; graphs; force, mass, and acceleration; equations of motion; curvilinear and rectilinear motion; rotation about an axis; moments. Systems of Particles: external and internal forces; general equations of motion; parallel forces; center of gravity. Statics: single pieces, cords, pulleys, structures and mechanisms. Motion of a Rigid Body: translation; rotation, moment of inertia of solids; plane motion. Work and Energy: work, power, energy; friction, brakes, dynamometers; efficiency and regulation of machines. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD.

3M22a. **Strength of Materials.** Sophomores. Nine weeks of second term. Credit three hours. Four recitations and one examination a week. Prerequisite course 3M21. Stress, strain; strength and elastic properties of materials in tension, compression and shearing; riveted joints; torsion of shafts; helical springs; shear, moment, safe loading and deflection of simple beams; special beams; eccentric loads; columns; impact loads. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD, and Mr. WELANETZ.

3M22b. **Strength of Materials.** Sophomores in Mechanical Engineering. Six weeks of second term. Credit two hours. Four recitations and one examination a week. A continuation of course 3M22a. Continuous beams; combined stresses;

principal stresses; Mohr's circle of stress; theories of failure; thick walled cylinders; curved bars; unsymmetrical bending. Professor CORNELL and others.

3M23. **Hydraulics.** Sophomores in Administrative and Electrical Engineering. Six weeks of second term. Four recitations and one examination a week. Credit two hours. Prerequisite course 3M21. Hydrostatics: pressures and centers of pressure. Hydrokinetics: general equations of energy; orifices, weirs, nozzles, Venturi meters, etc.; losses of head; flow in pipes. Hydrodynamics: forces on stationary and moving bodies. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD, and Mr. WELANETZ.

3M32. **Applied Mathematics.** Juniors in Mechanical Engineering. First term. Credit three hours. Three recitations a week. Curve plotting, choice of coordinates and scale, straight line plotting of simple equations; logarithmic plotting; fitting empirical equations to experimental data; first and second order differential equations; vibration problems in engineering; linear, torsional, and flexural vibrations without and with damping; forced vibrations; critical speeds; problems with two degrees of freedom. Professor SWITZER and others.

3M33. **Fluid Mechanics. Juniors in Mechanical Engineering.** Second term. Credit four hours. One lecture and three recitations a week. The Mechanics of fluids, including liquids and gases. An extension of course 3M23 to include compressible as well as incompressible fluids; simplified theory of hydraulic turbines and centrifugal pumps. Professor SWITZER and others.

3M53. **Ordnance Problems.** Two lectures a week throughout the year. To be taken for two years. Credit one hour each term. Prerequisite courses 3M21 and 3M22a and b. Captain DAVIS.

3M55. **Photo-elasticity.** Elective for seniors and graduates. First term. Credit three hours. Two lectures and one laboratory period with report a week. Prerequisite course 3M22b. Optics of photo-elasticity; plane and circularly polarized light, monochromatic and white light, fringes, isochromatics and isoclinics; discussion of models, materials and preparation. Elements of elasticity, including equilibrium and compatibility equations for plane stress, and stress functions; methods for determining principal stresses from photo-elastic observations and computations, isopachics. In the laboratory, experiments on the calibration of color and fringe scales by tension, compression, and bending, are followed by tests on centrally loaded beams, and the determination of stress concentration factors. Professor SWITZER.

AERONAUTICAL ENGINEERING (M)

3M35. **Aerodynamics.** Juniors. Second term. Credit two hours. Prerequisite courses 3M21 and 3M22a and b. Two recitations a week. Principles of flight, airplane performance and stability calculations. Assistant Professor WOOD.

3M36. **Airplane Design.** Seniors. First term. Credit two hours. Prerequisite course 3M35. Two recitations a week. Weight and balance analysis, elements of stress analysis, layout principles. Term problem on preliminary design for an airplane. Assistant Professor WOOD.

3M45, 3M46. **Airplane Design.** Seniors. Throughout the year. Credit two hours each term. Prerequisite course 3M35. Course 3M36 must accompany or precede course 3M45. Two drawing periods a week. The student makes calculations and drawings similar to those required by the Department of Commerce for approval of the design of an airplane. Factory and airport inspection trips. Assistant Professor WOOD.

3M51. **Aeronautic Problems.** Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Prerequisite course 3M35 or its equivalent. Preparation of report on investigation of some specialized phase of aerodynamics such as airfoil characteristics, propeller characteristics, airplane performance, airplane stability, load factors for design, autogyro performance, rocket propulsion, or fluid resistance. Assistant Professor WOOD.

HYDRAULIC-POWER ENGINEERING (M)

3M41, 3M42. **Hydraulic Power Plants.** Seniors and graduate students. Lectures throughout the year. Credit two hours each term. Prerequisite courses 3M21, 3M22a, 3M22b and 3M33. Power Development: description, design, and cost of reservoirs, dams, headworks, water conduits, surge chambers, power house, tail race, construction plant. Hydraulic Turbines: construction, installation, operating characteristics including effects of water hammer in long pipe lines and variable head, selection of equipment, testing, governing, and speed regulation. Power Study: market for power, competition and rates, hydrology, head, economics of pondage and storage, power available and usable within the load curve, economy of auxiliary power. Water power legislation and the Federal Power Commission. During the entire course considerable emphasis is placed upon the financial problems of construction and operation of the water power plant alone and as part of a large power system. Some time is devoted to elementary concrete design and foundations. Professor SWITZER. [Not given in 1936–37.]

3M43, 3M44. **Hydraulic Power Plant Problems.** Seniors and graduate students. Computation periods throughout the year. Credit two hours each term. Must be accompanied by course 3M41, 3M42. Problems are assigned involving the principles taken up in course 3M41, 3M42. Design problems are given to show the applications of the fundamental principles of mechanics, machine design, and hydraulics, to the solution of problems in the water power field. The characteristics of hydraulic turbines are studied through the use of experimental data on turbine performance, and these results are applied to specific problems in power plant practice. Problems in stream flow, pondage and storage, power available and its use under specified load conditions conclude the work. Professor SWITZER. [Not given in 1936–37.]

3M52. **Special Hydraulic Power Plant Problem.** Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Must be preceded by or taken with 3M41, 3M42. Selected topics from course 3M43, 3M44 and other special problems to meet the individual needs of each student. Students who have completed course 3M43, 3M44 or equivalent, may elect this course for more advanced work. Professor SWITZER.

HEAT-POWER ENGINEERING (P)

3P31, 3P32. **Heat-Power Engineering.** Required of all juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21 and 22 and 3D21, 3D23, 3D24, 3M21, 3M22a and b. Two recitations and one lecture a week throughout the year. Thermodynamics of gases and vapors; ideal cycles and their application in air compressors, internal combustion motors, steam engines, turbines and power plants; modifications in actual machines; efficiencies and performances; study of engine losses and the usual means of reducing them; compound, uniflow, and other types of steam engines; types of air compressors, internal combustion engines. On account of the importance of a thorough understanding of this subject, the student is required to solve a large number of problems in the classroom. Assistant Professor MACKEY.

3P33, 3P34. **Heat-Power Engineering.** Required of juniors in Electrical Engineering and in Administrative Engineering. Not open to students in Mechanical Engineering. Throughout the year. Credit three hours a term. One lecture and two recitations a week. Prerequisite courses, Physics 21 and 22 and 3D25, 3D26, 3M21, 3M22a. The course is an abridged treatment of substantially the same ground as courses 3P31, 3P32, and 3P41, 3P42. The longer courses 3P31, 3P32, and 3P41, 3P42 may be substituted for this one. Assistant Professor HOOK.

3P41, 3P42. **Heat-Power Engineering.** Required of all seniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite course 3P31, 3P32. Three recitations a week. An extension of course 3P31, 3P32. Engine and turbine types; steam turbine theory, development of present forms, performance, economy, suitability for particular service; fuels and fuel resources; combustion, ideal and in the actual furnace and engine; steam generating units

and their performance; furnaces, boilers, superheaters, economizers, and air preheaters; exit losses; draft; heat transfer; flow in pipes; feed water heaters, condensers, cooling towers and other apparatus; feed water treatment; consideration of the economical combination of elements in plants. Refrigeration. Professor ELLENWOOD and Assistant Professor CLARK.

3P43. **Heat-Power Engineering.** Required of seniors in Civil Engineering. Either term. Credit three hours. Two lectures and one two-hour laboratory or computing period a week. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics 11 and 12 (or the equivalent), Chemistry 106a, b, C.E. 220 and 221. One lecture and two recitations a week. Elementary consideration of behavior of gases and vapors as applied to heat engines; study of air compressors, internal combustion motors, steam boilers, engines, turbines and condensers; contractors' plants; cost of energy; and similar topics. This course is recommended for all students who wish to obtain a general basic knowledge of Heat-Power Engineering without great technical detail. Professor ELLENWOOD.

3P44, 3P45. **Steam-Power Plants.** M.E. seniors in Option A. Lectures throughout the year. Credit two hours a term. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32; must be accompanied or preceded by courses 3P41 and 3P42. Load curves; station factors; power-plant economics; cost of plants and of their equipment and output; principles of economic selection of plant equipment with respect to the load curve, cost factors and local conditions; steam prime movers, steam generators, condensers, and other plant apparatus; performance characteristics and design features of this apparatus; piping; coal and ash storage and conveying machinery; plant location; plant layout; and similar topics. Professor BARNARD.

3P46, 3P47. **Computing and Design.** M.E. seniors in Option A. Throughout the year. Credit two hours a term. Must be accompanied by 3P44, 3P45. Two three-hour periods a week. The practical solution of problems discussed in 3P44, 3P45. Professor BARNARD.

3P48. **Air Conditioning.** Elective for seniors in Mechanical, Administrative, or Electrical Engineering. First term. Credit two hours. Prerequisite courses, 3P31 and 3P32, or 3P33 and 3P34. Properties of mixtures of air and water vapor and the principles of air conditioning, including the heating, cooling, humidifying dehumidifying, filtering, and distribution of air in enclosures for improving human comfort or for the control of the properties of hygroscopic materials. Assistant Professor MACKEY.

3P49. **Refrigeration.** Elective. M.E., E.E., and A.E. seniors. First term. Credit two hours. Prerequisite course 3P32 or 3P34. Two lectures or recitations a week. A course dealing with the general principles, applications, and economic and commercial factors involved in various forms of modern refrigeration as applied to both domestic and industrial installations, including those pertaining to air conditioning. Professor ELLENWOOD.

3P50. **Power Plant Economics; Equipment Selection.** Elective for seniors. First term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. Two lectures a week. Cost of equipment and plants: energy costs; load curves, station factors; determining characteristics of equipment; selection of working pressures and temperatures and cycles; proper load distribution; economic number and size of units; selection of equipment based on these and other determining considerations; economic operation. Applications to central stations and to industrial power and heating plants. Other similar topics. Professor BARNARD.

3P51. **Steam Turbines.** Elective for seniors. Second term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. Two lectures a week. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbine in engineering practice. Assistant Professor CLARK.

3P52. **Internal Combustion Engines.** Elective for seniors. First term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33 and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Seminar. Reports and discussions. Fuels; general theory and salient points in the design and operation of internal combustion engines; study of existing commercial types, relative advantages, and questions of economy; current developments. Assistant Professor CLARK.

3P53. **Steam Boilers and Related Apparatus.** Elective. Seniors. Second term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Fuels, combustion, combustion apparatus; furnace and boiler types, proportions, materials, design of details; superheaters, economizers, air heaters; accessories; equipment, arrangement and operation of steam generating plants. Professor BARNARD.

3P55. **Graphical Computation and Representation.** Elective. Second term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33, 3P31, 3P32 or 3P33, 3P34. Slide rules; construction of net work charts and alignment charts for the solution of equations; representation of statistics; and derivation of empirical equations from experimental curve. Assistant Professor MACKEY.

3P57, 3P58. **Heat Engineering.** Throughout the year. M.E. seniors. Credit four hours a term. Must be accompanied or preceded by 3P41 and 3P42. Properties of mixtures, dimensional analysis, fluid flow, heat transmission, selection of fans and pumps, and refrigeration; applications to problems in air conditioning. Assistant Professor MACKEY.

3P60. **Advanced Heat-Power Engineering Research.** Elective for graduate students and others qualified for study in this field. Work and credit as arranged with Professors BARNARD and ELLENWOOD, and other members of the department.

SHOP WORK AND MACHINE CONSTRUCTION (S)

(For courses in Wood Working and Introductory Engineering Laboratory, see Courses 102 and 103 under courses offered to freshmen, page 50.)

3S22. **Foundry Work.** Required of M.E. and A.E. sophomores. Either term. Credit one hour. One two and one-half hour period a week. Moulding, core making, mixing, and casting of metals; use of moulding machines. Demonstrations of large work and production in quantities. Mr. PATTERSON.

3S21. **Pattern Making.** Required of M.E. and A.E. sophomores. One hour either term as assigned. Pattern making: the use of hand and machine tools, followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third Floor.*

3S31. **Machine Work.** Required of M.E. juniors. Credit three hours one term. Nine hours of work a week. Prerequisite courses 102, 103, 3S22, and 3S21. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and SCHALLOWITZ.

3S32. **Machine Work.** Required of A.E. and E.E. sophomores. Prerequisites 102 and 103. Credit two hours one term. Six hours of work a week. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and SHALLOWITZ.

EXPERIMENTAL MECHANICAL ENGINEERING (X)

The work in this department is given in five divisions: 1. Courses in Materials of Engineering and in Materials Testing Laboratory; 2. Courses in General Mechanical Laboratory Practice; 3. Heating, Ventilating and Refrigeration; 4. Courses in Automotive Engineering; and 5. Courses in Experimental Mechanical Engineering Research.

1. Courses in Materials and Materials Testing

3X21. **Engineering Materials.** Required of M.E. and A.E. in M.E. sophomores. First term. Credit three hours. Prerequisite Chemistry 106 a and b. Lectures on Fuels, Refractories, and Iron and Steel Metallurgy. Professor Diederichs.

3X22. **Engineering Materials.** Required of M.E. and A.E. in M.E. sophomores. Second term. Credit three hours. Prerequisite Chemistry 106 a and b, and 3X21. A continuation of 3X21. Lectures on the Constitution of Alloys, Heat Treatment of Steel, Alloy Steels, Properties of Materials, Corrosion, Boiler Water Treatment, Lubricants and Lubrication. Non-Ferrous Metals and Alloys and Non-Metallic Materials are covered by assigned collateral reading. Professor Diederichs.

3X23. **Engineering Materials.** Required of E.E. and A.E. in E.E. sophomores. First term. Credit two hours. Prerequisite Chemistry 106 a and b. An abridgment of Course 3X21 suited to the needs of students in Electrical Engineering. Mr. Goodman.

3X24. **Engineering Materials.** Required of E.E. and A.E. in E.E. sophomores. Second term. Credit two hours. Prerequisite Chemistry 106a and b, and 3X23. An abridgment of 3X22 and a continuation of Course 3X23 for students in Electrical Engineering. Mr. Goodman.

2. Mechanical Laboratory Practice

3X31. **Mechanical Laboratory—Properties of Engineering Materials.** M.E. Juniors. First term. Credit four hours. Prerequisite courses 3X21, 3X22, 3M21, 3M22 a and b. One laboratory period a week. Mechanical strength of materials; tension, torsion, transverse, and compression tests; the variation of the mechanical strength with differences in composition or heat treatment; demonstration of different methods of tempering, annealing, forging, etc. The student is required to write and submit one report each week upon the experiment of the previous week. Professor Davis and instructors.

3X32. **Mechanical Laboratory—Introductory Experimental Engineering.** M.E., E.E. & A.E. juniors. Second term. Credit three hours. Prerequisite courses, Mechanics 3M21, Strength of Materials 3M22a, Chemistry 106 a, b, Physics 21 and 22. One laboratory period a week as assigned; one written report a week. Calibration of indicator springs, steam gauges, thermometers, and dynamometers; flue gas analysis and calculations; viscosity and friction tests of lubricants on various testing machines; tests of heating values of coals; steam quality tests, with various forms of calorimeters; tests of ignition and carburetion of gasoline engines, etc. Reports are required and must include all the data and results of the various tests, together with conclusions. The preparation of the report is considered an important part of the course. Professor Davis and instructors.

3X33. **Mechanical Laboratory—Properties of Engineering Materials.** E.E. and A.E. juniors. First term. Credit three hours. Contents practically as course 3X31.

3X41. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and in Administrative Engineering in M.E. First term. Credit four hours. Prerequisite courses 3X32, 3P31, 3P32 and 3M22 a and b. One laboratory period a week. Efficiency tests of gas and gasoline engines, steam injectors, steam turbine, blowing fan, hydraulic turbine, and centrifugal pump. A written report is required for each experiment. Reports must be full and complete, and include data and results of each test, the testing methods used, the basic theory of the apparatus, and the performance results expressed numerically and graphically, with discussion. Professor Gage, Assistant Professor Andrae, and instructors.

3X42. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and in Administrative Engineering in M.E. Second term. Credit four hours. One laboratory period a week alternating with one com-

puting period. A written report is required on each experiment. Detailed study of methods of testing and methods of computation in the following subjects: testing of engines and boilers, air compressors, ice machines; measurement of flow of water and air, etc. Reports required as in 3X41. Professor GAGE, Assistant Professor ANDRAE, and instructors.

3X43. **Mechanical Laboratory.** Required of seniors in Electrical Engineering and in Administrative Engineering in E.E. First term. Credit two hours. Prerequisite courses 3X32, 3P33, 3P34, 3M23. Selected experiments from Course 3X41. Professor GAGE, Assistant Professor ANDRAE, and instructors.

3. HEATING, VENTILATING, AND REFRIGERATION

3X44. **Heating, Ventilating, and Refrigeration.** Required of seniors in Mechanical Engineering. Either term. Credit three hours. Lectures or recitations covering the methods of design and construction of various forms of heating and ventilating apparatus, and the principles of refrigeration. Professor SAWDON.

4. AUTOMOTIVE ENGINEERING

3X45, 3X46. **Motor Car Construction.** Seniors and graduates. Credit two hours each term. Two lectures a week, illustrated. Either term's lectures may be used as a senior elective. First term work deals with design of chassis and body, and power requirements for operation; second term deals with power plant design and operation. Professor UPTON.

3X47, 3X48. **Motor Car Construction.** Seniors. Drawing room, computing, or laboratory work paralleling the lecture courses 3X45, 3X46. Professor UPTON.

5. EXPERIMENTAL MECHANICAL ENGINEERING RESEARCH

3X51. **Experimental Engineering Research.** Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a limited number of seniors and graduates who have available at least two laboratory periods a week and who have shown proficiency in engineering subjects. Special problems and investigations which are in general carried on in the laboratories under the immediate direction of the members of this department. Professors DIEDERICHS, SAWDON, UPTON, GAGE, and DAVIS.

3X52. **Applied Metallography.** Elective. First term. Credit two hours. Prerequisite course 3X21, 3X22. Covers in historical sequence the development of knowledge of the internal structure of metals, and the relation of structure and properties; the technique of metallographic research, study of application of the laws of physical chemistry to interpretation and correlation of results. Study of stable and metastable conditions; heat treatment theory and practice. The practical aim of metallography is constantly emphasized. Professor UPTON.

SCHOOL OF ELECTRICAL ENGINEERING

OUTLINE OF THE INSTRUCTION

The regular four-year course in Electrical Engineering provides a strong fundamental training in the analytical study of scientific subjects common to all branches of professional engineering. On this foundation is built a broad introduction to the basic work in the several branches of general engineering technology, economics and administration, together with a major study of electrical engineering principles and their application in various fields.

A large proportion of the work in Mechanical Engineering is also taken by those who elect Electrical Engineering, so that the student is not limited in his outlook nor in his choice of work after graduation. For those desiring a still broader training, which shall include more of the liberal arts, a six-year course leading to the degrees of A.B. and E.E., is offered. (See page 124.)

The study in electrical engineering proper is begun in the Sophomore year, as soon as the student is sufficiently advanced in the fundamental sciences, and gradually becomes the major study. In the senior year the student is given considerable opportunity to study in the field which most interests him, although with no neglect of the more advanced study of his basic electrical engineering principles.

The instruction in Mathematics, Physics, Chemistry, and English is given in the College of Arts and Sciences. All other subjects in the regular curriculum are given in the various departments of the Sibley School of Mechanical Engineering, the School of Civil Engineering, and the School of Electrical Engineering.

The following is a brief outline of the scope and purposes of instruction in the various departments of the School of Electrical Engineering:

1. Fundamentals of Electrical Engineering

Beginning with the second term of the Sophomore year, instruction is given in fundamental electrical phenomena and relations, in the characteristics of electric, magnetic, and electrostatic circuits, and in the characteristics of direct current generators, motors, and allied equipment. The work is carefully arranged in sequence and difficulty to promote efficient study and effective understanding. The physical phenomena are expounded and demonstrated in the lecture room together with their mathematical analysis. Study of lecture material and text is assigned for home work and applied to the solution of simple problems. More difficult problems are solved in the computing room under the supervision of the instructor, and recitation periods are provided for the prompt clarification of common difficulties in concept, analysis, application, or computation.

Care is exercised, not only to build in the student's mind an orderly fund of factual information in which he may find continued confidence, but also to teach him to apply his information effectively, and to develop his judgment, sense of proportion, and accuracy.

In the Junior year instruction is given in alternating current fundamentals, in characteristics of ac circuits, and in ac machinery and equipment. The work is conducted in manner similar to that pursued in the Sophomore year.

The work given to Mechanical and Administrative students is no less fundamental than that given to Electrical students but is necessarily less extensive and is selected and presented in sympathy with their probable needs and point of view. Instruction is conducted, as for the electrical students, by lecture, homework, computation and recitation in a carefully coordinated sequence of study.

2. Advanced Electrical Engineering Theory and Practice

The object of the instruction in this department is to train the student in the principal quantitative methods and mathematical tools used in electrical engineering. First a bit of theory is taken up at a lecture or a recitation and a few simple numerical problems are solved by the student at home; then at least one practical application of the same theory is discussed, and finally a more elaborate practical layout is analyzed in the computing room. It is aimed to teach the theory and practice side by side, except in the Junior year where some mathematical topics are taught in anticipation of their use during the Senior year.

From the point of view of electrical engineering, the course consists of four main divisions: the electric circuit, the magnetic circuit, dielectrics, and gaseous conduction of electricity. From the point of view of mathematics, in addition to the usual analytic geometry and calculus, the following topics are taught and made use of: determinants, complex quantities, vectors, Fourier series, differential equations, hyperbolic functions, and probabilities.

A separate elective course in "Engineering Mathematics" is given to those Seniors who wish to pursue a special mathematical topic, or who are interested in one of the foregoing topics beyond their required scope.

3. Experimental Electrical Engineering

Throughout the junior and senior years, the student receives instruction in the electrical laboratories which closely parallels and is coordinated with the theoretical instruction. The laboratory work is carried on with the purpose of developing in the student a scientific attitude of research as well as to teach him the characteristics of the equipment and the methods of testing. In the first term of the junior year the student prepares experiments on direct-current circuits, generators, motors, and controllers and alternating-current circuits and measurements. The second term is devoted entirely to Electronics with experiments on vacuum tubes, gas conducting devices,

mercury vapor rectifier, and inverters. In the senior year the student gets a more advanced course in electrical machinery, covering the operation of generators in parallel, synchronous generators and motors, converters, transformers and a study of the properties of magnetic and dielectric materials. This work is planned to afford constant original application of principles previously covered in the theory courses.

4. Electrical Communication Engineering

In the courses in Communication Engineering the problems of radio, telephony and telegraphy are treated. The student in the second term of the junior year is given a course on the fundamentals of electronic devices, and studies their characteristics and theory of operation. While the course in electronics is not specifically limited to apparatus designed for communication purposes, it does treat of the fundamentals of electron tubes and similar apparatus, and serves as a basis for the more advanced instruction during the senior year. The work of the first term, senior year, is devoted to a study of communication apparatus and circuits, with special emphasis on the application of thermionic tubes to the art. The work of the second term is a continuation of the first term, and treats of the more advanced aspects of electrical communications, such as transmission theory over wires and through the ether, radiations systems and associated circuits. In connection with two auxiliary courses offered during the second term, the student is given an opportunity to specialize to a limited degree either in advanced circuit theory or practical operation.

5. Electrical Design

The object of this course is to set forth the fundamental principles upon which the design of electrical apparatus is based. (Generators, motors, and transformers.) Instruction is given both by recitation and computation of typical machines. This course is particularly recommended to those students who anticipate employment by electrical manufacturing companies.

6. Power Generation, Transmission, and Distribution

These subjects are studied not only from a technical viewpoint but also from the economic viewpoint as well. While it is well recognized that a thorough understanding of the technical problems arising in power generation, transmission and distribution is essential, it is also recognized that the economic problems arising in this field are no less essential.

7. Economics of Public Utilities

As the name implies, this course is a study of the economic questions arising in the conduct of Public Utilities, particularly electric utilities. The importance of such a study is hardly open to question.

8. Electrical Applications and Control

Courses are given in this department covering the principles of electric railway practice and industrial applications and control.

COURSES LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

1. THE REGULAR FOUR-YEAR COURSE

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop, laboratory, computing room, or drawing room count as one hour of credit, while each recitation hour assumes about two hours of outside preparation and counts as one hour of credit.

FRESHMAN YEAR

There is fundamentally a single schedule of studies prescribed for all students in the freshman year of the College of Engineering. That schedule is set forth in full under the head THE FRESHMAN YEAR, beginning on page 49.

SOPHOMORE YEAR

	Hours	
	1st Term	*2nd Term*
Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Hydraulics 3M23	0	2
Physics 21, 22	3	3
Kinematics, Rec. 3D25	3	0
Kinematics, Dwg. 3D26	2	0
Materials 3X23, 3X24	2	2
Econ. Organization 3A21	3	0
Machine Shop 3S32	0	2
Elec. Engineering 410	0	4
English or Pub. Speaking	0	3
	18	19

In addition to taking the courses named in the above schedule, all sophomores must satisfy the University's requirement of three hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

JUNIOR YEAR

Elec. Engineering Principles 411a, 412a	5	4
Elec. Engineering Lab. 431	3	0
Electronics 450	0	4
Heat Power 3P33, 3P34	3	3
Mech. Laboratory 3X33, 3X32	3	3
Machine Design 3D34	2	0
Industrial Organization 3I31	2	0
Applied Mathematics 420	0	3
Elective	0	2
	18	19

SENIOR YEAR

Electrical Engineering Practice 421, 422	2	2
Electrical Engineering Principles 423, 424	3	3
Electrical Engineering Laboratory 433, 434	3	4
Mechanical Laboratory 3X43	2	0
Non Resident Lectures 491	0	1
*Elective	8	8
	18	18

*Of the elective hours, at least 8 must be taken in the School of Electrical Engineering. The remainder of the elective hours may be taken in any department of the University, provided the student has the necessary preparation and the approval of his class adviser.

ELECTIVE COURSES OF STUDY

A student may elect any course of study offered by any department of the University, provided he has the necessary preparation for that course and the approval of his class adviser.

Not more than four hours credit in Advanced Military Science, in addition to the required military training of the freshman and sophomore years, will be accepted toward meeting the requirements for the E.E. degree.

Following is a list of technical electives to be given in the School of Electrical Engineering; they are for seniors and graduate students only.

	Hours	
	1st Term	*2nd Term*
Electric Power Plants 441	3	0
Electrical Machine Design 442	0	4
Economics of Public Utilities 444	0	2
Electric Transmission and Distribution 464	0	3
Electrical Communication Engineering 451, 452	3	3
Electrical Communication Network Theory 452a	0	2
Elements of Broadcast Engineering 452b	0	2
Elements of Electric Railway Practice 461	2	0
Industrial Applications and Control 462	0	2
Current Topics in Electrical Engineering 471, 472	2	2
Engineering Mathematics 481, 482	2	2
Heaviside's Operational Analysis 486, 487	3	3
Patents 488	1	0
Special Electrical Engineering Problems 483, 484	1–3	1–3
A.I.E.E. 492	0	1

OPTIONS IN PHYSICS, CHEMISTRY, MATHEMATICS

While no rigid curriculum is given, an E.E. Junior with high scholastic grades in Mathematics, Physics and Mechanics, and a satisfactory record in his other Freshman and Sophomore courses may, with the approval of his class adviser, substitute a group of courses in Physics and allied subjects for as much as necessary of the following required work in the Regular-Four-year course; substitution being permissible only after all elective hours are used:

JUNIOR YEAR

Machine Design 3D34	2–0
Industrial Organization 3I31	2–0
	4–0

SENIOR YEAR

Mechanical Laboratory 3X43	2–0

Juniors of high standing who wish to substitute a group of courses in other fields than Physics, such as Mathematics, Chemistry, or Economics, may be given special permission to omit from the regular required work the same courses as for the Physics Option.

Permission to continue in the above options may be withdrawn at any time should the student's scholastic standing in any of his work be not satisfactory.

2. A FIVE-YEAR COURSE LEADING TO THE DEGREES OF ELECTRICAL ENGINEER AND MECHANICAL ENGINEER

In various fields of practice and investigation the electrical engineer may need to have had more instruction in heat-power engineering, hydraulic-power engineering, mechanics, experimental engineering, and other phases of mechanical engineering than can be given in a regular four-year course in electrical engineering; similarly, the mechanical engineer often has use for a more extensive training in electrical engineering than can be included in a four-year course in mechanical engineering. To meet these broader requirements it may be possible to rearrange the required work in the respective four-year curricula in mechanical and electrical engineering so that both the M.E. and E.E. degrees may be obtained at the end of a five-year period of study. The necessary readjustment of work for obtaining both degrees must be made with the Directors of the Schools of Electrical Engineering and Mechanical Engineering before the beginning of the student's second year.

3. A SIX-YEAR COURSE LEADING TO THE DEGREES OF A.B. AND E.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Electrical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Electrical Engineering and to the Dean of the College of Arts and Sciences.

4. A FOUR-YEAR COURSE IN ADMINISTRATIVE ENGINEERING LEADING TO THE DEGREE OF B.S. IN A.E. WITH SPECIAL REFERENCE TO ELECTRICAL ENGINEERING

The object of this course is given under the heading "Administrative Engineering" on page 85.

The course differs from that offered in Mechanical Engineering in that more stress is given to fundamental Electrical Engineering with special reference to the applications of Electrical Power and to Public Utility Engineering.

The requirements for admission are the same as for the regular four-year E.E. course, see page 22.

It is possible by an additional year of study to receive the Electrical Engineering degree, provided the student signifies this intention at the beginning of the sophomore year.

FRESHMAN YEAR

	Hours 1st Term	2nd Term
Mathematics 5a, 5b	5	5
Physics 11, 12	4	4
Chemistry 106 a, b	3	3
Descriptive Geometry and Drawing 120, 121	3	3
Surveying 111	2 or 0	0 or 2
Wood Shop 102	0 or 1	1 or 0
Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours each term	19	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

SOPHOMORE YEAR

Mechanics 3M21	5	0
Strength of Materials 3M22a	0	3
Hydraulics 3M23	0	2
Kinematics, Recitations 3D25	3	0
Empirical and Kinematic Drawing 3D26	2	0
Materials of Engineering 3X21, 3X22	3	3
Pattern Shop 3S21	0	1
Foundry 3S22	1	0
Machine Shop 3S32	0	2
English 21	0 or 3	3 or 0
Technical Writing 3A33	2 or 0	0 or 2
Economic Organization 3A21	3	0
Business and Industrial Management 3A23	0	4
Graphical Computations 3P55	0	2
Total number of hours each term	19 or 20	20 or 19

In addition to taking the courses in the above schedule, all sophomores must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or Physical Training; see the General Information Number).

JUNIOR YEAR

Heat-Power 3P33, 3P34	3	3
Machine Design, Recitations 3D34	2	0
Machine Design, Drawing, 3D35	0	2
Mechanical Laboratory 3X33, 3X32	3	3
Electrical Engineering 405, 406	4	4
Accounting 3A31, 3A32	3	3
Business Statistics and Forecasts 3A41	3 or 0	0 or 3
Money and Banking, Economics 11	0 or 3	3 or 0
Total number of hours each term	18	18

SENIOR YEAR	Hours 1st Term	2nd Term
Industrial Engineering Problems 3I43, 3I44	3	3
Industrial Relations 3I46	2	0
Cost Accounting 3I47	0	2
Corporation Finance 3A34	0	3
Engineering Business Law 3A43, 3A46	3	3
Industrial Marketing 3A44	3	0
Public Speaking 1	3 or 0	0 or 3
Mechanical Laboratory 3X43	2	0
Electrical Engineering 401, 402	3	3
Non-resident Lectures 3G41	0	1
Electives	1 or 4	3 or 0
Total number of hours each term	20	18

A LIST OF THE COURSES OF INSTRUCTION

For Freshmen

A description of the courses of instruction for freshmen is given under the head The Freshman Year, beginning on page 49.

1. Courses Given in Other Schools and Colleges

Description of courses given by the various departments of Mechanical Engineering as well as descriptions of courses in Physics and Chemistry common to both schools will be found in the list of courses of instruction of the Sibley School of Mechanical Engineering beginning on page 83.

Information about other courses, not given in the College of Engineering, will be found in the Announcements of the Colleges concerned. (See back cover.)

2. Description of Courses Given in the School of Electrical Engineering

401. **Industrial Applications of Electrical Power.** Required of seniors in Administrative Engineering in Electrical Engineering. Three hours a week. First term only. A study of the principles underlying the economic application of electricity to industrial problems such as motor drives and control; electric heating and the use of electric furnaces and ovens; transportation and handling of materials; illumination and its effect on economic production. Professor Chamberlain.

402. **The Economics of Public Utilities.** Required of seniors in Administrative Engineering in Electrical Engineering. Second term only. Three recitations a week. A study of the Origin and Development of Public Utilities, Franchises, Regulation and Legislation, Valuation, Rates and Rate Structures, Public Ownership and Public Relations. Professor Lincoln.

405, 406. **Fundamentals of Electrical Engineering.** Required of juniors in Administrative Engineering. Throughout the year. Credit four hours a term. Two lectures, a computing period and a laboratory period each week.

First Term: D. C. Electric and Magnetic Circuits; Study and Tests of D. C. Motors, Generators and Control Equipment; Simple A. C. Circuits.

Second Term: A. C. Circuits, Measurements and Machinery; Industrial Applications; Distribution and Rates. A study of fundamental electrical principles and machinery and the application of electrical equipment in industry. Professor R. F. Chamberlain, Assistant Professors E. M. Strong, B. K. Northrop, and Mr. Bristol.

410. **Elements of Electrical Engineering.** Required of sophomores in Electrical Engineering. Second term only. Credit four hours. Prerequisite courses Physics 11, 12, Mathematics 5a, and 5b.

Two lectures and two computing periods a week. An introductory study of d. c. electric and magnetic circuit fundamentals and their application to d. c. electrical machinery and equipment. Assistant Professor STRONG, Dr. MESERVE and Mr. COTNER.

411a. **Elements of Electrical Engineering.** Required of juniors in Electrical Engineering. First term only. Credit five hours. Prerequisite E.E. 410. Two lectures, one recitation and two computing periods a week. An introductory study of a. c. circuit fundamentals. Assistant Professor STRONG, Dr. MESERVE and Mr. COTNER.

412a. **Elements of Electrical Engineering.** Required of juniors in Electrical Engineering. Second term only. Credit four hours. Prerequisite E.E. 411a. One lecture, one recitation and one laboratory computing period a week. A continuation of E.E. 411a. Application of circuit fundamentals to a. c. machinery and equipment. Assistant Professor STRONG, Dr. MESERVE and Mr. COTNER.

415, 416. **Principles of Electrical Engineering.** Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite course, Mechanics 3M21. Two lectures and a recitation-computing period a week. First term: Electric and magnetic circuits, and direct-current machinery. Second term: Alternating-current circuits and machinery. A study of the fundamental electrical principles and their practical application to commercial electrical circuits and machinery, with a view primarily towards enabling the student to choose intelligently the proper type of electrical equipment for various service requirements met with in ordinary engineering practice. Assistant Professors STRONG, M. G. NORTHROP, Dr. RAMADANOFF, and Dr. WIKSTROM.

417. **Essentials of Electrical Engineering.** Required of seniors in Civil Engineering. One term only; given both terms. Credit four hours. Two lectures and one laboratory experiment with report each week. The purpose of the course is threefold: (1) To review and emphasize the fundamental physical principles applied in electrical engineering; (2) to familiarize the student with and give practice in the handling of electrical machinery; (3) to enable the student to choose the proper type of apparatus for any particular service demanded in ordinary elementary practice. Professor BALLARD, Assistant Professor MCLEAN, and Mr. MOEDER.

420. **Applied Mathematics.** Required of juniors in Electrical Engineering. Second term only. Credit three hours a term. Two lecture-recitations and one computing period a week. Portions of mathematics are studied which are needed in the advanced theory of electric, magnetic, and electrostatic circuits and apparatus, such as determinants, harmonic analysis, simple differential equations, hyperbolic functions, mapping of fields, and probabilities. Professor KARAPETOFF and Dr. SOHON.

421, 422. **Electrical Practice.** Required of seniors in Electrical Engineering. Throughout the year. Credit two hours per term. Prerequisite courses 411a, 412a, 420, and 431. Two lectures and one computing period a week. This course is correlated week by week with the courses 423 and 424, which see for the topics covered. Practical aspects of the advanced electrical theory, as applied to various types of apparatus and to some manufacturing and operating problems, are discussed in this course. Professor KARAPETOFF and Dr. SOHON.

423, 424. **Advanced Electrical Theory.** Required of seniors in Electrical Engineering. Throughout the year. Credit three hours per term. Prerequisite courses 411a, 412a, 420, 431. Two recitations and homework problems per week. The work of the first term covers chiefly non-sinusoidal currents, unbalanced polyphase circuits, electric transients, long transmission lines, and the fundamentals of the dielectric circuit. The second term is devoted to the laws of the magnetic circuit, with applications to electrical machinery and lines, and to conduction of electricity in gases. This course is correlated week by week with the courses 421 and 422, in which practical applications of the advanced electrical theory are considered. Professor KARAPETOFF and Dr. SOHON.

431. **Electrical Laboratory for E.E. Juniors.** Required of juniors in Electrical Engineering. First term. Credit three hours a term. Prerequisite courses, Physics 21, 22; Mechanics 3M21, E.E. 410, and must be accompanied by 411a. One laboratory period and report each week. Experimental work on the subjects taken up in 411a, 412a. Assistant Professor B. K. NORTHROP and Mr. BRISTOL.

433, 434. **Advanced Electrical Laboratory.** Required of seniors in Electrical Engineering. Throughout the year. Credit three hours first term, four hours second term. Must be accompanied by 421, 422, 423, and 424. Laboratory experiment, one recitation, and one report a week. Special and commercial tests on direct and alternating generators and motors, transformers, synchronous converter, and other apparatus; work on instruments and on electrical materials in the standardizing laboratory. Professor CHAMBERLAIN, Assistant Professor BURCKMYER, and Mr. PAIGE.

435, 436. **Electrical Laboratory for M.E. Seniors.** Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 21, 22, Mechanics 3M21 and E.E. 415, 416. One recitation a week, laboratory experiment and report alternate weeks. Shorter course but similar in scope to 433 and 434. Professor CHAMBERLAIN and Mr. WOOD.

441. **Electrical Power-Plant Design.** First term only. Credit three hours. Prerequisite courses 411a, 412a and 431. One lecture, one recitation, and one computing period a week. Selection and arrangement of the proper electrical equipment for direct and alternating current power-plants. Some attention is also devoted to operating features, and to questions of public policy and finance. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

442. **Electrical Design.** Elective for seniors in Electrical Engineering. Second term only. Credit four hours. Must be accompanied by 422 and 424. Three recitations and one computing period a week. A study of the fundamental principles underlying the design of direct- and alternating-current machinery. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

444. **The Economics of Public Utilities.** Elective for seniors in Electrical Engineering. Second term only. Credit three hours. Three recitations a week. A study of the Origin and Development of Public Utilities, Franchises, Regulation and Legislation, Valuation, Rates and Rate Structures, Public Ownership and Public Relations. Professor LINCOLN.

450. **Electronics.** Required of Juniors in Electrical Engineering. Second term. Credit four hours. Prerequisite courses 410, 411a, and 431. Two lectures, one laboratory period and one report per week. A study of the theory and application of electrical apparatus which involves electronic conduction in vacuum and gases with particular reference to high vacuum thermionic apparatus, gas conduction devices, photo-electric cells, mercury vapor converters and inverters, and similar equipment. Professor BALLARD and Assistant Professor B. K. NORTHROP.

451. **Electrical Communication Engineering.** Elective for seniors in Electrical Engineering. First term. Credit three hours. Two lectures and one laboratory or computing period a week. Prerequisites, courses 411a, 412a, 431, and 450, and concurrent with 421 and 423. Consideration of the theory of alternating currents as applied to telegraph, telephone, and radio communication. Special emphasis is placed upon the theory and the application of thermionic devices to electrical engineering. Professor BALLARD, Assistant Professor MCLEAN, and Mr. MOEDER.

452. **Electrical Communication Engineering.** Elective. Open to seniors in Electrical Engineering. Second term. Credit four hours. Two lectures, one laboratory period and one report a week. Prerequisites, courses 450, and 451. Consideration of problems, apparatus and measurements particularly applicable to electrical communication engineering. Professor BALLARD and Assistant Professor MCLEAN and Mr. MOEDER.

452a. **Theory of Communication Networks.** Second term. Credit two hours. Two recitations a week, assigned problems and references. Must be accompanied

by 452. Foundation laws of elements and circuits with variable frequency. General network theorems. Two and four terminal structures. Recurrent networks and wave filters. Equalizers. Distributed circuits including continuous and concentrated loading of long lines. Special networks for very high frequencies. Assistant Professor McLEAN.

452b. **Elements of Broadcast Engineering.** Second term. Credit two hours. One recitation and one laboratory period a week. Must be accompanied by 452. The course includes the study of modern broadcast equipment including sound pickup equipment, amplifier design, sound reenforcement, sound recording as an adjunct to broadcasting, wire transmission and radio transmitting equipment. The facilities of a modern broadcasting station will be at the disposal of the student to familiarize him with many standard tests made in the field. Mr. MOEDER.

461. **Elements of Electric Railway Practice.** Elective for seniors. First term only. Credit two hours. Prerequisite courses 411a, 412a, and 431, 432. One recitation and one computing period a week. Apparatus and construction involved in a modern railway system, including cars and car equipment, overhead and track construction, and other topics of similar character. Some attention is devoted to the relation of electric railways to the public and to finance. Professor CHAMBERLAIN.

462. **Industrial Application and Control of Electricity.** Elective. Second term. Credit two hours. Open to seniors and graduate students. A study of electric motor drive; selection of motors; study and selection of motor control; power requirements for various kinds of machinery; electric hoists, welding, heating. Professor CHAMBERLAIN.

464. **Electrical Transmission and Distribution.** Elective for E.E. seniors. Second term only. Credit three hours. Two recitations and one computing period a week. This course is designed to give an understanding of the fundamentals of electric transmission and distribution. Prerequisites 411a, 412a, 431, 432, 421, 423. Must be accompanied by 422 and 424. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

466. **Illumination.** Elective. First term. Credit two hours. Open to juniors and seniors in the College of Engineering. Prerequisite courses: Physics 21, 22. A study of the production, measurement, and utilization of light with emphasis on the latter. Recitation, discussion and problem work. Oral reports on illumination topics of current interest are a feature of the course and supplement the textbook material. (Given in alternate years.) Assistant Professor STRONG.

471, 472. **Current Topics in Electrical Engineering.** Elective. Open to seniors and graduate students in Electrical Engineering. First or second term, or both. Credit two hours a term. Two one-hour seminar periods a week devoted to the presentation and discussion of noteworthy articles in current electrical literature. The purpose of the course is two-fold: (1) to familiarize the student with the latest development in the various branches of electrical engineering; and (2) to afford some practice in abstracting, presenting, and critically discussing engineering topics of timely interest. Assistant Professor M. G. NORTHROP.

481, 482. **Engineering Mathematics.** Elective. Open to seniors and graduate students only. Throughout the year. Credit two hours. Two recitations a week and home work. General methods by which engineering problems are expressed in mathematical form. The course consists of problems taken from mechanical, civil, or electrical engineering, involving analytical geometry and the elements of differential and integral calculus. The topic will be selected to suit the class. Professor KARAPETOFF and Dr. MALTI.

483, 484. **Special Electrical Engineering Problems.** Open to seniors. First or second term or both. Credit one or more hours. A course to meet the need of students who are not particularly interested in the other electives. Theoretical and experimental investigations on electrical apparatus. Each student selects his own subject, which, however, must meet with the approval of the Director of the School of Electrical Engineering. Professors and instructors as required.

486, 487. **Heaviside's Operational Analysis.** Elective for seniors and graduate students in Electrical Engineering. Throughout the year. Credit three hours a term. Two lecture-recitations and one computing period a week. Mathematical introduction. The classical solution of differential equations. The writing of operational equations for networks. The infinite integral theorem and its inverse. The Heaviside solution of indicial circuits. Some non-indicial circuits and their solutions. Assistant Professor MALTI.

488. **Patents.** Elective for seniors and graduate students in Engineering. Credit one hour. One recitation a week. First term only. A consideration of the fundamental principles of United States and foreign patents and their relationship to the engineer. Professor W. C. BALLARD, jr.

491. **Non-resident and Special Lectures.** Required. Credit one hour each year. Open to juniors and seniors. These lectures are primarily intended to include the technical addresses given during the academic year before the regular meeting of the local section of the A.I.E.E., and such other special lectures as may be designated. Notice of the lectures will be posted on the bulletin board of the School of Electrical Engineering. Credit of one hour may be obtained by attending at least fifteen of the lectures offered during the academic year. For credit a notebook giving a résumé of each lecture attended (not more than about one page for each lecture) must be handed in at the Director's office during Block Week at the end of the second term. The honor system applies to attendance at these lectures.

Seminary in Electrical Engineering. For graduate students. Seniors may attend by special permission but no credit will be given. Conducted by Professor KARAPETOFF.

492. **A.I.E.E., Student Branch.** Members of the junior and senior classes in Electrical Engineering may obtain one hour elective credit by joining and taking an active part in the activities of the Student Branch of the A.I.E.E. Application for membership should be made at the Director's Office.

Announcement of

THE ENGINEERING DIVISION OF THE GRADUATE SCHOOL

of Cornell University

This Division of the Graduate School is charged with the supervision of graduate study leading to the Master's Degrees in Engineering. It is intimately associated with the College of Engineering, in which the undergraduate instruction is given.

Note. The student or candidate for admission will find it necessary to consult also a separate pamphlet, the *Announcement of the Graduate School.*

THE GRADUATE SCHOOL OF CORNELL UNIVERSITY

FLOYD KARKER RICHTMYER,
Dean.

HAZEL ELLENWOOD,
Secretary to the Dean.

(Offices in Morrill Hall)

THE ENGINEERING DIVISION OF THE GRADUATE SCHOOL

HERMAN DIEDERICHS,
Chairman.

FREDERICK GEORGE SWITZER,
Secretary.

THE ENGINEERING DIVISION of the Graduate School consists of all professors and assistant professors of the College of Engineering, the Dean of the Graduate School, and such other members of the Faculty of the University as have supervision of the work of Graduate Students in the Division.

THE EXECUTIVE COMMITTEE of this Division has general supervision of the graduate work falling within its jurisdiction, and its chairman and secretary are the same as for the Division.

Each of the main branches (C.E., E.E., and M.E.) of the Division has a COMMITTEE ON GRADUATE WORK which has direct charge of the following: examining engineering credentials of applicants for admission, which, however, must first be sent to the Dean of the Graduate School; corresponding with applicants for the purpose of giving or receiving information or of giving advice concerning the availability of facilities for the graduate work desired in Engineering; the registration of students in the subdivision, after they have registered in the Graduate School; giving advice and approval regarding the student's program and the selection of his Special Committee, which has direct charge of his work; looking after the completion of language and undergraduate shortages; and making final review of the students' records to check the fulfillment of all scholastic requirements for the degrees. The membership of the Committees on Graduate Work in the three main subdivisions is as follows:

COMMITTEES ON GRADUATE WORK IN THE ENGINEERING DIVISION

CIVIL ENGINEERING.—S. C. Hollister, *Chairman*, 11 Lincoln Hall; E. W. Rettger, *Secretary*, 33-C Lincoln Hall; S. L. Boothroyd, 158 Rockefeller.

ELECTRICAL ENGINEERING.—P. M. Lincoln, *Chairman*, Franklin Hall; W. C. Ballard, jr., *Secretary*, Franklin Hall; Vladimir Karapetoff, 17 Franklin Hall.

MECHANICAL ENGINEERING.—Herman Diederichs, *Chairman*, 18 West Sibley; F. G. Switzer, *Secretary*, 303 West Sibley; G. B. Upton, Mechanical Laboratory.

Division Representative on the General Committee of the Graduate School, and Chairman of Group E.—Walter L. Conwell.

GRADUATE STUDY IN ENGINEERING

The instructing staffs and the laboratories, libraries, and other facilities of the various departments of the College of Engineering and those of the other departments of the University are available for students desiring to pursue original graduate study and research in engineering and allied fields. Graduate students in engineering will also find among the regular and elective courses given in the College and in mathematics, physics, chemistry, and in other departments of the University, many suitable for advanced study. For the courses offered, and for the laboratory, library, and other facilities in Engineering, see pages 34–46 of this pamphlet.

THE PURPOSE OF GRADUATE STUDY

It is the purpose of the Engineering Division of the Graduate School to offer facilities for advanced study and for research with the object (1) of providing a student with a more comprehensive view of the field of engineering and (2) of training him for individual investigation in that field. In carrying on graduate studies in engineering the student is expected to assume the initiative and responsibility.

ADVANCED DEGREES OFFERED

The degrees of Master of Civil Engineering (M.C.E.), Master of Electrical Engineering (M.E.E.), Master of Mechanical Engineering (M.M.E.), Master of Science in Engineering (M.S. in Engineering), and Doctor of Philosophy (Ph.D.), are granted for engineering work.

The Degree of Ph.D.

The rules governing admission to candidacy for, and those for graduating with, the degree of Doctor of Philosophy (Ph.D.) are established and administered directly and solely by the Graduate Faculty as a whole.* For further information concerning these degrees see the Announcement of the Graduate School. This Announcement of the Engineering Division relates primarily to the technical degrees in Engineering.

The Degrees of M.C.E., M.E.E., M.M.E., and M.S. in Engineering

Subject to certain general regulations of the Graduate School, the rules governing admission to candidacy for and for graduation with one of the professional degrees (Master of Civil Engineering, M.C.E., Master of Electrical Engineering, M.E.E., Master of Mechanical Engineering, M.M.E., and Master of Science in Engineering, M.S. in

*Although not under the supervision of the Engineering Division, it is to the advantage of candidates for non-professional degrees in Engineering who have registered in the Graduate School to register also in the appropriate branch of the Engineering Division.

Engineering) are established and administered by the Engineering Division of the Graduate School.

For purposes of administration, the Engineering Division of the Graduate School has created three *Committees on Graduate Work*, one for each of the subdivisions (C.E., E.E., and M.E.). See page 132.

TUITION AND OTHER FEES

The Matriculation and Examination Book Fee is $11; the Tuition Fee is $150 a year, payable $75 a term; and the Graduation Fee is $20. Additional fees payable each term are: Administration Fee, $12.50; Health and Infirmary Fee, $6; Willard Straight Hall Membership Fee, $5; and, in some cases, laboratory fees.

Under certain conditions, graduate students holding appointments as assistants or instructors are exempt from tuition, laboratory, and shop fees. (For further information regarding fees and exemptions, consult the Announcement of the Graduate School. For information regarding fees for graduate work pursued during the summer for credit, either in the Summer Session or under "personal direction", see the Announcement of the Graduate School and that of the Summer Session.)

FELLOWSHIPS AND GRADUATE SCHOLARSHIPS

Fellowships and graduate scholarships, except the McMullen Scholarships, are awarded by the Graduate School. Students interested in them should consult the Announcement of the Graduate School. Blank forms of application are to be obtained from the Dean of the Graduate School, to whom correspondence should be addressed, for all except the McMullen Scholarships. For the latter, see the statement which follows.

OPEN TO GRADUATE STUDENTS IN CIVIL ENGINEERING

THE MCGRAW FELLOWSHIP: $400 a year and free tuition, offered to graduates of the School of Civil Engineering and similar schools of equivalent rank.

A GRADUATE SCHOLARSHIP: $200 a year and free tuition; offered under similar conditions.

THE ELON HUNTINGTON HOOKER FELLOWSHIP IN HYDRAULICS: $510 a year; offered for research in experimental hydraulics in Europe or America; open to graduates of the School of Civil Engineering and similar schools of equivalent rank. This fellowship was founded in 1919 by E. H. Hooker, a graduate of the School of Civil Engineering of the class of 1894.

OPEN TO GRADUATE STUDENTS IN MECHANICAL ENGINEERING

THE SIBLEY FELLOWSHIP: $400 a year and free tuition.

THE EDGAR J. MEYER MEMORIAL FELLOWSHIP: $400 a year and free tuition.

OPEN TO GRADUATE STUDENTS IN ELECTRICAL ENGINEERING

THE CHARLES BULL EARLE MEMORIAL FELLOWSHIP: $400 a year and free tuition.

OPEN TO ALL GRADUATE STUDENTS IN ENGINEERING

THE JOHN MCMULLEN RESEARCH SCHOLARSHIPS: Open to graduate students in Civil, Mechanical, or Electrical Engineering. These scholarships were founded by a bequest of John McMullen, of Norwalk, Conn., to Cornell University "for the purpose of creating and maintaining free scholarship or scholarships for the education of young men as engineers, the details as to the amounts of said scholarships and the qualifications of the beneficiaries to be left to said institution to determine, said scholarships to be known as the John McMullen Scholarships." With the avails of this bequest the Board of Trustees has established several research scholarships of an annual value varying from $1,500 to $2,400. The scholarships have not been assigned to any particular branch of engineering, but will be awarded as conditions dictate. Applications should be sent to the Dean of the College of Engineering. (Not available in 1936–37.)

TUITION SCHOLARSHIPS: The Board of Trustees of Cornell University has established a number of tuition scholarships to be awarded by the General Committee of the Graduate School. These Scholarships, several of which are available to graduate students in Engineering, entitle the holder to exemption from payment of tuition fees, but not other fees, for the duration of the appointment. These scholarships are awarded from nominations made by the professor or professors in whose field the nominee is working.

ADMISSION TO GRADUATE STUDY IN ENGINEERING

(1) All applications for admission to the Graduate School and all applications for Graduate Fellowships and Scholarships must be sent to the *Office of the Graduate School*. Obtain the necessary blanks and instructions from that office.

(2) If the applicant wishes to become a candidate for one of the advanced Engineering Degrees (M.C.E., M.E.E., M.M.E., or M.S. in Engineering) his credentials should include not only (a) the official transcript of his entrance credits and his undergraduate study, and (b) the official statement concerning his previous graduate study (if any), as required by the Graduate School, but, in addition, they should also include (c) a catalogue of the institution from which he graduated, with each subject that he has completed clearly marked therein, and (d) a detailed statement concerning his practical experience, together with letters from his employers.

(3) In all cases, the applicant should designate as definitely as possible his chosen fields of study, both major and minor, so that he may be advised concerning the facilities and personnel available in those fields.

(4) A prospective graduate student may write to the office concerned (Civil Engineering, Electrical Engineering, or Mechanical Engineering) for advice or information concerning graduate work in Engineering.

(5) Candidacy for the Advanced Engineering Degrees, M.C.E., M.E.E., or M.M.E., presupposes the substantial equivalent of the corresponding first degree at Cornell University. In the evaluation of a candidate's credits, however, the quality of his previous work, his practical experience, and his chosen field of advanced study will be considered in making adjustments for candidates whose undergraduate course has not been the exact equivalent of the corresponding undergraduate courses at Cornell.

(6) Candidacy for the Advanced Engineering Degree M.S. in Engineering presupposes graduation from a School or College of recognized standing and thorough and adequate training in the particular field chosen for advanced work.

(7) The minimum language requirement for graduation with one of the advanced Degrees M.C.E., M.E.E., or M.M.E., is three entrance units in one foreign language or two units in each of two foreign languages. A student may, however, be admitted to candidacy for one of these degrees if he has credit for two units in one foreign language; but he must make up the shortage before he receives the degree. He may be permitted to make up his language shortage in regular classes in accordance with the rule governing shortages. (See Rule 2 below.) For this purpose language shortage of one entrance unit will be considered as equivalent to six university credit hours. When the student's Special Committee considers that a reading knowledge of French or German is essential for satisfactory progress in his particular field of study, the student will be required to demonstrate such knowledge before proceeding with this study.

(8) The minimum language requirement for admission to candidacy for, and for graduation with, the advanced Degree, M.S. in Engineering, is two entrance units in one foreign language.

(9) Applicants who do not care to meet the requirements for entrance to candidacy for any of the above degrees may arrange for a program of work as "non-candidates," provided only that they have had previous training which is adequate for advanced work in the field of engineering which they desire to pursue.

(10) A student whose mother tongue is other than English may be required by the Committee on Graduate Work to furnish satisfactory evidence of his ability to speak, write, and read English to a degree sufficient for satisfactory progress in his graduate work. The Committee may lengthen the minimum time of residence and prescribe some study of English when a student's deficiency in this respect is deemed to place an undue burden upon him and upon the faculty members with whom he is to come in contact.

REGISTRATION

All graduate students must first register in the Graduate School at the beginning of each term. In addition, a graduate student in engineering must, at the beginning of each term of residence, register at the office of the Engineering School of whose faculty his major professor is a member.

RULES GOVERNING GRADUATE STUDY LEADING TO MASTER'S DEGREES IN ENGINEERING

(1) A Master's Degree in Engineering shall be awarded only after the candidate has spent at least one full academic year, or the equivalent, in residence and study at the University.

(2) If a student's training is considered short of that required for the advanced degree desired, his shortage will be noted.

A minor shortage, not to exceed six university credit hours, may be made up as extra work. A shortage more than this usually will require additional residence. If a student's shortage is more than the equivalent of one term of work, he will be required to enter an undergraduate school.

In general, a graduate student should remove his shortage before he enters his chosen field of graduate work. Since it is not always practicable to do this, the student may receive permission to make up his shortages while doing his graduate work.

Often arrangements can be made for making up language and other deficiencies in the Summer Session; and sometimes graduate work may be done in the summer, either in the Summer Session or under "personal direction." For the requirements as to registration and the payment of fees for summer work, see the Announcement of the Graduate School and that of the Summer Session.

In making up a shortage, the student is under the general supervision of the Committee on Graduate Work.

(3) (a) A student shall select a major field of study to which he shall devote not less than one-half nor more than three-fourths of his time. He must also select one or more secondary fields of study to which he shall devote the remainder of his time.

(b) A student shall select one Professor* who shall supervise his work in his major field. For each secondary (or minor) field to which he intends to devote not less than one-fourth of his time, he shall select one Professor to supervise his work in that field. The Professor or Professors thus selected shall be known as his *Special Committee*. The Professor in charge of the major field shall be Chairman of the Special Committee. If the student selects a secondary field to which he intends to devote less than one-fourth of his time, he shall in that field be under the supervision of the Committee on Graduate Work.

(4) A student shall select his program of study and his Special Committee with the advice and approval of the Committee on Graduate Work. No change in the program of study nor in the personnel of the Special Committee shall be made without the written approval of the appropriate Committee on Graduate Work and the advice of the student's Special Committee.

(5) When a candidate for an advanced degree in Engineering takes a course specified by the Committee on Graduate Work or approved by his Special Committee, he must register in that course and must conform to all the requirements of that course, including the examinations.

(6) If, in the opinion of the Special Committee, a candidate at any time during his residence shows insufficient preparation in any

*Members of the Faculty who are qualified to supervise the work of graduate students are Professors, Assistant Professors, and those Instructors who hold the doctor's degree. For the sake of brevity any such member is herein referred to as "Professor".

subject or subjects, he may be required to register in and take the work of specified undergraduate courses. His residence requirement will be increased accordingly.

(7) A candidate for a master's degree in Engineering must present a *thesis* on a subject in his major field. The thesis must show initiative and originality and must conform to the general requirements of the Graduate School. It may take one of the following forms:

(a) An analytical or interpretative discussion of results already in existence.

(b) A design or construction or both, of sufficient importance and originality to demonstrate thoroughly a knowledge of the principles involved and of their applications.

(c) A dissertation based upon his own original investigation, analytical or experimental.

(8) When a student has satisfied all the requirements set by his Special Committee, including a satisfactory final examination, the Special Committee will so certify to the Committee on Graduate Work. The Committee on Graduate Work will then review the student's record and if the student has fulfilled all scholastic requirements imposed upon him, he will be duly recommended for his degree.

FIELDS OF GRADUATE INSTRUCTION IN ENGINEERING

The regular graduate courses, the courses which are normally for undergraduates but which may also be of interest to advanced students, and the laboratory and library facilities in this field, are described in the first part of this pamphlet to which reference should be made. For opportunities for study in other branches of the Graduate School, see the Announcement of that School.

The work of a graduate student in engineering will be limited presumably to one field. This may be chosen in any one of the three larger branches of Engineering, i. e., Civil, Mechanical, or Electrical, although further sub-division will always be required. It is, however, always possible to elect work and to pursue research in two or more schools, provided one field only is involved, as, for example, in hydro-electric power or in hydro-electric traction.

For better teaching facilities, some duplication exists, both in subject matter and in equipment, and a student should therefore select in such a case the branch naturally making the same applications that he himself desires to make. For example, in Mechanical Engineering, hydraulics naturally leads towards, and is developed with a view to, turbine or pump design or hydraulic power plants. In Civil Engineering, on the other hand, hydraulics looks forward to water power installations, to canal and harbor construction, to sewerage and waterworks.

In some cases, as for example in studies on cement or steel specifications, further training in chemistry might be found imperative, though that might involve work in still another branch. Such ad-

ditional study is desirable, sometimes essential, for successful pursuit of many kinds of graduate work in Engineering.

It is particularly desirable that a thorough knowledge of all fundamental theory be in hand before any attempt is made to carry out its applications into engineering design, construction, analysis, laboratory research, or interpretative investigation of results already in existence.

APPROVED MAJOR AND MINOR SUBJECTS

Major and minor subjects taken in the Engineering Division are to be selected from the following list, in which the boldface numerals have the meaning:
1, approved as major subject for the Ph.D.
2, approved as major subject for the master's degree.
3, approved as minor subject when the major is in the same field.
4, approved as minor subject when the major is in another field.

In Civil Engineering

Astronomy
  Geodetic Astronomy **2, 4**
  Geodesy **1, 2, 4**
Highway Engineering **2, 4**
Hydraulic Engineering **2, 3, 4**
Hydraulics
  Theoretical **1, 2, 3, 4**
  Experimental **1, 2, 3, 4**
Materials of Engineering **2, 4**
Mechanics **1, 2, 3, 4**
Railway Engineering
  Railway Maintenance **1, 2, 3, 4**
  Railway Location **1, 2, 3, 4**
  Railway Operation and Management **1, 2, 3, 4**
Sanitary Engineering
  Garbage Collection and Disposal **3, 4**
  Sewage Treatment **1, 2, 3, 4**
  Water Purification **1, 2, 3, 4**
  Soil Mechanics **1, 2, 3, 4**
Structural Engineering
  Structural Engineering **1, 2, 3, 4**
  Theory of Structures **1, 2, 3, 4**
Surveying
  Geodetic Engineering **1, 2, 4**
  Topographic Engineering **1, 2, 4**

In Electrical Engineering

Economics of Public Utilities **1, 2, 3, 4**
Electrical Communications **1, 2, 3, 4**
Electrical Design **1, 2, 3, 4**
Electric Power Generation, Transmission and Distribution **1, 2, 3, 4**
Electric Circuit Analysis **1, 2, 3, 4**
Electrical Conduction through Gases **1, 2, 3, 4**
Electrical Machinery **1, 2, 3, 4**
Electrical Measurements **1, 2, 3, 4**
Electric Power Applications **1, 2, 3, 4**
Experimental Electrical Engineering **1, 2, 3, 4**
Materials of Engineering (In Electrical Engineering) **1, 2, 3, 4**

In Mechanical Engineering

Administrative Engineering
  Industrial Accounting **2, 3, 4**
  Industrial Marketing **1, 2, 3, 4**
  Industrial Statistics, **3, 4**
Aeronautical Engineering **1, 2, 3, 4**
Automotive Engineering **1, 2, 3, 4**
Experimental Mechanical Engineering **1, 2, 3, 4**
Heat Power Engineering **1, 2, 3, 4**
Hydraulic Engineering **1, 2, 3, 4**
Industrial Engineering **1, 2, 3, 4**
Machine Design **1, 2, 3, 4**
Materials of Engineering **1, 2, 3, 4**
Mechanic Arts **1, 2, 3, 4**
Mechanics **1, 2, 3, 4**
Metallography **1, 2, 3, 4**

GRADUATE WORK OFFERED IN ENGINEERING

The facilities and opportunities offered for graduate work in engineering are discussed in the following pages.

Administrative Engineering

Professors J. R. Bangs, Jr., S. S. Garrett, and G. R. Hanselman.

Note: Only a limited number of graduate students can be taken in this department. Those contemplating graduate work in Administrative Engineering are advised to make advance arrangements with the department.

Problems relating to Industrial Accounting, Industrial Marketing, and Industrial Statistics may be selected for advanced study. Students desiring to take a minor in the field may find courses 3A31, 3A32, 3A41, 3A44, and 3A45 suitable as a foundation. (See page 108.)

Aeronautical Engineering

Professor K. D. Wood.

Problems relating to the design and theoretical performance of airplanes may be carried on in this field. The laboratories of the Experimental Engineering department (see page 40) are available for experimental work on internal combustion engines. Arrangements may be made with the authorities of the Ithaca airport for flight instruction and experimental investigations. Students desiring to take a minor in this field may find courses 3M35, 36, 45 and 46 suitable as a foundation (see page 113).

Automotive Engineering

Professors G. B. Upton, V. R. Gage, and A. C. Davis.

Special problems relating to Automotive Engineering may be selected for advanced study. Laboratory facilities of the Department of Experimental Engineering (see page 40) are available for research on internal combustion engines, and arrangements may be made for investigations on other automotive topics. Students desiring to take a minor in this field may find courses 3X45, 46, 47 and 48 suitable as a foundation.

Electrical Engineering

Professors P. M. Lincoln, V. Karapetoff, W. C. Ballard, R. F. Chamberlain, B. K. Northrop, E. M. Strong, L. A. Burckmyer, M. G. Malti, True McLean, and M. G. Northrop.

The laboratories in this department available for graduate research include the following: High-tension Laboratory, Electrical Laboratory, Standardization Laboratory, Communication Laboratory. These laboratories are described on pages 43 to 45.

A considerable amount of advanced theoretical investigations by the members of the faculty is going on at all times, the subjects studied in the past having been: the general properties of electric, magnetic, and electrostatic circuits, theory of machinery and lines, dielectrics, electron theory, relativity, electric waves, etc. Graduate students are not only invited but expected to participate in these researches. Some of the above topics are taken up in the courses mentioned below, especially in the Seminar and Engineering Mathematics.

The regular courses offered in Electrical Engineering are described on pages 119–130.

Students intending to do experimental research will be given all the available resources and assistance by the faculty and by the college mechanicians. Resources of the other departments of the University are also available when needed. Those intending to study a special topic or phenomenon are advised to communicate with the Director in advance, in order that they may know what facilities are available along these particular lines.

Fields of Advanced Work

Theory of Electrical Machinery: Professor Karapetoff and Assistant Professor Malti.

Characteristics of Electrical Machinery: Professor Karapetoff and Assistant Professor Malti.

Conduction of Electricity in Gases: Professor Karapetoff.

Solid Dielectrics: Assistant Professor Malti. A study of the anomalous behavior of solid dielectrics under varying conditions of EMF, time, frequency, temperature pressure, humidity, and ionizing radiations.

Heaviside's Operational Analysis: Assistant Professor Malti.

Fundamentals of Electrical Engineering: Assistant Professor Strong.

Electric Power Plants: Professor Lincoln and Assistant Professor M. G. Northrop.

Electrical Design: Professor Lincoln.

Electrical Communications: Professor Ballard and Assistant Professor McLean.

Electrical Laboratory: Professor Chamberlain and Assistant Professor Burckmyer.

Engineering Mathematics: Professor Karapetoff.

Industrial Applications of Electrical Power: Professor Chamberlain.

Electric Railway Practice: Professor Chamberlain.

Transmission Line Stability: Professor Karapetoff.

The Graduate Seminar in Electrical Engineering: Professors Lincoln and Karapetoff. A topic is selected each year to suit the range of interests and the preparation of the students taking it. The primary purpose is to acquaint the students with modern research on the border line between physics and electrical engineering, in topics which are expected to become of practical importance within the next few years.

Graduate Seminar in Communication Engineering: Professor Ballard.

Experimental Mechanical Engineering

Professors H. Diederichs, W. M. Sawdon, G. B. Upton, V. R. Gage, and A. C. Davis.

The laboratories in this department available for graduate research include the following:

Materials Testing; Heat Treatment; Steam Machinery; Internal Combustion Engines; Hydraulic Machinery; Oil Testing; Refrigeration; Cement Testing; and Fuel Testing. These laboratories are described on pages 40 and 42.

For the major work in this department the graduate student is required to select a subject in the field of experimental research. This work is in charge of officers of instruction who devote a considerable portion of their entire time to it and give advice and assistance to graduate students who are carrying on investigations in this department.

The laboratories of this department are available for use by graduate students who are carrying on theoretical investigations in any other department and who wish to do experimental work in parallel with the theoretical work.

Students contemplating experimental research should communicate with the department as far as possible in advance of beginning work in order to arrange for the use of available equipment.

The regular courses in Experimental Engineering are described on pages 116 and 118.

Fields of Advanced Work

Mechanical Laboratory Practice.
Instrumentation.
Experimental Research along various lines.

Heat-Power Engineering

Professors W. N. Barnard, F. O. Ellenwood, R. E. Clark, W. H. Hook, and C. O. Mackey.

In each of the many branches of this very extensive field are innumerable opportunities for making advanced studies of interest and value. This advanced work includes such studies as original investigations in various phases of engineering thermodynamics; interpretative studies of available data and other material; investigations in power plant economics; the design, selection, and arrangement of apparatus, and plant layout, to meet specific requirements; analytical and experimental research; to mention but a few of the opportunities available. The department and college libraries are liberally provided with reference books, periodicals, transactions of engineering societies, and reports relating to this field.

The regular courses in this subject are described on pages 114 and 116. Students desiring to take a minor in this field may find courses, 3P44, 45, 46 and 47, or 3P57 and 58, suitable as a foundation.

Fields of Advanced Work

Advanced Engineering Thermodynamics.
Steam Engineering.
Internal Combustion Engineering.
Economic Studies.
Heat Transmission.
Fuels, Combustion, Burners, Furnaces.
Flow of Fluids through Closed Conduits: Power Plant Piping.
Refrigeration.
Compressors and Pneumatic Machinery.
Air Conditioning.

Highway Engineering

Professors W. L. Conwell and R. Y. Thatcher.

The Highway Laboratories, one for testing rocks, aggregates, and other non-bituminous materials and concrete, and the other for testing bituminous materials, bituminous mixtures, and subgrade soils, are described on page 36.

The other Laboratories of the School of Civil Engineering, equipped for the purpose of investigating the properties of engineering materials, and the Ceramic Laboratory of the Department of Geology, which is equipped with kilns and a brick machine, are also available for students specializing in highway engineering.

The Library of the School of Civil Engineering and the University Library contain a comprehensive collection of books on highway engineering, periodicals, publications of technical societies, etc., while the office of the Department of Railroad and Highway Engineering has on file city and state specifications and reports, government bulletins and reports, reports on highway engineering research, standard plans and plans of highway projects, catalogues of equipment, etc., all of which are available to students.

For a description of the courses in Highway Engineering, see pages 75–77.

Fields of Advanced Work

Advanced Highway Engineering.
Advanced Highway Laboratory.

Note. For larger highway structures see Structural Engineering.

Hydraulics and Hydraulic Engineering
(In Civil Engineering)

Major work in Experimental Hydraulics, Theoretical Hydraulics, or Hydraulic Engineering may consist in part (subject to the thesis requirement) of advanced courses, or the entire minor work may consist of such courses accompanied by such special work and reports as may be arranged with the faculty members of the special committee.

A candidate for the degree of Master of Civil Engineering (or of Science), or Doctor of Philosophy who desires to take either a major or a minor subject in these fields of study must ordinarily have completed, preliminary to graduate work, courses in Hydraulics, Municipal Sanitation (including sewer design and construction and sewage disposal), and Water Supply, substantially equivalent to these courses as required of all undergraduates in the School of Civil Engineering. If a graduate student lacks one or more of these preliminary courses or considerable portions of any of them, more than the minimum period of residence may be necessary.

HYDRAULIC ENGINEERING

Professor F. J. Seery.

Ordinarily for major work in Hydraulic Engineering the thesis requirement of the Graduate School must be satisfied by work involving original designs, estimates, or analyses based on actual engineering data, these to be gathered by the student himself as an essential part of advanced work in this field, and the requirement may not be satisfied by the so-called descriptive type of thesis with only rather vague design based on assumed data.

For a description of the courses in Hydraulic Engineering, see pages 72–73.

Fields of Advanced Work

Hydraulic Construction.
Water Power.
Hydraulic Engineering.
Conservancy and Reclamation Problems.
Water Power and Pumping Plants.

HYDRAULICS

Professor E. W. Schoder.

For major work in Experimental (or Theoretical) Hydraulics the thesis requirement may be satisfied by individual experimental (or theoretical) investigation and a thesis based thereon. Ordinarily fully half of the student's total time should be devoted to the thesis investigation. The tendency is to underestimate the time required for preliminary work and that necessary for a thorough digestion of results in preparation of the thesis. Consequently the thesis work should be begun, if possible, early in the first term of residence.

For a description of laboratory facilities and of the courses in Theoretical and Experimental Hydraulics, see page 73.

FIELDS OF ADVANCED WORK

Advanced Hydraulics.
Hydraulic Measurements.
Experimental Hydraulic Motors and Pumps.
Engineering Research in fields of Experimental or Theoretical Hydraulics.

(IN MECHANICAL ENGINEERING)

Professor F. G. SWITZER.

For the regular courses in Hydraulics in Mechanical Engineering, and in Water Power Engineering, see page 114. Advanced work is offered in each of these fields, the topics to be arranged by consultation. Students desiring to take a minor in water power engineering may find courses 3M41, 42, 43 and 44 suitable as a foundation.

FIELDS OF ADVANCED WORK

Hydraulic Turbines.
Draft Tube Design and Performance.
Centrifugal Pumps.
Economics of Water Power Plants.

INDUSTRIAL ENGINEERING

Professors M. A. LEE and ————————.

The courses offered include a consideration of the organization, administration and selection and location of equipment for industrial enterprises.

No formal graduate courses are offered but facilities are available for original work in micro-motion analysis and in other phases of the field of Industrial Engineering.

To take advanced work in this department the student must have had the equivalent of the undergraduate courses 3I31, 43, 44 and 48, described on pages 111 and 112 of this announcement. Students desiring to take a minor in this field may find the above listed courses of undergraduate work suitable as a foundation.

MACHINE DESIGN

Professors C. D. ALBERT, F. S. ROGERS, C. E. TOWNSEND, E. F. GARNER, and F. S. CLEARY.

The drawing rooms, libraries, and museums of this department are described on pages 34 and 45. The regular courses offered in this field are described on pages 109 and 112.

FIELDS OF ADVANCED WORK

Descriptive Geometry.
Kinematics and Dynamics.
Machine Design and Design Methods.
Special Design Problems.
Investigational Work.

MATERIALS OF ENGINEERING

(IN CIVIL ENGINEERING)

Professor H. H. SCOFIELD.

The library of the School of Civil Engineering is well supplied with reference works of various kinds on the subject of structural materials, their properties, specifications, and tests. Especial effort is made to add continually the most recent investigations and researches as the results find their way into print.

The laboratory equipment (see page 35) is selected to make all ordinary and many special tests and investigations of the materials of construction. The tests of toughness, abrasion, and wear may be made upon rock, paving brick, and similar materials. Core drills, diamond saws, lap grinders, and other apparatus for the proper preparation of these test pieces are available.

The cement and concrete laboratories are equipped to make all the standard tests upon cement and the various other ingredients entering into concrete. A specialty is made in the tests and investigations of the finished concrete under various conditions, as to proportion, manufacture, and design.

For a description of the courses in Materials of Construction given in Civil Engineering, see pages 71 and 82.

Field of Advanced Work

Engineering Research in Materials. Special investigations of an advanced nature of the properties of structural units and the materials of construction. Proper investigational methods are insisted upon so that the results shall be of the caliber and scope deemed essential for publication.

(In Electrical Engineering)

Professors Karapetoff, Malti, and Burckmyer.

The properties of materials used in electrical apparatus are covered in the regular undergraduate courses in Electrical Engineering described on pages 126–130 of this announcement.

Fields of Advanced Work

The Magnetic Circuit. Professor Karapetoff and Assistant Professor Malti. A study of the properties of magnetic materials such as hysteresis, permeability of magnetic materials, the effect of crystal structure and heat treatment on the magnetic properties of materials and magnetic analysis (*i.e.* the correlation of magnetic and mechanical properties).

Solid Dielectrics. Assistant Professor Malti. A study of the anomalous behavior of solid dielectrics under varying conditions of e. m. f., time, frequency, temperature, pressure, humidity, and ionizing radiations.

Electrical Testing. Assistant Professor Burckmyer. The testing of the materials of construction for determining their magnetic and electric properties.

(In Mechanical Engineering)

Professors H. Diederichs, G. B. Upton, W. M. Sawdon, and A. C. Davis.

The materials testing laboratories and heat treatment laboratories are described on pages 40–43. Experimental problems relating to the origins and control of the properties of ferrous and non-ferrous metals, cements, woods, etc., may be carried on in this department. For advanced work in this field the student must have had course 3X31 or its equivalent. Advanced work is also offered in Applied Metallography.

Mechanic Arts

Professors A. E. Wells and W. E. Mordoff.

The shops available for graduate research work include the following: forge shop, foundry, welding shop, pattern shop, and machine shop. These are described on page 43. The shops are also available for use in the building of equipment for research in any department. Research problems for advanced work may be selected from the following fields:

Melting of ferrous and non-ferrous metals.
Selection and testing of foundry sands.
Welding practice.
Foundry practice.
Machine shop practice.

Mechanics

(In Civil Engineering)

Professors S. G. George, S. C. Hollister, E. W. Rettger, and E. V. Howell.

An extensive departmental library in Lincoln Hall, in addition to the University Library, affords facilities for advanced work in the field of applied mechanics, especially in applications such as occur in structural engineering.

The prerequisite training for graduate work in this subject should cover the fundamental principles and applications in mathematics, physics, materials, mechanics and structural design required for graduation in civil engineering at Cornell University. Many of the advanced treatises are in French or German, and an ability to read technical works in these languages is extremely valuable.

For a description of the courses in Mechanics, see page 70.

Fields of Advanced Work

Advanced Mechanics.
Special Research.
Engineering Mathematics.
Theory of Elasticity.
Photo-elastic Analysis.

(In Mechanical Engineering)

Professors E. H. Wood, F. G. Switzer, W. R. Cornell, H. C. Perkins, and K. D. Wood.

In addition to the regular laboratory equipment, there are also available facilities for the study of balancing problems, and for photo-elastic investigations (see page 112). Problems for advanced study, either theoretical or experimental, can be arranged by consultation.

Fields of Advanced Work

Vibration problems.
Theory of Elasticity.
Photo-elastic stress analysis.

Railroad Engineering

(In Civil Engineering)

Professors F. A. Barnes, J. E. Perry, and R. Y. Thatcher.

The library of the School of Civil Engineering contains an excellent and up-to-date collection of books, periodicals, and publications of railway and other technical societies on the location, construction, maintenance, and operation of railways and on transportation. Specifications, standard plans, and maps and profiles are available for use in the study of economics of location, railway structures, signaling, yard and terminal design, etc. Instrumental equipment is available for securing additional data for special problems in relocation and in design of structures.

For a description of the courses in Railroad Engineering see pages 75, 81 and 82.

Fields of Advanced Work

Railroad Maintenance.
Railroad Operation and Management.
Railroad Engineering Design.
Railroad Engineering Research.

In addition to the above courses, the student may take courses in other departments, such as courses in transportation in the College of Arts and Sciences, or in the applications of electricity to railway work in the School of Electrical Engineering.

Note. For the larger railway structures, see Structural Engineering.

(In Electrical Engineering)

Professor R. F. Chamberlain.

The regular course offered in this subject is described on page 129.

Advanced work may be carried on in this subject involving a detailed study of electrification and the economics involved in electric operation of railroads.

Sanitary Engineering

Professors H. N. Ogden and C. L. Walker.

The courses offered to graduate students may be divided into two classes: those dealing with the design, construction, and operation of sewage-disposal plants, and water purification plants; and those fundamental studies in chemistry, biology, and bacteriology, which the undergraduate student in civil engineering may not have been able to pursue.

A sewage-disposal plant in the city of Ithaca offers opportunity for experimental study of sedimentation, sludge digestion, and sludge drying. Within a short distance from Ithaca are five other plants, well adapted for critical examinations of efficiencies. Numerous other opportunities are offered for the study of similar questions.

For a description of the Sanitary Laboratory, see page 38.

The laboratories in all the related subjects are open to graduate students in sanitary engineering. The courses in organic chemistry are well adapted to the study of the disposal of trade wastes. The courses in mycology and botany afford excellent opportunity for studying the life history of algae and other water plants which affect both stream pollution and purification. The courses in bacteriology deal not only with water bacteria and the colon types but also with pathogenic forms interesting from the point of view of epidemiology. A well-equipped sanitary laboratory established in the College gives an opportunity for students to acquire not merely laboratory technique in water analysis, but also a practical training in the forms of interpretation. This laboratory is also available for experimental studies of the efficiency of water and sewage plants and of methods of dealing with the refuse from factories. The library is well provided with the literature of the various subjects bearing on municipal sanitation.

The following courses in other subjects in the University may profitably be taken by graduate students in sanitary engineering: Economics 76; Chemistry 305; Chemistry 615, 620; Entomology 52; Veterinary College, Course 43.

In order to take advanced work in this department, the student must have had an equivalent of the following preliminary courses described in the Announcement of the College of Engineering: Sanitary Biology; Municipal Sanitation; Purification and Control of Water Supplies; Sewage Works.

For a description of the Courses in Municipal and Sanitary Engineering, see page 73.

Fields of Advanced Work

Purification of Water.
Methods of Sewage Disposal.
Laboratory Investigations.

Soil Mechanics

Professors S. C. Hollister, C. E. O'Rourke, and H. T. Jenkins.

The new and extensive field of soil mechanics offers the graduate student innumerable opportunities for advanced study. The mechanical and physical properties of soil as an engineering material are being investigated, and experimental problems relating to the physical characteristics are carried on in the Soil Mechanics Laboratory.

Earth pressures, stability, shear, elasticity and permeability are among the major divisions of a correlated study which is at present under way. Other investigations are being undertaken as the interest in them develops.

The Soil Mechanics Laboratory is fully equipped for work by graduate students. The freezing room and humid room are available for research work as well as the machine shop for use in the building of new equipment.

Fields of Advanced Work

Physical Properties of Soils.
Bearing Capacity of Soil.
Permeability of Soil.
Stability of Soil.
Flow of Water through Earth Dams.

Structural Engineering

Professors L. C. Urquhart, C. E. O'Rourke, and E. N. Burrows.

In this subject instruction is offered in the determination of loading and stresses and the design of roofs, buildings, bridges, arches, foundations, piers, retaining walls, and other structures of timber, steel, and concrete.

To qualify for graduate work in structural engineering, a knowledge of theoretical mechanics, of strength of materials, of engineering construction, and elementary courses in stresses and design in timber, steel, and concrete are required.

For a description of the courses in Structural Engineering, see pages 77-79, 81-82.

Note. Higher Structures, course 272, is required of every student taking his major or minor in Structural Engineering.

Fields of Advanced Work

Analytical Analysis of Statically Indeterminate Structures.
Experimental Analysis of Statically Indeterminate Structures.
Research in Methods of Structural Analysis.
Design of Bridges, Buildings and Other Structures.

Topographic and Geodetic Engineering

Professors S. L. Boothroyd, P. H. Underwood, and L. A. Lawrence.

The preliminary training as a qualification for work in this department should include the equivalent of the regular undergraduate course in civil engineering, including work in General and Practical Astronomy. A thorough training in Mathematics and Physics is desirable.

Graduate work for those interested in Topographic and Geodetic Engineering includes courses in Advanced Topographic Surveying, in Geodesy, Least Squares, Geodetic Astronomy, and in Photographic and Aerial Surveying. The Library of the School of Civil Engineering contains an extensive collection of reference books in the subjects mentioned. The surveying equipment of the School is also available for practice work.

The regular courses in this field are described on pages 69 and 70.

Fields of Advanced Work

Least Squares and Adjustment of Observations. Theory of Least Squares and the application to the adjustment of observations for time, latitude, longitude and azimuth as well as to the adjustment of precise level circuits and extensive triangulation nets and to adjustment of precise traverses. Professor Underwood.

Geodetic Laboratory. Prerequisite Astronomy 186 and Surveying 218. Determination of Gravity, using the Mendenhall half-second pendulum apparatus. Study of other methods and instruments of more recent design for the determination of the intensity of gravity on land and sea is also included in this course. Professor Boothroyd.

Geodesy. Prerequisites Astronomy 186 and Surveying 213. Theory of the figure of the earth and methods for determining the size and shape of the earth from geodetic surveys and from pendulum observations. Theory of Isostacy and discussion of methods of determining the depth of isostatic compensation. Professor BOOTHROYD.

Geodetic Astronomy. Prerequisite Astronomy 186. In this work the student undertakes a critical study of the astronomical transit, the zenith telescope, and the altazimuth instrument, determining the instrumental constants for as many of the instruments as time permits, besides making observations for time, latitude and azimuth, such observations to be of the highest degree of refinement attainable with least square adjustment of the results of the observations. Professor BOOTHROYD.

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