CORNELL UNIVERSITY
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Announcement of the

College of Engineering

including

THE SCHOOL OF CIVIL ENGINEERING
THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING
THE SCHOOL OF ELECTRICAL ENGINEERING
THE SCHOOL OF CHEMICAL ENGINEERING
THE COURSES IN ADMINISTRATIVE ENGINEERING

and Announcement of

THE ENGINEERING DIVISION OF
THE GRADUATE SCHOOL

for 1938-39

PUBLISHED BY CORNELL UNIVERSITY AT ITHACA, N. Y.
Monthly in September, October and November
Semi-monthly, December to August inclusive

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THE UNIVERSITY CALENDAR FOR 1938–39

1938			**FIRST TERM**
Sept.	19,	*Monday,*	Entrance examinations begin at 8 a. m.
Sept.	26, 27,	*Mon.-Tues.,*	Registration and assignment of new students, 9 a. m.–4 p. m.
Sept.	27, 28,	*Tues.-Wed.,*	Registration and assignment of old students, 9 a. m.–4 p. m.
Sept.	29,	*Thursday,*	Instruction begins at 8 A. M.
Oct.	20,	*Thursday,*	Last day for payment of tuition for the first term, 4:30 P. M.
Nov.	23,	*Wednesday,*	Instruction ends at 6 P. M. (Thanksgiving Recess)
Nov.	28,	*Monday,*	Instruction resumed at 8 A.M. (Thanksgiving Recess)
Dec.	21,	*Wednesday,*	Instruction ends at 4 P. M. (Christmas Recess)
1939			
Jan.	5,	*Thursday,*	Instruction resumed, 8 A. M. (Christmas Recess)
Jan.	11,	*Wednesday,*	Founder's Day.
Jan.	28,	*Saturday,*	Instruction ends, 1 P. M.
Jan.	30,	*Monday,*	Term examinations begin, 8 A. M.
Feb.	8,	*Wednesday,*	Term examinations end, 6 P. M.
Feb.	9,	*Thursday,*	Midyear Recess.
			SECOND TERM
Feb.	10,	*Friday,*	Registration of all students, 9 A. M.–4 P. M.
Feb.	13,	*Monday,*	Instruction begins at 8 A. M.
March	6,	*Monday,*	Last day for payment of tuition for the second term, 4:30 P. M.
April	1,	*Saturday,*	Instruction ends at 1 P. M. (Spring Recess)
April	10,	*Monday,*	Instruction resumed, 8 A. M. (Spring Recess)
May	—,	*Saturday,*	Spring Day: a holiday*
June	3,	*Saturday,*	Instruction ends, 1 P. M.
June	5,	*Monday,*	Term examinations begin, 8 A. M.
June	13,	*Tuesday,*	End of term examinations, 6 P. M.
June	19,	*Monday,*	COMMENCEMENT.

*Spring Day is ordered by the University Faculty to take place on that Saturday of May which shall be chosen annually by the Committee on Student Activities in consultation with the Athletic Association, provided that the day appointed shall precede the beginning of final examinations by more than one week.

CONTENTS

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 Engineering College buildings. Above and to the left of the Quadrangle are shown the laboratories of Chemistry and Physics.

THE COLLEGE OF ENGINEERING

HISTORY AND ORGANIZATION

Engineering has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to. . . . the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs, who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator, who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities.

This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. The first was originally called the College of Mechanic Arts and later the Sibley College of Mechanical Engineering and Mechanic Arts, in recognition of munificent gifts by Hiram Sibley, founder of the Western Union Telegraph Company, and his son, Hiram W. Sibley. Civil Engineering, originally a separate school in the College of Mathematics and Engineering, and later as the College of Civil Engineering, has also retained its identity to the present day.

In 1883 Cornell opened the first courses in electrical engineering to be offered by any American university; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established as one of the three component units, on a par with the Sibley School of Mechanical Engineering and the School of Civil Engineering.

The College of Engineering organized a five-year course leading to the degree of Chemical Engineer in 1931, and more recently four-year courses leading to the degree of Bachelor of Science in Administrative Engineering in civil, mechanical, and electrical engineering. The School of Chemical Engineering was established in 1938 and to it was transferred supervision of the curriculum leading to the degree of Bachelor of Chemical Engineering.

Students in engineering at Cornell use the facilities of Sibley Hall, which houses the Sibley School of Mechanical Engineering; Lincoln Hall, which houses the School of Civil Engineering; Franklin Hall, which houses the School of Electrical Engineering; Rand Hall, which contains the machine shop, pattern shop, and electrical laboratory; the Hydraulic Laboratory on Beebe Lake above Triphammer Falls; and part of the Baker Chemical Laboratory, a building given to the University in 1922 by George F. Baker. For various preparatory and elective courses they also use the facilities of Rockefeller Hall, erected by John D. Rockefeller for the Department of Physics, and other buildings and equipment available in the College of Arts and Sciences.

Cornell engineers enjoy all the benefits and privileges of an outstanding university community. They associate continually, in fraternities and dormitories, in extra-curricular activities and in general University functions, with students of liberal arts, agriculture, law, veterinary medicine, and architecture. Concerts by world-famous soloists and orchestras, lectures by renowned scholars in widely varying fields, dramatic productions and art exhibits add to the cultural atmosphere in which Cornell engineers move as undergraduates.

These facts, in addition to the beauty of the Campus and the surrounding Finger Lakes region and the consideration that Ithaca is a small city, removed from the distractions of a metropolitan area but easily accessible by railroad and highway, help to explain the composition of the student population, which each year includes students from every part of the United States and numerous foreign countries.

The College of Engineering now comprises the School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering and the School of Chemical Engineering. Courses in Administrative Engineering are given in the first three of these Schools.

THE COLLEGE OF ENGINEERING

OFFICERS

Dean of the College. . . . . .S. C. HOLLISTER
Office: Sibley Dome

Acting Director of the School of Civil Engineering. . .P. H. UNDERWOOD
Office: Room 12, Lincoln Hall

Acting Director of the School of Electrical Engineering . .P. M. LINCOLN
Office: Franklin Hall

Director, Sibley School of Mechanical Engineering. . . W. N. BARNARD
Office: Room 18, West Sibley

Director of the School of Chemical Engineering. . . . . .F. H. RHODES
Office: Room 74, Baker Laboratory of Chemistry

Director of Admissions. . . . . .E. F. BRADFORD
Office: Morrill Hall

FACULTY*

EDMUND EZRA DAY, S.B., A.M., Ph.D., LL.D., President of the University.
LIVINGSTON FARRAND, A.B., M.D., L.H.D., LL.D., President, Emeritus.
SOLOMON CADY HOLLISTER, B.S., C.E., Dean of the College and Professor of Civil Engineering.

The School of Civil Engineering

PAUL HALLADAY UNDERWOOD, C.E., Acting Director of the School, and Professor of Surveying.
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 Engineering College Faculty.
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.

*This list does not include the many members of other College Faculties of Cornell University who give instruction to engineering students in mathematics, physics, chemistry and other subjects.

WILLIAM EDWARD STANLEY, B.S. in C.E., C.E., Professor of Sanitary 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 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, and Secretary of the Faculty of Civil Engineering.
ROMEYN Y. THATCHER, C.E., Assistant Professor of Civil Engineering.
HERBERT THEODORE JENKINS, B.S. in C.E., M.S.E., Assistant Professor of Civil Engineering.
CLAUDE M. PENDLETON, C.E., Marc Eidlitz Instructor in Civil Engineering.
FRED J. SPRY, M.C.E., Instructor in Surveying.
HAROLD VERN HAWKINS, B.S. in C.E., M.C.E., Ph.D., Instructor in Hydraulics.

The Sibley School of Mechanical Engineering

WILLIAM NICHOLS BARNARD, M.E., Director of the School, Professor of Heat-Power 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.
MILLARD CLAYTON ERNSBERGER, A.B., M.E., Professor of Power Engineering, Emeritus.
EDGAR HARPER WOOD, M.M.E.,Professor of Mechanics of Engineering, Emeritus.
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 Automotive 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 Mechanics and 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.
CHARLES OSBORN MACKEY, M.E., Professor of Heat-Power 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.
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CLYDE IRA MILLARD, E.E., Assistant Professor of Industrial Engineering.
MERLE HALSEY DAVIS, B.S., Major Ordnance Department, U. S. A., Assistant Professor of Ordnance.
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ROBERT CUNNINGHAM MORRIS, Instructor in Machine Design.
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HERBERT LYBRAND MANNING, B.S. in M.E., Instructor in Industrial Engineering.
CECIL WERNER ARMSTRONG, B.S. in M.E., M.S. in Eng., Instructor in Mechanics of Engineering.
JAMES KINNEY, B.S. in M.E., Instructor in Machine Design.
KENDALL CRITTENDEN WHITE, E.E., Instructor in Administrative Engineering.
LEON CHARLES PIGAGE, M.E., Instructor in Engineering Drawing.
FREDERICK SEWARD ERDMAN, B.S., B.S. in M.E., M.M.E., Instructor in Experimental Engineering.
BARTHOLOMEW JOSEPH CONTA, B.S., M.S., Instructor in Experimental Engineering.
WILLIAM PEARSON BEBBINGTON, B.Chem., Instructor in Experimental Engineering.
MILLARD VERNON BARTON, B.S. in M.E., M.S. in C.E., Instructor in Machine Design.
GEORGE HAMOR LEE, B.S., M.S. in Eng., Instructor in Mechanics of Engineering.
ANDREW SCHULTZ, jr., B.S. in A.E., Instructor in Administrative 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.
ARTHUR JAY MACK, Assistant in the Machine Shop.

The School of Electrical Engineering

PAUL MARTYN LINCOLN, M.E. (in E.E.), D.Eng., Acting Director of the School and Professor of Electrical Engineering.

VLADIMIR KARAPETOFF, C.E., M.M.E., D.Sc., 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 and Personnel Officer of the School 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, E.E., M.E.E., Instructor in Electrical Engineering.

WILBUR ERNEST MESERVE, B.S. (in E.E.), M.S., M.E.E., Ph.D., Instructor in Electrical Engineering.

FRANK JESSUP BRISTOL, E.E., Instructor in Electrical Engineering.

WILLIAM DANIEL MOEDER, E.E., Instructor in Electrical Engineering.

JOHN PALEN WOOD, M.E., M.E.E., Instructor in Electrical Engineering.

HARRY SOHON, E.E., M.E.E., Ph.D., Instructor in Electrical Engineering.

HOWARD GODWIN SMITH, E.E., M.E.E., Ph.D., Instructor in Electrical Engineering.

ELTON WRIGHT JONES, B.S. (in E.E.), M.S., Instructor in Electrical Engineering.

EMMETT WHITNEY MANNING, B.S. (in E.E. and Math.), M.S., Instructor in Electrical Engineering.

The School of Chemical Engineering

FRED HOFMANN RHODES, Ph.D., Director of the School, Professor of Chemical Engineering, and Personnel Officer of the School.

CHARLES CALVERT WINDING, Ph.D., Assistant Professor of Chemical Engineering.

WILLIAM NICHOLS BARNARD, M.E., Professor of Heat-Power Engineering.

CLYDE WALTER MASON, Ph.D., Professor of Chemical Microscopy and Metallography.

ADAM CLARKE DAVIS, jr., M.E., Professor of Experimental Engineering.

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

MARTIN JENKINS BARNETT, B.S., Assistant in Chemical Engineering.

CHARLES HENRY BRIDGES, B.Chem., Assistant in Chemical Engineering.

GEORGE NORMAL CORNELL, B.Chem., Assistant in Chemical Engineering.

CORNELIUS M. VANDERWAART, B.S., Assistant in Chemical Engineering.

Other Members of the College Staff

MAUDE S. NEWMAN, Assistant to the Dean.

RAYMOND F. HOWES, Assistant to the Dean.

RICHARD N. HOAR, Technical Assistant to the Dean.
LULU M. MARKELL, Secretary to the Dean.
PHYLLIS J. ATWATER, Stenographer to the Dean.
MARGARET KOMAROMI, Stenographer of Personnel and Employment Department.
MARY R. KORHERR, Secretary to the Director of the School of Civil Engineering.
MAY S. PINO, Stenographer in the School of Civil Engineering.
BEATRICE C. TERRY, Stenographer in the School of Civil Engineering.
MABEL H. WALBRIDGE, Librarian of the School of Civil Engineering.
DAVID FRANCIS POWERS, Mechanician in the School of Civil Engineering.
ALONZO AUSTEN, Mechanician in the School of Civil Engineering.
STANLEY S. MANNING, Assistant Mechanician in the School of Civil Engineering.
DOROTHY S. WILLIAMS, Secretary to the Director of the Sibley School of Mechanical Engineering.
FRANCES KLINKO, Stenographer in the Sibley School of Mechanical Engineering.
MARY L. RICHARDS, Stenographer in the Sibley School of Mechanical Engineering.
HILDA GEGG, Stenographer in the Sibley School of Mechanical Engineering.
LENA GERTRUDE MARSH, Librarian of the Sibley School of Mechanical Engineering.
ARTHUR W. JENKINS, Mechanician in the Sibley School of Mechanical Engineering.
SCOTT W. CROSS, 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.
FRANCIS KRAMER, Toolkeeper, Sibley School of Mechanical Engineering.
KATHERINE HANDLEN, Secretary to the Director of the School of Electrical Engineering.
MRS. I. M. BATCHELOR, Librarian of the School of Electrical Engineering.
GEORGE ALFRED CULLIGAN, Mechanician in the School of Electrical Engineering.

ENGINEERING EXPERIMENT STATION

SOLOMON CADY HOLLISTER, B.S., C.E., *Director*

THE EXPERIMENT STATION COUNCIL

SOLOMON CADY HOLLISTER, B.S., C.E., *Chairman*

PAUL HALLADAY UNDERWOOD, C.E., in charge of Research in Civil Engineering.
WILLIAM NICHOLS BARNARD, M.E., in charge of Research in Mechanical Engineering.
PAUL MARTYN LINCOLN, M.E. (in E.E.), D.Sc., in charge of Research in Electrical Engineering.
FRED HOFMANN RHODES, Ph.D., in charge of Research in Chemical Engineering.
WILL MILLER SAWDON, B.S., M.M.E., Secretary.

MEMBERS OF THE STAFF (1937–38)

TREVOR RHYS CUYKENDALL, B.S. in E.E., M.S., Ph.D., McMullen Research Associate.
DAVID DROPKIN, M.E., M.M.E., McMullen Research Associate.
FRITZ HERZOG, Ph.D., Westinghouse Research Associate.
LAWRENCE BRYON SPENCER, E.E., Westinghouse Research Assistant.

JOHN McMULLEN RESEARCH SCHOLARS, 1937–38

PAUL GEORGE BOHLKE, B.S. in A.E.
FREDERICK LEE BROWNE, B.S., M.A.
LEWIS DALCIN CONTA, B.S. in M.E., M.S.
HUGO VINCENT CONTI, B.S. in C.E.
WILLIAM NICHOLAS FINDLEY, A.B., B.S.E. in Math., B.S.E. in M.E.
JAMES HENRY NORRIS, B.S. in A.E.
JOHJ OSCAR OSTERBERG, B.S.; C.E.; M.S.
WILLIAM EDWARD PARKINS, B.S.
GEORGE FRANCIS STROLLO, B.S. in C.E.
ROYAL DAVID THOMAS, jr., B.Chem.

HOLDERS OF OTHER GRADUATE SCHOLARSHIPS AND FELLOWSHIPS, 1937–38

MILLETT GRANGER MORGAN, B.A..The Charles Bull Earle Memorial Fellowship
EDGAR CHARLES SONDERMAN, B.C.E.Graduate Scholarship in Civil Engineering
LUNG FU WANG, B.S. in C.E., M.C.E.....Graduate Tuition Scholarship
CHEN-HSU TÁNG, M.C.E.....The McGraw Fellowship

NON-RESIDENT LECTURERS FOR 1936–37

(Including those sponsored by Student Chapters of the National Engineering Societies)

MR. HOWARD L. DAVIS, New York Telephone Co.: *Selection of a Job; Preparation for Seeking Employment; Employment Demonstration.*
PROF. F. A. MAGOUN, Massachusetts Institute of Technology: *Human Relations in Industry.*
MR. J. H. BIGELOW, New York Telephone Co.: *Business Ethics.*
MR. R. E. HELLMUND, Westinghouse E. & M. Co.: *Industrial Economics.*
MR. J. W. PARKER, Vice-Pres., The Detroit Edison Co.: *Sit-Down Strikes—An Engineer's Observations on Labor Organization.*
DR. H. W. GILLETT, Battelle Memorial Inst.: *Controlled Atmospheres in Heat-Treating Steel.*
MR. ALEXANDER WALL, Sec.-Treas., Robert Morris Associates: *Measuring Factors of Safety in Credit Granting.*
MR. J. G. DETWILER, Technologist, The Texas Company: *Petroleum—With Special Reference to the Manufacture of Lubricating Oils.*
MR. C. D. HART, Supt. of Wire Products Shop, Western Electric Co.: *Layout of a Modern Plant for Producing Rubber Covered Wire.*

MR. HOMER DEDO, Ethyl Gasoline Corp.: *Combustion Process in Automotive Engines.*

MR. L. B. KNIGHT, Vice.-Pres., National Eng'g. Co.: *The Opportunity and Need for the Engineer in the Foundry Industry.*

MR. C. S. COLER, Mgr., Employment and Training, Westinghouse Electric & Mfg. Co.: *Decisions Necessary in Selecting your Job.*

MR. L. W. W. MORROW, Gen. Mgr., Fibre Products Division, Corning Glass Co.: *Business Problems and Policies Today.*

MR. J. F. LINCOLN, President Lincoln Electric Co.: *Welding as a Manufacturing Tool.*

MR. PAUL R. SIDLER, Brown, Boveri Co.: *The Velox Steam Generator.*

MR. SAMUEL L. HOYT, A. O. Smith Corp.: *It's All in an Engineer's Life.*

MR. DANA W. LEE, N. A. C. A. Laboratory: *Recent Developments in Airplane Engines.*

DR. PHILLIP THOMAS, Westinghouse Research Laboratories: *Adventures in Electricity.*

DR. D. B. STEINMAN, Consulting Engineer, New York: *Registration of Engineers.*

MR. A. E. CUMMINGS, Raymond Concrete Pile Co., Chicago: *Foundation Engineering.*

MR. LEON S. MOISSEIFF, Consulting Engineer, New York: *The San Francisco Bridges.*

MR. BENJAMIN K. HOUGH, jr., U. S. Army Engineers: *Investigation of Soils for Dam Construction.*

MR. S. A. GREELEY, Consulting Engineer, Chicago: *Buffalo Sewage Disposal System.*

MR. K. B. MCEACHRON, General Electric Company: *Lightning Research.*

MR. O. K. MARTI, Allis Chalmers Company: *Grid Control Electronic Inverters and Converters.*

MESSRS A. C. STEVENS and W. C. HUTCHINS: *Modern Welding Technique and its Equipment.*

PROF. W. H. TIMBIE, Massachusetts Institute of Technology: *Sins of an Engineer.*

MR. R. E. HELLMUND, Westinghouse Electric and Manufacturing Co.: *Divergent Tendencies in Electrical Engineering in the United States and Abroad.*

MR. A. M. MCCUTCHEON, President A. I. E. E.: *The Section's Part in Institute Activities.*

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 145.

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 four main Schools—those of Civil Engineering, Mechanical Engineering, Electrical Engineering, and Chemical Engineering and these schools are further divided into Departments, each with a staff specializing in its own particular branch. 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 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. 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 eco-

nomics 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 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 also offers, through its engineering schools, both optional courses and complete curricula in what is generally called Administrative Engineering.

Bachelor Degrees

The regular four-year courses in the College of Engineering lead to the respective degrees of Bachelor of Civil Engineering (B.C.E.), Bachelor of Mechanical Engineering (B.M.E.), Bachelor of Electrical Engineering (B.E.E.), and Bachelor of Science in Administrative Engineering (B.S. in A.E.); and the five-year course in Chemical

Engineering leads to the degree of Bachelor of Chemical Engineering (B. Chem. E.) at the end of the fifth year. (For the ADVANCED DEGREES offered in the Engineering Division of the Graduate School, see p. 147.)

PROFESSIONAL ENGINEERING DEGREES

The degrees of Civil Engineer, Mechanical Engineer, and Electrical Engineer, which were formerly conferred at the end of the four-year undergraduate course, and the degree of Chemical Engineer, which was formerly conferred at the end of the five year undergraduate course, are now designated as Professional Degrees and hereafter will be conferred only on graduates who have been successful in the actual practice of their profession and meet certain other requirements.* The deferred Professional Degrees of C.E., M.E., E.E., and Chem.E., may be awarded under the following regulations:

(a) The Professional Degrees of C.E., M.E., E.E. and Chem.E., may be awarded only to applicants who hold baccalaureate degrees given by this College. Applications for these degrees should be sent to the Dean of the Engineering College at least one year before the time the degree is desired.

(b) Each applicant for one of these professional degrees must have had after baccalaureate graduation four years of acceptable professional experience in the field of the degree sought. Each year of graduate residence credit in this field at Cornell or at some other accredited Graduate School, or each year of teaching in that field at Cornell or in any college of comparable rank may be counted as one year towards satisfying the requirement of professional experience. Detailed statements regarding his professional experience must be submitted by persons, firms, or colleges, under whom the experience was acquired.

(c) The applicant must write and present an original thesis of a type which would be accepted as a technical paper by one of the professional engineering societies. Detailed information regarding the proposed thesis must be submitted, in duplicate, preferably before the writing of the thesis is undertaken. The thesis must be submitted in triplicate to the Dean of the Engineering College three months prior to the June Commencement, and must conform to the requirements of the Graduate School relating to theses.

(d) The applicant must present himself at the University for an examination by a Faculty Committee. Such examination may be written, or oral, or both, and cover both the subject matter of the thesis and the professional experience. The candidate must pay such fees as may be required by the Treasurer of the University.

COURSES OFFERED

Undergraduate instruction is offered in 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 student who can afford the additional time and expense take one of the longer courses in order to broaden his training.

*Undergraduates who matriculated before February 15, 1937 have the choice between the degrees of B.C.E., B.M.E., or B.E.E., and the degrees of C.E., M.E., or E.E., appropriate to the curriculum pursued by them. Undergraduates who matriculated in the five-year course in Chemical Engineering before June 1, 1938, have the choice between the degree of Chemical Engineering and the degree of B. Chem. E.

The Regular Four-Year Courses

Each of the regular curricula in engineering except Chemical 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 B.C.E.) with specialization in Hydraulic Engineering, Sanitary Engineering, Transportation Engineering, Structural Engineering, Highway Engineering, Administrative Engineering, or Geodetic Engineering. (For more complete description see p 51.)

MECHANICAL ENGINEERING (Degree of B.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. 86.)

ELECTRICAL ENGINEERING (Degree of B.E.E.) with specialization in Electrical Power Stations, Electrical Design, Electrical Communication, Electric Circuit Analysis, Electric Traction, Illumination, Physics, etc. (For more complete description, see p. 123.)

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. 54 (C.E.), p. 88 (M.E.), p. 132 (E.E.).)

Five-Year Course Leading to the Degree of Bachelor of Chemical Engineering

Because a competent chemical engineer must be thoroughly familiar not only with the fundamentals of engineering and with the special field of chemical engineering but also with the science of chemistry, it is impossible to provide adequate preparation for professional work in Chemical Engineering in four years. The curriculum leading to the degree of Bachelor of Chemical Engineering outlines an integrated five-year course. Provision is made for a considerable amount of elective work. The elective work may be either in cultural subjects or in fields in which the student desires specialized or advanced instruction.

Other Five-Year Courses

FIVE-YEAR COURSES LEADING TO THE SINGLE DEGREE OF B.C.E., B.M.E., B.E.E., OR B.S. IN A.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.

FIVE-YEAR COURSE LEADING TO THE A.B. AND B.C.E. DEGREES

In Civil Engineering, the A.B. degree and the degree of Bachelor of Civil Engineer may be obtained in five years plus two summer sessions. The entrance requirements for this course must correspond to those for the first degree taken.

FIVE-YEAR COURSES LEADING TO THE DEGREES OF B.C.E., B.M.E., OR B.E.E. AND B.S. IN A.E.

In Administrative Engineering it is possible so to arrange the work of the five-year course that the degree of B.C.E., B.M.E. or B.E.E. 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 not later than the end of the second year.

FIVE-YEAR COURSE LEADING TO THE DEGREES OF B.M.E. AND B.E.E.

It is possible to rearrange the required work in the respective four-year curricula in mechanical and electrical engineering so that both the B.M.E. and B.E.E. degrees may be obtained in a five-year period of study. The necessary adjustment of work for this purpose must be made with the Directors of the Schools of Mechanical Engineering and Electrical Engineering before the beginning of the student's second year.

Six-Year Courses

The six-year course, leading to the degrees of A.B. and B.C.E., or A.B. and B.M.E., or A.B. and B.E.E., or A.B. and B.S. in A.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 B.C.E., B.M.E., B.E.E. or B.S. in A.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 B.C.E. may be obtained in five years plus two summer sessions.

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, except in the five-year course in Chemical 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 46.)

Upon entering the college, 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, construction, and operation 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 principally with the fundamental principles of the law of contracts. Opportunity is also given to seniors to specialize to a limited extent, or to broaden their training, by the election of certain courses, some of which may be chosen from approved courses in any department of the University. (For outline of the regular course, see page 56.)

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, advanced applied mathematics, materials of construction, kinematics and drawing, economics, and machine construction, the junior student in Mechanical Engineering receives training in fluid mechanics (including hydraulics), machine design, shop processes, industrial organization, accounting, 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, Heat Engineering (including fluid flow, heat transmission, refrigeration, and air conditioning), 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 106. The special work in these Options (A to H incl.) is described on pages 94 to 102. (For complete outlines of the four-year, five-year, and six-year courses in Mechanical Engineering see pages 103 to 104.)

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 128.)

Administrative Engineering students in three Schools of Engineering (C.E., M.E., E.E.) 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 engineering 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 64 (C.E.), 105 (M.E.), 132 (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 138.)

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 hydro-electric 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, or 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 re-

search. 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 officer 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. In each of the four Schools, a member of the faculty has been assigned as Personnel Officer.

The personnel officer 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; and advises the student which of the undesirable traits may be changed. 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 courses in the Department of Military Science and Tactics, see the General Information Number and the Announcement of the Department of Military Science and Tactics.

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

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. All freshmen are required to take courses in hygiene throughout the year, and additional courses are offered by the department.

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

ENGINEERING SOCIETIES

The College of Engineering is closely associated with the Ithaca Sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. In addition, the College maintains very active Student Branches of these national

societies as well as of the American Institute of Chemical Engineers. The many interesting meetings of these Branches are addressed by engineers of eminence, or are used for the presentation of papers by students, or for discussion, or for contests in public speaking on engineering subjects.

EXTRA-CURRICULAR ACTIVITIES

Supplemental to the classroom instruction, engineering students have opportunity to engage to a wholesome extent in various outside activities connected with the College, University, or community. Those interested in athletics find ample opportunity to take active part in or to witness a great variety of games and contests. Valuable experience is obtained from participating in the activities of the Student Branches of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and American Institute of Chemical Engineers; from attending the sessions of the Ithaca Sections of these societies; from becoming associated with the honorary engineering and scientific societies, national and local, such as Sigma Xi, Tau Beta Pi, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, Phi Kappa Phi, Eta Kappa Nu; from acting on the board of the *Cornell Engineer*, published by the students of the College; from membership in one of the musical clubs, the Dramatic Club, the Cosmopolitan Club, or in one or more of the many other clubs; and from taking part in some of the numerous other campus activities. However, such participation should, of course, not be so extensive as to interfere with the student's scholastic duties.

DEAN'S HONOR LIST

In recognition of high scholastic accomplishment the Dean of Engineering announces on an occasion held each Spring, and known as "Honors Night", the names of the undergraduate students in the College of Engineering whose weighted average is 85 or better. Such a list includes approximately the upper 10 per cent of the enrolled students in the College.

THE ENGINEERING EXPERIMENT STATION

The Engineering Experiment Station of the College of Engineering was established for the purpose of conducting scientific and technical research of importance to the engineering profession and the industries. The station affords opportunities for members of the faculty, graduate scholars, and specialists to use for that purpose not only the facilities of the College, but also those of other departments of the University. The investigations may consist of analytical studies to develop new theories, laws, or concepts, or to interpret and make more useful information and data already available; they may consist of the design and construction of new and useful forms of apparatus of importance; or they may be experimental investigations of materials

and their properties or of structures, instruments, apparatus, machines, prime-movers, air-conditioning equipment, heat-transfer apparatus, etc., etc. The laboratory facilities available for experimental investigations are described on pages 41 to 43, but provision is made also for buying or constructing additional research apparatus needed.

The management of the Station is vested in the Dean of the College, who is also officially designated the Director of the Engineering Experiment Station. He is assisted by a Council consisting of himself, as Chairman, and the Directors of each of the four Schools; and each Director is aided by a School committee on research. All members of the faculty are encouraged to carry on research or to supervise investigations conducted by the John McMullen Graduate Scholars and others. At present there is provision for twelve of these scholars, with annual stipend of $1000 and opportunity to work for an advanced degree (see p. 149). The Station publishes Bulletins giving reports of the investigations completed.

Cooperative Research

In addition to the research conducted with the funds provided for the Engineering Experiment Station, and which may not be available or applicable for investigations made in cooperation with trade associations or companies, or government bureaus, the College or Station conducts cooperative investigations which are financed, at least in part, by those sponsoring the work.

The operation of the Experiment Station serves not only to advance the state of the art or science of engineering, but aids in keeping the Faculty abreast of the times; and it also serves as an inspiration to the students of the College.

SPECIAL FUNDS

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.

Henry Herman Westinghouse Endowment Fund. Gift of $500,000 by H. H. Westinghouse, class of '72, under a trust established in 1925, the income to be used for such purpose or purposes consistent with the objects, aims, and policies of Cornell University, as in the sole discretion of its Trustees shall seem most appropriate and desirable, the desire, however, of the donor being that if practicable, such funds be devoted to the advancement of the science of engineering. It was established in 1933. The income of this fund has been allocated to promote engineering research.

In addition to these special funds many other donations have been made to the University to endow engineering scholarships, fellowships, professorships, book funds, prizes, etc. These funds are discussed elsewhere.

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 Courses and Five-Year Course in Chemical Engineering

For admission to the freshman class in the regular four-year courses in Engineering, the applicant must be at least sixteen years of age and must offer fifteen specific units of entrance subjects, as follows, from the list on p. 29:

English		3 units
Mathematics:		
Elementary Algebra	1 unit	
Intermediate Algebra	1 "	
Plane Geometry	1 "	
Advanced Algebra or Solid Geometry	½ "	
Plane Trigonometry	½ "	
Total Mathematics		4 units
History, 2 units, or		2 units
One Foreign Language*, 2 units		
(German, French, Spanish, Italian, Greek, or Latin)		
Physics or Chemistry**		1 unit
Electives		5 units
Total		15 units

With respect to this specific list of entrance subjects, the following should be noted:

1. The four units of Mathematics required may be offered under the specific subjects and units above listed, or they may be offered as four years of continuous training in Mathematics throughout the

*Students who expect to enter the Graduate School after obtaining a first degree should note that a minimum of two units of one foreign language, preferably German or French, is required of candidates for the master's degrees in engineering, see p. 150.

Students desiring to enter the Course in Chemical Engineering **must offer one unit of Chemistry.

high or preparatory school course, provided that in the latter case a declaration is attached to the certificate of credits stating that the course in Mathematics has included the essentials of the four units of Mathematics as required by the Gamma Examination of the College Entrance Board.

2. The five elective units may be made up from any subjects on the list on p. 29 with the restriction that, if further foreign language is offered, it must consist either of one or more units of the same language in which two units are already offered above, or it may not be less than two units in any other foreign language.

3. Applicants offering fifteen units which do not differ materially from the specific list may present their credits for special consideration, for under proper circumstances some adjustment may be permitted. If there is a deficiency in the mathematics specified, and it does not exceed a total of one unit, the applicant may be admitted, provided he agrees to remove this shortage in college during the first term, then to begin the regular freshman mathematics at mid-year and to complete the remainder of this course in the following summer session. It is preferable, however, for the student to be free from entrance shortages at the time he enters. Attention is called to the possibility of obtaining additional credits by attending the summer session (see the Announcement of the Summer Session) or by taking the September examinations.

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 important literature on the theory and practice of engineering. For the purpose of entrance requirements, the substitution, unit for unit, of scientific French or German, in lieu of a more general literary course in either of those subjects is permitted, and this substitution will apply to all such courses in any secondary schools approved by the Director of Admissions.

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. More detailed information about courses requiring more than four years for graduation will be furnished upon application to the Dean of the College of Engineering.

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.

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 Year 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.

2. By passing the College Entrance Examination Board Examinations 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.

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 27.

Admission to the Five-Year Courses in Engineering Other Than Chemical 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 Six-Year Courses

These courses lead to the degree of A.B. and one of the Engineering degrees (B.C.E., B.M.E., B.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 18.

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, and should include (1) 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, (2) a detailed statement of the courses pursued, and (3) the drawings and reports for which credit is desired. 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 STUDENTS

Applicants who do not wish to become candidates for any of the undergraduate degrees, either because they can not meet the specific entrance, or because they find it impracticable to spend the number of years required for graduation, may, in exceptional cases, be admitted to the College of Engineering as special students.

Such students may be of two classes:

1. Those students who can not meet the entrance requirements or do not wish to spend the required time to complete the course. Special students of this kind must be at least 21 years of age, must have had some engineering training, and must have the prerequisites for the courses they wish to take.

2. Those students who, having a baccalaureate degree, wish to pursue further work at the undergraduate level. Such students must have the prerequisites for the courses they wish to pursue.

It is further provided that all special students must register for a minimum of 15 credit-hours of work each term, and pay the same tuition and fees required of other undergraduate students. Special students may not receive a degree except upon the completion of both the entrance requirements and the undergraduate work specified for that degree.

ADMISSION AS A GRADUATE STUDENT

Graduates of this college or other engineering colleges may enter the Graduate School of Cornell University and pursue advanced work in engineering. Such a student may enter either as a candidate for a degree (M.C.E., M.M.E., M.E.E., M.Chem.E., M.S. in Engineering, or Ph.D.) or not, according to the character of his previous training. A prospective graduate student should consult the Announcement of the Graduate School and apply to the Dean of the Graduate School. See also page 149.

A NECESSARY PRECAUTION

Before coming to the University, the student should consult an oculist 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 148.

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, when applying for admission, 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, with the exception of students in the first and second years of the five year Chemical Engineering course, 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; third, fourth, and fifth year students in Chemical Engineering, $25 a year. Students taking any other 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 ot 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. 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 Uniform Deposit of $20 is required of students enrolled in the Basic Course of the Department of Military Science and Tactics. The major part of this

deposit is returned to the student as earned uniform allowance upon completion of the two-year course.

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 thereupon 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 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.

UNDERGRADUATE 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 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 148 of this Announcement; and about prizes in a pamphlet entitled Prize Competitions. Any of these publications may be obtained from the Secretary of the University.

UNDERGRADUATE SCHOLARSHIPS—GENERAL

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 SCHOLARSHIPS. 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 John McMullen Regional Scholarships, Undergraduate Scholarships, and Graduate Research Scholarships. The Regional and Undergraduate Scholarships are discussed in the next two paragraphs. For information regarding the Graduate Scholarships, see p. 148.

THE JOHN MCMULLEN REGIONAL SCHOLARSHIPS, each having annual value of $400, 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 120 scholarships are awarded annually in fifteen districts, the State of New York being excluded. Boys eligible for a New York State Scholarship are excluded. About February 1 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., before May 1. A faculty committee selects the five most promising candidates in each district and forwards their application 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, Electrical, or Chemical Engineering. The Board of Trustees has established at the present time a considerable number (48) of these undergraduate scholarships of an annual value of $200 each, and divided them among the four schools of the College of Engineering. These scholarships are awarded primarily for the purpose of providing able students with scholastic opportunities which would otherwise be denied them. These scholarships are not normally granted to freshmen. Applications should be made to the Director of the school concerned before April 1.

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 before April 1.

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." Applications should be made to the Dean of the College before April 1.

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. Applications should be made to the Dean of the College before April 1.

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. Applications should be made to the Director of the School of Mechanical Engineering before April 1.

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 to the Director of the School of Civil Engineering before April 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. Applications should be made to the Dean before April 1.

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. Applications should be made to the Dean before April 1.

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. Applications should be made to the Dean before April 1.

THE REDMOND STEPHEN COLNON SCHOLARSHIPS: Supported by the income from $20,000 bequeathed by Mrs. Katharene Fruin Colnon in 1935 in memory of her husband. Four scholarships of $200 each awarded annually (two in Mechanical Engineering and one each in Civil and Electrical Engineering) to sophomores, juniors, or seniors, upon the recommendation of the School concerned. Candidates in order to be eligible must be upon the annual Honor List, and may hold the scholarships for more than one year provided they remain upon that list. Applications should be made to the Director of the school concerned before April 1.

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 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.

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 $80, one of $40, and one of $20, 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 four 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 seven in number—one selected by the College of Architecture, one selected by each of the four 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 and Electrical Engineering. Under a gift of the late Hiram Sibley, made in 1884, the sum of eighty dollars is awarded annually in several 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 J. G. WHITE PRIZE IN SPANISH. Through the generosity of James Gilbert 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 JOHN KNICKERBACKER FUND, established in 1919 by John Knickerbacker '87, of Troy, N. Y., supports a limited number of bursaries; the bursars are required to be young men of good minds, healthy and strong bodies, good moral character and sound moral opinions and beliefs, to be earnest and persevering workers, and to come from parents born in the United States and known to be or to have been good citizens. Applications are invited by the Secretary of the University in the spring, and a standing committee fills any vacant bursaries by election in the summer.

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 JOHN N. OSTROM FUND was founded by John N. Ostrom, C. E. '77, for making loans to students in the School of Civil Engineering upon recommendation of the Director of that School. The loans are to be in the amount of $200 per annum to each student. Rules governing the procedure of granting the loans are in process of being formulated.

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 AND EQUIPMENT

CIVIL ENGINEERING

The principal building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, laboratories, museums, and the working library. The library facilities include the KUICHLING MEMORIAL LIBRARY donated and endowed by Mrs. Sarah L. Kuichling in memory of Emil Kuichling, A.B., C.E. The IRVING PORTER CHURCH FUND, donated by former students of the School, aids in purchasing books for the working library. The **Highway Laboratory** is housed in a separate building and is equipped for making the standard tests and for research problems in the field of highway engineering. The astronomical equipment is housed in the **Fuertes Observatory,** which contains the instruments required for determining time, latitude, longitude and azimuth.

A large and unusual **Hydraulic Laboratory,** located at the outlet of Beebe Lake, is under the jurisdiction of this School. In addition to student instruction and research, this laboratory provides facilities for numerous important hydraulic investigations carried on in cooperation with governmental agencies and private companies. Experimental work is now being carried on at the laboratory by the United States Army Corps of Engineers in connection with the projects of the Southern New York Flood Control District.

The laboratories located in Lincoln Hall are as follows: the **Testing Laboratory,** equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by Civil Engineers; the **Mechanics Laboratory,** equipped for demonstration and experimentation in connection with the undergraduate instruction in Mechanics; the **Laboratory of Applied Elasticity,** equipped for experimentation by advanced students; the **Sanitary Laboratory,** with facilities for physical, chemical, bacteriological, and biological analyses of water and sewage; and the **Soil Mechanics Laboratory,** with all the facilities for performing standard tests on soil. Further investigations in soil mechanics may be carried on cooperatively by the School Staff and the Army Engineers in another laboratory housed in a separate temporary building constructed on the campus by the Federal Government.

MECHANICAL ENGINEERING

The Sibley School of Mechanical Engineering, named in recognition of important gifts made by Hiram Sibley and his son, Hiram W. Sibley, occupies a group of large buildings at the north end of the campus. In addition to the Sibley Buildings, this group includes Rand Hall, which was added through the generosity of Mrs. Florence O. R. Lang as a memorial to Jasper R. Rand, Addison C. Rand and

Jasper R. Rand, Jr. The School is provided with a central working library in Sibley Dome and many of the departments also maintain special working and reference libraries.

Numerous laboratories and shops are available for carrying on the many activities of the School of Mechanical Engineering, as follows:

The **Materials Testing Laboratory,** for determination of the physical properties of engineering materials under different kinds of stress and heat treatment; the **Photo-Elastic Laboratory,** for instruction and research in Photo-Elastic work; the **Steam Laboratory,** for instruction and research involving Steam Power; the **Internal-combustion Engine Laboratory,** for work with this type of power equipment; the **M. E. Hydraulic Laboratory,** a pump operated laboratory for hydraulic problems; the **Lubrication Laboratory,** for determination of the physical properties of lubricants; the **Refrigeration Laboratory,** for the study of refrigeration; the **Cement Laboratory,** for the testing of cement and concrete; the **Fuel Testing Laboratory,** for determination of the composition and calorific value of all types of fuel; the **Belt Testing Laboratory,** for measurement of belt tension, power transmitted, and slip; the **Micro-Motion Laboratory,** for time and motion study; the **Introductory Engineering Laboratory,** for demonstrating the principal operations in forging, welding, soldering, brazing, etc.; the **Heat Transfer, Heating, Ventilating, Air Conditioning Laboratories;** a series of **Research Laboratories;** the **Forge Shop, Woodworking and Pattern Shop, Machine Shop, Foundry,** and **Boiler House.**

ELECTRICAL ENGINEERING

The School of Electrical Engineering is housed in Franklin Hall, a portion of Rand Hall, and at the Broadcasting Station and Studios. The School Library, located in Franklin Hall, is known as the ALEXANDER GRAY MEMORIAL LIBRARY, founded originally by the McGraw Hill Book Company in honor of Professor Alexander Gray, deceased.

Laboratories and demonstration facilities of the School of Electrical Engineering are as follows:

The **Lecture Room,** with provision for experimental demonstrations to accompany the earlier lectures in electrical principles and applications; the **Electrical Machinery Laboratories,** with a great variety of both direct and alternating-current machines; the **Electronic Laboratory,** equipped for a wide variety of tests; the **Standardizing Laboratory,** for checking of secondary standards and meters; the **Electrical Communication Laboratory,** well provided with apparatus to illustrate modern electrical communication; and the **Broadcasting Station and Studios,** from which numerous University programs are broadcast, and which are available for instruction and research.

CHEMICAL ENGINEERING

The specialized training in Chemical Engineering, and the general instruction in chemistry for all students, are given in the **Baker Laboratory of Chemistry,** which is adjacent to the engineering buildings. This large and splendidly equipped building includes, in addition to many other laboratories and class rooms, a special laboratory for experimental work on unit operations and unit processes, and facilities for research in chemical engineering. Other laboratories are also available for specialized and research work in chemical engineering and metallography. An excellent technical library covering the fields of chemistry and chemical engineering is available at Baker Laboratory.

OTHER FACILITIES

In addition to the various school and departmental libraries previously mentioned, the facilities at the general library building of the CORNELL UNIVERSITY LIBRARY are available to engineering students. This library contains one of the largest collections of its kind in the country.

Mathematics is taught in WHITE HALL, located adjacent to the engineering college buildings. All instruction in Physics for undergraduate and graduate students is given in nearby ROCKEFELLER HALL, a large and well equipped building used solely for work in this field. This building also houses the library of the Department of Physics.

COURSES OF STUDY IN THE COLLEGE

THE REGULAR FOUR-YEAR COURSES

As stated already in the preceding pages, three Schools of the College offer regular four-year courses leading to the degrees of B.C.E., B.M.E., and B.E.E., and B.S. in A.E.

The first year of all of these 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; it is preferable, however, that the choice be made at the end of the first term. The curriculum of the first year is given on page 46 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, particular statements of the curriculums 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 the elective courses are clearly defined in the announcement of each school on subsequent pages.

FIVE AND SIX-YEAR COURSES

The course leading to the degree of Bachelor of Chemical Engineering is an integrated five-year course. The student registered for this degree is under the direct supervision of the School of Chemical Engineering throughout all five years of the course.

As already mentioned on page 18 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., B.C.E., B.M.E., or B.E.E., as the case may be.

Five-year courses can be so arranged that two baccalaureate degrees in engineering may be obtained in that time, one at the end of the fourth year and the other at the end of the fifth year.

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

THE REQUIREMENTS FOR GRADUATION

The degrees of B.C.E., B.M.E., B.E.E., B.S. in A.E., or B. Chem. E., are 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 in the payment of tuition and fees.

2. If admitted to the 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 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.

CREDIT HOUR DEFINED

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 FRESHMAN YEAR

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

For Freshman year in Chemical Engineering, see page 138.

SCHEDULE OF STUDIES

	Credit Hours	
	1st Term	*2nd Term*
Analytical Geometry and Calculus 5a, 5b	5	5
General Physics, 11, 12	4	4
General Chemistry 102 or 104	3	3
Drawing 200, 201 (C.E.)	3	3
Drawing and Descriptive Geometry 120 (M.E., E.E.)	3	0
Mechanical Drafting 121 (M.E., E.E.)	0	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
Wood Shop 102 (M.E., E.E.)	0 or 1	1 or 0
Introductory Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours per term (C.E.)	20 or 18	17 or 19
Total number of hours per 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, and for the curriculum in Chemical 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 B.C.E., B.M.E., B.E.E. and B.S. in A.E., and the additional courses offered in Hygiene and in Military Science. The courses in Mathematics, Physics, and Chemistry are given in the College of Arts and Sciences; the other courses in the list, except Hygiene and Military Science, 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 heat.

Rockefeller Hall. 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 light.

Rockefeller Hall. Professor GRANTHAM and instructors.

CHEMISTRY

Entrance credit in chemistry does not carry with it University credit in Courses 102 *or* 104. *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* 104*a and* 104*b that is obtained by passing this examination does not carry with it entrance credit in Chemistry.*

102. **General Chemistry.** Throughout the year. Credit three hours a term. Both terms of the course must be completed to obtain credit unless the student is excused by the department. Open only to those students who do not offer entrance chemistry. Deposit, $11 each term. Professor BROWNE, Professor LAUBENGAYER, and assistants. Lecture: Th, or F, 11, Main Lecture Room, Baker. Recitation: one hour a week, to be arranged. Laboratory: M, T, W, Th, or F 1:40–4.

This course deals with the fundamental laws and theories of chemistry and the properties of the more common elements and their compounds.

104. **General Chemistry.** Throughout the year. Credit three hours a term. Both terms of the course must be completed to obtain credit unless the student is excused by the department. Prerequisite, entrance credit in chemistry. Deposit, $11 each term. Professor LAUBENGAYER, Dr. HOARD, and assistants. Lecture: M or T 11, Main Lecture Room, Baker. Recitation: one hour a week, to be arranged. Laboratory: M, T, W, Th, or F 1:40–4.

This course deals with the fundamental laws and theories of chemistry and the properties of the more common elements and their compounds.

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, Assistant Professor LAWRENCE and Mr. SPRY. *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; fundamental 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, Assistant Professor LAWRENCE and Mr. SPRY. *Lincoln Hall.*

120. **Drawing and Descriptive Geometry.** Required of candidates for the degree of B.E.E. or B.M.E. or B.S. in A.E. with special reference to either E.E. or M.E. First term. Credit three hours. One recitation and 2 two and one-half hour drawing periods a week.

Coordinated instruction in subjects prerequisite to a study of the engineering applications of drawing. The drafting arts. Geometric analysis and composition of structures including considerations of: the elements of structure and their properties, interspace relations of structural elements, determinants of elements and structural organization along paths of physical and functional ties. Graphic computation and description of the geometric qualities and quantities of structure. Professor TOWNSEND, Assistant Professor CLEARY and Instructors. *East Sibley.*

121. **Mechanical Drafting.** Required of candidates for the degree of B.E.E. or B.M.E. or B.S. in A.E. with special reference to either E.E. or M.E. Second term. Credit three hours. One recitation and 2 two and one-half drawing periods a week. Prerequisite course 120 and must be taken with or preceded by courses 102 and 103.

Basic studies of the functional and structural divisions of machines, structural standards and shop methods of producing structural qualities and quantities are coordinated in this course with instruction and drill in the fundamental techniques of determining machine structure by layouts and specifying structural information on working drawings in a manner consistent with both the convenience of the shop and the need of restricting the accumulation of production errors. Freehand sketching pictorial drawing, tracing, etc. are studied and applied in this work.

This is the first course in the engineering curriculum which deals with a subject of express engineering application. Students who become proficient in this subject are eligible for employment as junior mechanical draftsmen and are thus afforded their first opportunity for summer work of recognized value as basic training in the field of engineering practice. The benefits to be derived when studies of fundamentals are overlapped with practical experience are of such importance that every eligible student should attempt to take advantage of this opportunity. Professor TOWNSEND, Assistant Professor CLEARY and instructors. *East Sibley.*

125. **Drawing.** Required of candidates for the degree of Bachelor of Chemical Engineering. Second term. Credit three hours. One recitation and 2 two and one-half hour drawing periods a week. A brief course in the basic subjects of drawing and the techniques of applying these subjects to the determination of structure by layouts and the specification of structure on working drawings. Professor TOWNSEND, Assistant Professor CLEARY 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. *Lincoln Hall.*

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. *Lincoln Hall.*

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: Professor SMILEY, Assistant Professors GOULD, SHOWACRE, DEYOE, ROSE, and Doctor PARRATT.

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: Professor SMILEY, Assistant Professors GOULD, SHOWACRE, DEYOE, ROSE, and Doctor PARRATT.

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*.

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. Anatomy lecture room, *Stimson*, F 9. 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. Assistant Professor DEYOE.

W 12. Histology Lecture Room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

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. **Hygiene: Mental Hygiene.** First term. Section 2 repeated second term. Credit two hours. Section 1. *Boardman*. M F 11. Assistant Professor ROSE. Section 2. Histology Lecture Room, *Stimson*. W F 2. Dr. STELLE. Registration at Hygiene Office, *Old Armory*.

The relationship of the structure of the total personality to environmental maladjustment as evidenced by physical and social behavior; a discussion of the more common personality difficulties and the role of insight in the prevention of these.

9. **Hygiene: Mental Hygiene.** Second term. Credit two hours. Prerequisites: Hygiene 1, 2 and 8. M F 11. *Boardman*. Assistant Professor ROSE.

A study of the social applications of psychiatry to Child Guidance, Juvenile Delinquency, the problem of crime and the care of the psychotic. Recommended for those interested in social welfare work and especially psychiatric social work.

MILITARY SCIENCE AND TACTICS

1. **Basic Course.** Required. Throughout the year. The complete course covers two years. Three hours a week, either M T W or Th 1:40–4:10 P.M.

The course of training is that prescribed by the War Department for Senior Division Units of the Reserve Officers' Training Corps for basic students. Instruction is offered in Infantry, Field Artillery and Signal Corps. For details concerning the course see the Announcement of the Department of Military Science and Tactics.

Required of all able bodied first and second year male students who are American citizens, and candidates for a baccalaureate degree. The requirements of Military Science and Tactics must be completed in the first terms of residence, otherwise the student will not be permitted to register again in the University without the consent of the faculty.

Advanced standing: With the approval of the Department of Military Science and Tactics, credit may be allowed a student for all or part of the Basic Course requirement, upon presentation of evidence of satisfactory work completed at an approved institution.

2. **Advanced Course.** Elective. Throughout the year. Credit two hours a term. The complete course covers two years. Prerequisite, Basic Course in the arm or service selected. Five hours a week, and in addition attendance at a Summer Training Camp of six weeks duration. Hours by assignment. *Drill Hall*.

The course of training is that prescribed by the War Department for Senior Division Units of the Reserve Officers' Training Corps for advanced students. Instruction is offered in Infantry, Field Artillery, Ordnance and Signal Corps.

Upon successful completion of the Advanced Course a student may be commissioned as a Reserve Officer of the United States Army, in the appropriate arm or service, upon the recommendation of the Professor of Military Science and Tactics. For details concerning the course see the Announcement of the Department of Military Science and Tactics.

3. **Advanced Signal Corps Course.** Elective. Three lectures a week and one hour of leadership throughout the junior and senior years. Credit one hour per term. Prerequisite courses Physics 21, 22. Concurrent courses Electrical Engineering Principles 411a, 412a, or Electrical Engineering 405, 406 or E.E. Theory 415, 416. Courses 451, 452, 452a, desirable but not required. First year covers wire and radio communication and military subjects. Second year, in general, is of a military nature.

4. **Ordnance Problems.** Course 3 M 53. See description on page 117.

SCHOOL OF CIVIL ENGINEERING

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to impart knowledge of the fundamental principles of design, construction and operation of structures and works of the civil engineering type, in addition to providing a liberal opportunity for study of general and cultural subjects. Emphasis is placed upon civil engineering as an applied science rather than as a vocational technique.

The instruction in Mathematics, Chemistry, Physics, Geology, Economics, Psychology, 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 School of Civil Engineering, or in the Schools of Mechanical Engineering or Electrical Engineering. Some electives may be taken in other Colleges of the University.

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

1. Drawing and Descriptive Geometry

Engineering Drawing is the graphic language of the industrial and professional world, and is used by engineers because of its exactness of expression. It is very important that the engineering student understand the basic principles of this universal language as well as obtain facility in the art of drawing.

The elementary courses offered give practice in the handling and use of instruments as well as training in accuracy, neatness, and speed. Descriptive Geometry strengthens the power and habit of logical and exact thinking, increases the ability to visualize in space, and develops the mental processes used in the solution of any kind of problem. The advanced courses emphasize the use of theory in professional practice and provide knowledge and skill in making engineering drawings.

The technical training acquired by the student engineer in these courses is important and necessary for his design courses, laboratory work, and later, his professional service.

2. 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 topographic surveying, hydrographic surveying, and in precise leveling. Railroad and highway location surveying practice is also provided for the students. They become familiar with field organization, and hold the various positions in field and office parties.

3. 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.

4. 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.

5. Hydraulics and 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 and operation of public water supplies. Instruction is also afforded the student in reclamation, canalization, and river and harbor development.

6. 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.

7. 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.

8. 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. The new and growing field of Soil Mechanics is being developed as a part of the work of this department.

9. 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.

10. 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 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 an Administrative Option leading to the degree of B.C.E., also a four-year course in Administrative Engineering leading to the degree of B.S. in Administrative Engineering (B.S. in A.E.). Students working for the regular B.C.E., degree also take some of the administrative courses such as Engineering Law 290 and Engineering Management 293.

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 administration, 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 is also 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 41–43 of this pamphlet. For discussion of graduate research in Engineering, see the Announcement of the Engineering Division of the Graduate School, beginning on p. 147 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, (see list on page 12). Inspection trips in the field are provided from time to time. 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 OFFERED IN THE SCHOOL OF CIVIL ENGINEERING

The curricula offered by the School of Civil Engineering leading to the several degrees 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 also be well prepared in the other branches of civil engineering.

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.

For the professional degree of C.E., see page 16.

1. THE REGULAR FOUR-YEAR COURSE

(For the degree of B.C.E.)

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
See schedule on page 46	20 or 18	17 or 19
SOPHOMORE YEAR		
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	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220	5	0
Mechanics Laboratory 220A	2	0
Mechanics of Engineering 221	0	4
Mechanics Laboratory 221A	0	1
Engineering Construction 264	3 or 0	0 or 3
English 2	0 or 3	3 or 0
Total number of hours per term	19	18
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 Training.

JUNIOR YEAR		
Introduction to Economics, Economics 3	3	0
Materials of Construction 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
Soil Mechanics 287	3 or 0	0 or 3
Total number of hours per 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
Foundations 281	3 or 0	0 or 3
Engineering Law 290	3	0
Elective*	6 or 9	9 or 6
Total number of hours per term	18	18
Grand total for the Four-Year Course	148 Hours	

*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.

2. ADMINISTRATIVE OPTION

(For the degree of B.C.E.)

(For the Administration Engineering Course, see p. 64.)

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
See schedule on page 46	20 or 18	17 or 19
SOPHOMORE YEAR		
Public Speaking 1	3 or 0	0 or 3
Business and Industrial Management 3A23	0	4
Field Astronomy 182	0	2
Drawing 203	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3	0
English 2	0 or 3	3 or 0
Total number of hours per term	19	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 Training.

JUNIOR YEAR		
Accounting for Engineers 3A31	3	0
Introduction to Economics, Economics 3	0	3
Engineering Management 293A	0	3
Materials of Construction 225	3	0
Materials Laboratory 226	3	0
Concrete Construction 280	3	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Hydraulics 240	0	4
Engineering Geology 501	0	3
Total number of hours per term	16	16
SENIOR YEAR		
Money and Banking, Economics 11	0	3
Corporation Finance, Economics 31	0	3
Cost Accounting 293B	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 Engineering, 3P43	0	3
Essentials of Electrical Engineering 417	4	0
Foundations 281	0	3
Elective*	3	0
Total number of hours per term	19	18
Grand total for the Four-Year Course	149 Hours	

*Any of the following courses may be taken profitably as an elective: Industrial Combinations, Ec. 32; Public Utilities, Ec. 33; Transportation, C.E. 269; Valuation Engineering, C.E. 295; Municipal Government, C.E. 256. See also p. 66.

3. SANITARY ENGINEERING OPTION

(For the degree of B.C.E.)

Freshman Year	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	20 or 18	17 or 19

Sophomore Year

Engineering Geology 501	0	3
Zoology	2	0
Drawing 203	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Chemistry	0	3
English 2	0	3
Engineering Construction 264	3	0
Introduction to Economics, Economics 3	3	0
Total number of hours per term	19	18
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 Training.

Junior Year

Foundations 281	3	0
Soil Mechanics 287	0	3
Materials of Construction 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 per 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
Sewerage Works 254	3	0
Sanitary Biology 251	3	0
Treatment of Wastes 255	3	0
Purification and Control of Water Supplies 253	0	3
Public Health Engineering 256A	0	3
Odor Control of Sewage Works 254A	0	3
Elective (see page 66)	3	0
Total number of hours per term	18	18
Grand total for the Four-Year Course		148 Hours

4. STRUCTURAL ENGINEERING OPTION
(For the degree of B.C.E.)

FRESHMAN YEAR	*Credit Hours 1st Term*	*2nd Term*
See schedule on page 46	20 or 18	17 or 19

SOPHOMORE YEAR		
Engineering Geology 501	0	3
Field Astronomy 182	0	2
Drawing 203	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
English 2	0	3
Engineering Construction 264	3	0
Public Speaking 1	3	0
Total number of hours per term	19	18
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 Training.

JUNIOR YEAR		
Introduction to Economics, Economics 3	0	3
Materials of Construction 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 271	0	3
Concrete Construction 280	3	0
Foundations 281	3	0
Soil Mechanics 287	0	3
Total number of hours per 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
Bridge Design 274 or Highway Bridges 284	0	3
Reinforced Concrete Design 285	3	0
Elective	0	6
Total number of hours per term	19	18

Grand total for the Four-Year Course ..... 148 Hours

5. HYDRAULIC ENGINEERING OPTION

(For the degree of B.C.E.)

Freshman Year	*Credit Hours 1st Term*	*2nd Term*
See schedule on page 46	20 or 18	17 or 19
Sophomore Year		
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	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 2	0 or 3	3 or 0
Total number of hours per term	19	18
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 Training.

Junior Year		
Hydraulics 240	4	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Municipal Sanitation 252	0	4
Introduction to Economics, Economics 3	0	3
Materials of Construction 225	3	0
Materials Laboratory 226	0	3
Concrete Construction 280	3	0
Foundations 281	3	0
Soil Mechanics 287	0	3
Total number of hours per 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
Hydraulic Measurements 242	3	0
Hydraulic Construction 231	0	3
Hydraulic Group Options*	3	3
Elective	3	6
Total number of hours per term	18	19
Grand total for the Four-Year Course	149 Hours	

*From Courses Water Power 232, Hydraulic Engineering 233, Conservancy and Reclamation Problems 234, Water Power and Pumping Plants 236, Engineering Mathematics 224-A, Hydrodynamics, Physics 451 and 452, Advanced Hydraulics 241, Hydraulic Engineering Design 291(c), Hydraulics Research 297 (c), Thesis 298.

6. TRANSPORTATION ENGINEERING

(For the degree of B.C.E.)

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	20 or 18	17 or 19

SOPHOMORE YEAR		
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	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 2	0 or 3	3 or 0
Total number of hours per term	19	18
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 Training.

JUNIOR YEAR		
Introduction to Economics, Economics 3	3	0
Materials of Construction 225	0	3
Materials Laboratory 226	0	3
Hydraulics 240	4	0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Concrete Construction 280	0	3
Foundations 281	3	0
Soil Mechanics 287	0	3
Route Location 263	0	3
Engineering Management 293	3	0
Total number of hours per term	17	18

SENIOR YEAR		
Prime Movers	0	3
Engineering Problems 223	0	2
Engineering Law 290	3	0
Transportation 269	0	3
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 262	0	3
Municipal Sanitation 252-A	3	0
Water Supply 230	3	0
Elective (See page 66)	0	3
Total number of hours per term	18	17
Grand total for the Four-Year Course	149 Hours	

7. GEODETIC ENGINEERING

(For the degree of B.C.E.)

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	20 or 18	17 or 19

SOPHOMORE YEAR		
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	0	2
Descriptive Geometry 204	3	0
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Mechanics of Engineering 220, 221	5	4
Mechanics Laboratory 220A, 221A	2	1
Engineering Construction 264	3 or 0	0 or 3
English 2	0 or 3	3 or 0
Total number of hours per term	19	18
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 Training.

JUNIOR YEAR		
Introduction to Economics, Economics 3	3	0
Materials of Construction 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	3
Mapping 214	2	0
Topographic Surveying 214-A	1	0
Total number of hours per 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
Problems in the Adjustment of Observations 215	1	0
Least Squares: Adjustment of Observations 216	2	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 per term	18	18

Grand total for the Four-Year Course ..... 148 Hours

8. A SIX-YEAR COURSE LEADING TO THE DEGREES OF A.B. AND B.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. Assistance in arranging the course may be obtained from the Director of the School.

9. A FOUR-YEAR COURSE IN ADMINISTRATIVE ENGINEERING (*IN CIVIL ENGINEERING*) LEADING TO THE DEGREE OF B.S. IN A.E.

The requirements for admission to this Course are the same as for the regular four-year B.C.E. Course. (For Administrative Option, see page 58.)

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	20 or 18	17 or 19
SOPHOMORE YEAR		
Introduction to Economics, Economics 3	3	0
Public Speaking 1	0	3
Business and Industrial Management 3A23	0	4
Mechanics of Engineering 220, 221	5	4
Engineering Construction 264	3	0
English 2	3	0
Engineering Geology 501	0	3
Advanced Surveying 211	3	0
Route Surveying and Drawing 260B	0	3
Drawing 202, 203	1	2
Total number of hours per 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 Training.

JUNIOR YEAR		
Money and Banking, Economics 11	3	0
Accounting for Engineers 3A31	3	0
Corporation Finance, Economics 31	0	3
Engineering Management 293A	0	3
Psychotechnology in Business and Industry, Psychology 16b	0	3
Labor Conditions and Problems, Economics 41	3	0
Materials of Construction 225	3	0
Materials Laboratory 226A	2	0
Hydraulics 240B	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 per term	19	18

SENIOR YEAR

	Credit 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
Prime Movers	0	3
Elective	3	3
Total number of hours per term	17	18

Grand total for the Four-Year Course . . . . . 151 Hours

10. A FIVE-YEAR COURSE LEADING TO THE DEGREES OF B.C.E. AND B.S. IN A.E.

It is possible so to arrange the work of a five-year course that the B.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 this five-year curriculum should be made at the beginning of the second year.

NOTE

1. In all of the several Courses and Options in the School of Civil Engineering, elective credit toward meeting the degree requirements may be obtained for satisfactory work on the board of the *Cornell Engineer*. Credit is limited to the junior and senior years with a maximum of two hours credit each year, i. e., a total credit of four hours. However, in the case of the Administrative, Sanitary, and Transportation Engineering Options, each of which provide for only three elective hours, not more than three hours of the *Cornell Engineer* credit can be used toward the degree requirement.

2. Not more than four hours credit for elective work in Advanced Military Science and Tactics will be accepted toward meeting the degree requirements. However in the case of the Administrative, Sanitary, and Transportation Engineering Options, each of which provide for only three elective hours, not more than three hours of credit in Advanced Military Science and Tactics can be used toward the degree requirement.

3. An organized Inspection Trip, during the second semester, is required of all Juniors in Civil Engineering, except those excused by the Director, and is optional for Seniors and graduates. The trip is in charge of a Faculty Committee and the Student is required to write and submit a satisfactory report to the Committee.

SCHOOL OF CIVIL ENGINEERING
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, beginning on page 46. 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 (juniors in case of Administrative Option). Either term. 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.** Required of all C.E. sophomores or juniors. Either term. Credit three hours. A survey of the existing economic order, its more salient and basic characteristics, and its operation. Professor O'LEARY.

11. **Money and Banking.** Required for Administrative Option and B.S. in A.E. Course. Elective for others. Either term. Credit three hours. Prerequisite, Economics 1 or its equivalent. A study of the history and the theory of money and banking. *Goldwin Smith Hall.* Professor REED.

41. **Labor Conditions and Problems.** Required for juniors in B.S. in A.E. Course. Elective for others. First term. Credit three hours. Prerequisite, Economics 1 or its equivalent.

An introduction to the field of Labor Economics and a survey of the more basic labor problems growing out of modern economic arrangements. *Goldwin Smith Hall.* Professor MONTGOMERY.

31. **Corporation Finance.** Required of juniors or seniors in Administrative Option and B.S. in A.E. Course. Second term. Credit three hours. Prerequisite course 3A31, Accounting for Engineers.

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

ENGLISH

English 2. Either term. Credit three hours. Required of all sophomores in the School of Civil Engineering. A course in composition with readings mainly from contemporary English and American Literature. Professor SIBLEY, Assistant Professor TENNEY and others. Registration in charge of Assistant Professor TENNEY.

PSYCHOLOGY

16b. **Psychotechnology in Business and Industry.** Required of juniors in B.S. in A.E. Course. Second term. Credit three hours.

A critical review of the attempts to apply psychological facts and methods to the solution of technological problems. *Goldwin Smith Hall.* Dr. ARTHUR RYAN.

PUBLIC SPEAKING

1. **Public Speaking.** Required of all Civil Engineering sophomores (seniors in case of Sanitary Engineering Option). Either term. Credit three hours. 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. *Goldwin Smith Hall.* Professor DRUMMOND.

MECHANICAL ENGINEERING

3A23. **Business and Industrial Management.** Required of all sophomores in Administrative Engineering Option and the B.S. in A.E. Course. Either term. Credit four hours. 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.** Required of juniors in Administrative Option and B.S. in A.E. Course. Second term. 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; modern mechanical methods of performing the accounting function. Professor BANGS and others.

3P43. **Heat-Power Engineering.** Required of seniors in Civil Engineering except in Sanitary, Structural, and Transportation Engineering Options and B.S. in A.E. Course. Either term. Credit three hours. For a description of this course see page 118 of this Announcement. Professor ELLENWOOD.

ELECTRICAL ENGINEERING

417. **Essentials of Electrical Engineering.** Required of seniors in Civil Engineering except in Sanitary, Structural, and Transportation Engineering Options and B.S. in A.E. Course. Either term. Credit four hours. Professor BALLARD. For description of this course see page 134 of this Announcement.

ASTRONOMY

182. **The Elements of Field Astronomy.** Required of Civil Engineering sophomores except in Sanitary Engineering Option and the B.S. in A.E. Course. Second term. Credit two hours. Prerequisite, Surveying 110 or (Astronomy 180 and Mathematics 3). Professor BOOTHROYD.

183. **Nautical Astronomy.** Elective. First term. Credit three hours. Prerequisites, Mathematics 3, Spherical Astronomy. Position of a ship by dead reckoning and by astronomical observation, with laboratory exercises, using sextant, to determine time, latitude, and longitude. Students who already have two hours credit for Course 182 will get one hour additional upon completion of the extra work necessary to obtain credit for Course 183. Professor BOOTHROYD.

186. **Geodetic Astronomy.** Either term or spread throughout the year. Credit three hours. Prerequisites, Astronomy 182 and Advanced Surveying 211 or (Mathematics 4a and 4b and Astronomy 181) or approved equivalents. This course is given in alternate years. Professor BOOTHROYD. *See also course 297a on page 84.*

DESCRIPTIVE GEOMETRY AND DRAWING

(200 and 201. **Drawing.** Freshmen. Credit three hours each term. See page 48 for description.)

202. **Drawing.** Sophomores in B.S. in A.E. Course. First term. Credit one hour. A study of the representation of lines, planes, surfaces, and solids, with practical applications. Professor PARSON and Assistant Professor JENKINS.

203. **Drawing.** Second term. Required of all Civil Engineering sophomores. 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 and Assistant Professor JENKINS.

204. **Descriptive Geometry.** Required of all Civil Engineering sophomores except in B.S. in A.E. course. First 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 47 for description.)

211. **Advanced Surveying.** Required of all Civil Engineering sophomores. First term. Credit three hours. Prerequisite Elementary Surveying 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. **Landscape Engineering I.** For students in Landscape Architecture. Second term. Credit three hours. Prerequisites Elementary Surveying 110 and Mechanics of Materials (Architecture 210). Topographic surveying; transit and stadia methods; plane table; survey plotting; circular curves, vertical curves; super-elevation; profile leveling; cross-sectioning; secondary road location; earthwork computations. Recitations and field work. Textbook: Breed and Hosmer's *Elementary Surveying*. Vol I. Given in alternate years. May be taken before or after Course 288. Not given in 1938–39. (For Landscape Engineering II, see course 288.) 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 Advanced Surveying 211. 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 for upperclassmen and required for juniors in Geodetic Engineering Option. 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.** Required for juniors taking the Geodetic Engineering Option; elective for others. First term. Credit one hour. Prerequisite courses 211 and 213. 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 for upperclassmen and required for seniors taking the Geodetic Engineering Option. First 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.** Required of seniors taking the Geodetic Engineering Option, elective for others. First 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 for upperclassmen and required for seniors taking the Geodetic Engineering Option. First term. Credit three hours. Prerequisite courses 182 and 211. 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 for upperclassmen and required for seniors taking the Geodetic Engineering Option. Second term. Credit three hours. Prerequisite, Advanced Surveying 211. 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.

For Research in Geodetic Engineering, see Course 297i on page 48.

MECHANICS OF ENGINEERING

220. **Mechanics of Engineering.** Required of all Civil Engineering sophomores. First term. Credit five hours. Repeated in one section, second term, if there are sufficient students. 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; moments 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.** Required of Civil Engineering sophomores except in Sanitary Engineering Option and B.S. in A.E. Course. First term.

Credit two hours. One two and one-half hour period in the laboratory together with a computation period of equal length under instruction. Courses 220 and 220-A are closely correlated and should 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.** Required of all Civil Engineering sophomores. Second term. Credit four hours. Repeated in one section, first term, if there are sufficient students. 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 semigraphic treatment. Review problems showing application of principles in Engineering Design. Four recitations a week. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

221-A. **Mechanics Laboratory.** Required of Civil Engineering sophomores except in Sanitary Engineering Option and B.S. in A.E. Course. Second term. 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 should 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.** Required of Civil Engineering seniors except in Sanitary, Structural, and Hydraulic Engineering Options. 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.** Elective. Seniors and graduates. Required of seniors in Structural Engineering Option. First term. Credit three hours. Prerequisite, Mathematics 5b. An elementary course in ordinary differential equations with applications to engineering problems. Trigonometry, calculus and algebra are dealt with in so far as this is necessary for a clear understanding of the treatment of differential equations. The purpose of this course is to lay the foundation for the more advanced courses in engineering mathematics. Professor RETTGER.

224-B. **Advanced Engineering Mathematics.** Elective. Seniors and graduates. Second term. Credit three hours. This course is an introduction to the mathematics used in the solution of advanced engineering problems. Special emphasis is given to partial differentiation. Fourier Series, line integrals, formation of partial differential equations, integration in form of infinite series of several of the partial differential equations arising in engineering problems, vector notation, conformal representation, determinants, theory of the complex variable, development of function into series, etc., are reviewed in so far as a knowledge of these are essential to the Course. Professor RETTGER.

224-C. **Advanced Differential Equations.** First term. Graduates only. Credit three hours. Prerequisites, Courses 224-A and 224-B or their equivalents. A systematic study of differential equations. Partial differential equations and their solutions are emphasized. Professor RETTGER.

224-D. **Special Mathematical Topics.** Second term. Graduates only. Credit three hours. Prerequisites, Courses 224-A and 224-B. The content of this Course depends largely on the needs and interests of those enrolled. Generalized coordinates, vector analysis, and the calculus of variation are three subjects to be considered. Professor RETTGER.

228. **Theory of Elasticity.** Elective. Primarily for graduate students. Second term. Credit three hours. Prerequisite, 224-A and 224-B. 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. Professor RETTGER.

228-A. **Engineering Physics of Metals.** Elective. Primarily for graduate students. Second term. Credit 3 hours. An introduction to the physical basis of matter in relation to its elastic and plastic behaviour. Topics for discussion include: Atomic basis of generalized Hooke's Law, atomic cohesive forces and potential troughs, the yield value, primary bonds, dipole and Van der Waal's forces, influence of temperature on elastic properties, thermoelastic basis of internal friction, experimental and theoretical strengths of crystals, distortion of the lattice, Smekal's criticism of Born's lattice theory of metals, evidence of submicroscopic structure, elementary concepts of the cooperative phenomena in metals. Dr. CUYKENDALL.

229-A. **Elastic Foundations and Thin Structural Shells.** Primarily for graduate students. Three hours a week. First term. Study of the properties of elastic foundations and the application of the elastic foundation theory to the analysis of large diameter, low head tanks, hemispherical domes, hemispherical headers on large pipes, and thin shell pipes under flexure. Dr. HAWKINS.

MATERIALS OF CONSTRUCTION

225. **Materials of Construction.** Required of all Civil Engineering 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. Professor SCOFIELD and Dr. HAWKINS.

226. **Materials Laboratory.** Required of all Civil Engineering juniors except in B.S. in A.E. Course. 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 Dr. HAWKINS.

226-A. **Materials Laboratory.** Required of juniors in B.S. in A.E. Course. First 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 Dr. HAWKINS.

227. **Testing of Materials.** (Laboratory.) Second 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 and Dr. HAWKINS.

(For Research in Engineering Materials, see Course 297b on page 84.)

HYDRAULIC ENGINEERING

230. **Water Supply.** Required of all Civil Engineering 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 for seniors and graduates and required of seniors in Hydraulic Engineering Option. 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 adaptation 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. Credit three hours. 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.

(*For Hydraulic Engineering Design, see Course 291c on page 83.*)

THEORETICAL AND EXPERIMENTAL HYDRAULICS

240. **Hydraulics.** Required of all civil engineering juniors except for B.S. in A.E. Course. First term. One section second term. Credit four hours. Prerequisite courses 220 and 221. Three recitations and one laboratory period a week; about ten of the recitation periods are utilized for demonstration lectures. Hydro-

static 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 and Dr. HAWKINS.

240-A. **Hydraulics.** For special groups. First term. Credit one hour. This course covers the laboratory work only of Course 240. Professor SCHODER.

240-B. **Hydraulics.** Required of juniors in B.S. in A.E. Course. Second term. Credit three hours. Prerequisite courses 220 and 221. Three recitations a week. About ten 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 and required for Seniors in Hydraulic Engineering Option. 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.

(*For Engineering Research in Hydraulics, see Course 2970 on page 84.*)

MUNICIPAL AND SANITARY ENGINEERING

250. **Sanitary Biology.** Elective. Juniors, seniors, and graduates. Second term. Credit three hours. The course is designed to familiarize the student with current standard practice in the bacteriological control of water treatment plants and of swimming pools. 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.** Required of seniors in Sanitary Engineering Option. Elective for other juniors, seniors, and graduates. First term. Credit two hours. The collection and examination of the various forms of microscopic plants and animals most prevalent in water supplies; the methods of their identification and control; a study of the biological forms most prevalent in sewage wastes; sludges and sewage polluted water ways; the method of making biological counts of water; and the use of biological forms of life as indices of pollution. Lectures, notes, and various references. One lecture or recitation, and one laboratory period per week. Professor WALKER.

252. **Municipal Sanitation.** Required of juniors and seniors in all courses except Transportation Engineering Option and B.S. in A.E. Course. Either 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. Professors STANLEY and WALKER.

252-A. **Municipal Sanitation.** Required of seniors in B.S. in A.E. Course and Transportation Engineering Option. Credit three hours. First term. A shorter course covering a field similar to that of 252. Professors STANLEY and WALKER.

253. **Purification and Control of Water Supplies.** Elective for seniors and graduates and required of seniors in Sanitary Engineering Option. 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 STANLEY and WALKER.

254. **Sewerage Works.** Elective for seniors and graduates and required for seniors in Sanitary Engineering Option. 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, by reference to recent descriptions of sewage-disposal plants in the current literature. The general character of the subjects covered is indicated by 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 STANLEY.

254-A. **Odor Control of Sewage Works.** Elective for seniors and graduates and required for seniors in Sanitary Engineering Option. Second term. Credit three hours. The work to include consideration of ventilation and other methods of odor control, landscaping and attention to appearance of structures inside and out as related to the removal of the objectionable phases of sewage works. The objective in the course is to acquaint the student with the possibilities of, and the technical procedures for obtaining improvements in appearances and esthetic conditions around a sewage works and thus enhance efficiency of operation and general satisfaction with such works. Two hours recitations and lectures and one computing period per week. Professor STANLEY.

255. **Treatment of Wastes.** Elective for seniors and graduates and required for seniors in Sanitary Engineering Option. 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. Professors OGDEN and STANLEY.

256-A. **Public Health Engineering.** Elective for seniors and graduates and required of seniors in Sanitary Engineering Option. Second term. Credit three hours. A study of the relation between engineering and public health. Organization and operation of boards of health. Vital statistics, industrial sanitation, public health laws and the sanitary code. Lectures, reports and reading. Professor ODGEN.

257. **Purification of Water.** Elective. Graduates. Credit three hours. Either term. Specific problems in water purification; control of watersheds; effect of sedimentation on waters of different compositions; treatment of waters for particular requirements such as removal of hardness, sediment, bacteria, etc. A report on some existing water system will be required from each student. Professor STANLEY.

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

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. Either term. Hours to be arranged. Professors STANLEY and WALKER.

(*For Sanitary Engineering Design and Research, see Courses 291d and 297d on pages 83 and 84.*)

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.** Required of all sophomores. Second term. Credit three hours. One recitation and two field or drawing periods a week. Prerequisite Advanced Surveying 211. 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 a preliminary line surveyed 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. This Course or Course 266 is required of seniors in the Transportation Engineering Option. 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. This Course or Course 267 is required of seniors in the Transportation Engineering Option. 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. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

263. **Route Location.** Required of juniors in Transportation Engineering Option; elective for other seniors and graduates. Second term. Credit three hours. A detailed study is made of the economic principles and other factors governing the location of new routes for both railroads and highways, and the revision of existing lines to effect the most efficient and satisfactory transportation. Some of the topics treated are estimation of traffic and revenue; costs and rates; steam, electric and other locomotive and motor operation; gradients, distance, curvature and rise and fall; line and grade revisions; grade crossing eliminations; location surveys and estimates. Lectures and recitations with problems involving investigations of projects, revisions and comparisons of alternate routes. Three hours a week. Professor BARNES.

264. **Engineering Construction.** Required of all civil engineering 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.** Required of all Civil Engineering seniors. Elective for certain graduates. Either term. Credit three hours. Prerequisite courses 260-A and 260-B. The course consists of lectures and recitations considering the economic selection of routes, economics of location, modern tendencies in design and practice, subgrade soils, drainage, subgrade stabilization, 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.

265-A. **Low Cost Roads.** Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite course 265 or its equivalent. Study of economic importance of routes and selection of farm to market roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage and drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construc-

tion of low cost roads. Design, construction and maintenance of road mixes, plant mixes, etc. Professor CONWELL.

266. **Highway Laboratory.** Elective. Seniors and graduates. This course or course 261 is required of seniors in the Transportation Engineering Option. Either term. Credit three hours. Prerequisite course 265 or may be taken concurrently with course 265. Non-bituminous and bituminous materials are tested. Subgrade soils are sampled and their properties examined; subgrade stabilization admixtures are also tested and studied. Bituminous mixtures are designed and their properties examined. Professor CONWELL.

266-A. **Advanced Highway Laboratory.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite courses 265 and 266. Non-bituminous and bituminous materials are tested and their characteristics studied. Soils are sampled and examined, and investigations made of the behavior of mixtures of soils with bituminous and non-bituminous materials. 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.

267. **Advanced Highway Engineering.** Elective. Seniors and graduates. This course or course 262 is required of seniors in the Transportation Engineering Option. Second term. Credit three hours. Prerequisite course 265. This course is conducted as a seminar. Meetings are held once each week at hours to be arranged. The topics for assignment and discussion include the economics of highway engineering, highway finance, legislation, regulation, traffic, 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, etc. Professor CONWELL.

268. **Modern Highway Planning and Design.** Elective. Seniors and graduate students. Second term. Credit three hours. Prerequisite course 265 or its equivalent. Study of geographical, political, and economic divisions of communities with particular reference to highway transportation requirements; analysis of regional plans chiefly concerning the classification of roads and the selection of routes to be abandoned or improved, based upon their economic justification. Design of regional systems of highways, freeways, and parkways, including the consideration of the economic, safety, and aesthetic aspects. Traffic studies, legislation, financing, and zoning. Design of intersections and grade separations. Problems and reports required. Professors CLARKE and CONWELL.

269. **Transportation.** Required of seniors in Transportation Engineering Option and B.S. in A.E. course and may be elected by other qualified seniors, and graduates. Second term. 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.

(*For Railroad and Highway Engineering Design and Research, see Courses 291e, 291g, 297e, 297g on pages 83 and 84.*)

STRUCTURAL ENGINEERING

270. **Stress Analysis and Structural Design.** Required of juniors except in B.S. in A.E. course. First term. (One section second term for irregular students.) 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.** Required of juniors in the B.S. in A.E. course. 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 amd O'ROURKE and Assistant Professor BURROWS.

271. **Structural Design.** Required of all juniors. Second term. (One section first term for irregular students.) 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 for seniors and graduates and required of seniors in Structural Engineering Option. 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. This course or course 284 is required for seniors in the Structural Engineering Option. 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 Professors 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 de-

termine either the unit stresses under a specified load, or the safe load or rating according to standard specifications. Assistant Professor BURROWS.

280. **Concrete Construction.** Required of all Civil Engineering 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.** Required of all Civil Engineering juniors or seniors. 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 for seniors and graduates and required for seniors in Structural Engineering Option. 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 arch and its abutments. Lectures, recitations, and computations. Six hours a week. Professors URQUHART and O'ROURKE.

284. **Highway Bridges.** Elective. Seniors and graduates. This course or course 274 is required for seniors in the Structural Engineering Option. 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 drawings. Professor O'ROURKE.

285. **Reinforced Concrete Design.** Elective for seniors and graduates and required for seniors in the Structural Engineering Option. Either term. Credit three hours. Prerequisite course 280. Theory and design of gravity, cantilever, and counterfort 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. First 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.

The field covered usually includes 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. Given in alternate years. Offered 1938–39.

287. **Soil Mechanics.** Either term. Credit three hours. Required of juniors in Regular Four Year Course, Sanitary, Structural, Hydraulic, and Transportation Engineering Options. Two lectures and one laboratory period per week.

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. Laboratory tests for identification of soils; mechanical analysis, determination of water content, specific gravity, density, permeability, etc. Tests for physical properties of soils. Professor O'ROURKE and Assistant Professor JENKINS.

287-A. **Applied Soil Mechanics.** Second term. Credit three hours. Prerequisite course 287. Elective for seniors and graduate students. Advanced application of soil mechanics, based on the principles and physical studies of course 287. The plastic flow theory; the consolidation theory; stability of earth slopes; flow of water through earth structures; theories of earth pressure on retaining walls, caissons and tunnels. Review of modern soil mechanics research. Professor O'ROURKE and Assistant Professor JENKINS.

288. **Landscape Engineering II.** For students in Landscape Architecture. Second term. Credit three hours. Prerequisites, Elementary Surveying 110 and Mechanics of Materials (Architecture 210). *Roads*—Soils and drainage, stabilization of soils, materials, road construction and low cost surfacing. *Structures*—Short span bridges of timber, steel or concrete, bridge trusses, small dams, retaining walls, culverts, curbs, gutters, ditch linings, catch basins, septic tanks. Given in alternate years. May be taken before or after course 212. Given in 1938–39. Professors CONWELL, URQUHART or O'ROURKE.

(*For Structural Engineering Design and Research, see Courses 291a, 291f, 297f on pages 83 and 84.*)

ADMINISTRATIVE ENGINEERING

290. **Engineering Law.** Required of all Civil Engineering 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, bond, form of proposal, information to bidders, agreement form, specifications, 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.** Required of seniors in B.S. in A.E. course and open to others who have completed course 290. Second term. Credit three hours. Some of the topics treated in Course 290 are here enlarged upon and extended, particularly laws relating to the various phases of construction contracts, employer-employee relationship, workman's compensation, mechanics liens, patents, copyrights, trademarks, and insurance. Among other subjects covered are suretyship, conditional sales, bailments, trusteeship, and taxation. Actual cases are used for illustrating the above and reference is also made to recent court deci-

sions regarding engineering matters. Professor BARNES and Assistant Professors PERRY, CRANDALL and THATCHER.

293. **Engineering Management.** Required of juniors in regular four-year course, Transportation and Geodetic Engineering Options. Also open to qualified juniors and seniors in other courses. Either term. Credit three hours. 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 planning 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.** Required of juniors in the Administrative Engineering Option and the B.S. in A.E. course. Second term. Credit three hours. 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 Option and the B.S. in A.E. Course, 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 for seniors and graduates and required for seniors in B.S. in A.E. course. 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.

(*For Management Engineering Research, see Course 297h on page 84.*)

REGIONAL AND CITY PLANNING

710. **Principles of Regional and City Planning.** Elective. Registration limited to 50. Open to graduates and upperclassmen in all colleges of the University. Throughout the year. Credit two hours each term. 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 at the College of Architecture on registration day. M W 12. *White* 28. Professor CLARKE.

711. **Seminar in Regional and City Planning.** Elective. Throughout the year. Credit one hour each term. 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*. Professor CLARKE.

713. **Seminar in Parkway, Freeway, and Highway Planning.** Elective. Second term. Credit two hours. 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*. Professor CLARKE.

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, or approved equivalent course, and may not be elected otherwise. The following problems indicate the scope of the work: (1) Computations, design, and detail drawings for the design of sewer sections for tile, brick or concrete sewers of various diameters and forms of cross sections. (2) Computations, 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 inlets and outlets of settling tanks. (5) Design and detail drawings of a sewage screen, involving a device 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 or an asylum or school. Professor STANLEY.

(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.** Either term. The problems are those encountered in the selection, location, design, and construction of highways. They include the

following: Economic selection of routes, economic location, design of highways, highway intersections, culverts, highway 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.

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 186 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 STANLEY 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. Prerequisite courses 265 and 266. Studies of traffic and traffic regulation and legislation may be made. The field of economics of highway engineering offers a wide variety of problems. Laboratory investigations of subgrade soils, subgrade stabilization, and the effects of modifications in design of bituminous and non-bituminous mixtures provide a wide range of topics for research. Professor CONWELL.

(h) **Management Engineering.** Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals. Professor BARNES.

(i) **Geodetic Engineering.** Either term. Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation and photographic surveying as may be arranged. Professor UNDERWOOD.

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 special 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 and Aeronautical Engineering, (8) Hydraulic Power Plant Engineering, (9) Metallurgical Engineering, and (10) 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 Sibley 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 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. Kinematics is studied and applied to the solution of cam, gear, linkage, instant center, velocity, and acceleration problems. The courses in kinematics are followed by recitation and drawing room instruction in general machine design. The theory and principles developed are applied to the solution of many short problems in the class room and to the solution of longer problems in the drawing room for which computations and drawings are made. Only such problems 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, refrigeration, 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 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 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; tests of boilers, steam engines, turbines, pumps, heaters, condensers, injectors, and other steam apparatus; tests of heat transfer; tests of fans, air compressors and refrigerating machines; tests of 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 in this department instruction in industrial history and the principles and present 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 apparatus.

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. In the course in Advanced Industrial Relations, problems arising in industry are studied by the case method.

The subject of cost-accounting is treated in coordination with the above subjects including principles and practise of standard, process and order costs. In the course in Industrial Auditing, the theory and practice of auditing pertaining to industrial concerns are studied.

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, in this department, 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.

In the special course in Administrative Engineering, 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.

About 68% of the course content, as given to the students in the M.E. school, 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 and Aeronautical 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.

In Aeronautical Engineering the College does not offer a complete four-year course, 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 only 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.

8. 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 B.M.E. and the B.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.

9. 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 Metallography, and Analytical Chemistry. This is followed in the senior year by courses in Physical Chemistry, Applied Metallography, and Furnace Metallurgy.

10. 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 41–43 of this pamphlet. For discussion of graduate research in engineering, see the Announcement of the Engineering Division of the Graduate School, beginning on p. 147 following.)

Undergraduates who have shown the requisite proficiency and have available the necessary time may have opportunity to aid in the investigations conducted by the Engineering Experiment Station (see p. 25) or to conduct special investigations of their own 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.

Opportunities for Professional Development

The School has the benefit of being closely associated with the Ithaca Section of the American Society of Mechanical Engineers and with participation in its frequent meetings. The Cornell Student Branch of the same Society contains a large proportion of the M.E. junior and senior classes and during the year has many interesting meetings, which are addressed by engineers of national eminence, or are used for the presentation of papers, or for contests or discussions by the students. In addition, many students derive benefit from belonging to such honorary engineering or scholastic societies as those mentioned on page 24; and some students gain valuable experience by serving on the board of the *Cornell Engineer*, the magazine published by the students of the College. Credit towards the requirements for graduation can be earned through membership in the Student Branch of the A.S.M.E., and by serving on the board of the magazine.

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, industrial, and administrative engineering, (see list on page 12). Seniors are required to attend these lectures. The students may attend also the many public scientific lectures given in other departments of the University by local or 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 OFFERED IN THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

1. THE REGULAR FOUR-YEAR COURSE LEADING TO THE DEGREE OF B.M.E.

The curricula offered by the Sibley School of Mechanical Engineering, leading to the degree of Bachelor of Mechanical Engineering, all contain the fundamental studies in Mathematics, Physics, Chemistry, Mechanics, Materials, Kinematics and Machine Design, Heat Power Engineering, Electrical Engineering, and Experimental Engineering, 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, however, that there is not a great deal of time available for such special work, and that the emphasis must be kept on fundamentals. Hence not more than from 8 to 12 credit hours 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 it 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.

For the professional degree of M. E., see page 16.

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.

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
See schedule on page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, Drawing 3D23	2	0
Kinematics, Recitations and Drawings 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours per term	19	19
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 106)	1 or 4	5 or 2
Total number of hours per term	19	19
Grand total for the Four-Year Course	150 Hours	

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 are 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 are given.

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, Drawing 3D23	2	0
Kinematics, Recitations and Drawings 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours per term	19	19

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 106)	4	5
Total number of hours per term	19	19

Grand total for the Four-Year Course ..... 150 Hours

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.

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
For schedule see page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

In addition to these courses, sophomores are required to take Miliatry Training.

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours per term	19	19
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	0
Industrial Engineering 3I43, 3I44	**3**	**3**
Industrial Relations 3I46	**2**	**0**
Cost Accounting 3I47	**0**	**3**
Industrial Engineering 3I48	**0**	**2**
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 106)	2	1
Total number of hours per term	19	19
Grand total for the Four-Year Course		150 Hours

OPTION D. AUTOMOTIVE ENGINEERING

The specialization in this option is confined to the senior year and begins in the first term with the 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.

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
For schedule see page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours per term	19	19
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
Automotive Lectures 3B41, 3B42	2	2
Automotive Design 3B43, 3B44	2	2
Non-resident Lectures 3G41	0	1
Electives (See suggested list on page 106)	3 or 6	5 or 2
Total number of hours per term	19	19
Grand total for the Four-Year Course		150 Hours

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.

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
For schedule see page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Aerodynamics 3B35	**0**	**2**
Total number of hours per term	19	19
SENIOR YEAR		
Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Automotive Power 3B42	0	2
Internal Combustion Engines 3P51	**2**	**0**
Airplane Design Recitations 3B46	**2**	**0**
Airplane Design Computations 3B47, 3B48	**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 106)	2 or 0	0 or 2
Total number of hours per term	19 or 17	17 or 19
Grand total for the Four-Year Course	148 Hours	

OPTION F. HYDRAULIC POWER PLANT ENGINEERING

The aim of the special course 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.

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
For schedule see page 46	19	18

SOPHOMORE YEAR		
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
Kinematics, 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

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
Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours per term	19	19

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 601)	0 or 2	5 or 3
Total number of hours per term	19 or 18	19 or 20
Grand total for the Four-Year Course	150 Hours	

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 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.

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
For schedule see page 46	19	18
SOPHOMORE YEAR		
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
Kinematics, 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
Applied Mathematics 3M32	0	3
Total number of hours per term	18 or 20	19 or 17

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

JUNIOR YEAR, IN 1938–39		
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
Industrial Organization 3I31	0	2
Introductory Metallography, Chem. 545	**3**	**0**
Analytical Chemistry 201	**4**	**0**
***Furnace Metallurgy, Chem. Eng. 750** (Not given in 1939–40)	**0**	**3**
Total number of hours per term	19	19

SENIOR YEAR, IN 1939–40		
Heat-Power 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
*Accounting 3A31	0	3
Fluid Mechanics 3M33	4	0
Machine Shop 3S31	3	0
Applied Metallography 4X52	**2**	**0**
Introductory Physical Chemistry 405	**3**	**3**
Introductory Physical Chemistry Lab. 410	**0**	**3**
Non-Resident Lectures 3G41	0	1
Total number of hours per term	21	19

Grand total for the Four-Year Course.....152 Hours

*Courses 3A31 and Chem. Eng. 750 will be given in alternate years for both juniors and seniors taking this option. The senior year for 1938–39 is made up as follows:

SENIOR YEAR, IN 1938–39

Heat-Power 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Industrial Organization 3I31	0	2
Machine Shop 3S31	3	0
Physical Chemistry 405	3	3
Physical Chemistry Laboratory 410	0	3
Analytical Chemistry 201	4	0
Applied Metallography 3X52	2	0
Furnace Metallurgy, Chem. 750	0	3
Non-Resident Lectures 3G41	0	1
Total number of hours per term	21	21

Grand total for the Four-Year Course ..... 152 Hours

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. Grand total for the Four-Year Course, 150 hours.

2. A FIVE-YEAR COURSE LEADING TO THE DEGREE OF B.M.E.

A five-year course leading to the degree of Bachelor 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 other studies, generally in the College of 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.

	Credit Hours 1st Term	2nd Term
YEAR I		
See Freshman Year on page 46	19	18
YEAR II		
See Sophomore Year of Option A, page 94	18 or 20	19 or 17
YEAR III		
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
Fluid Mechanics 3M33	4	0
Electives	6	5
Total number of hours per term	19	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
Accounting 3A31	0	3
Electives	6	4
Total number of hours per term	18	17
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 per term	19	19
Grand total for the Five-Year Course	185 Hours	

3. A FIVE-YEAR COURSE LEADING TO THE DEGREES OF B.M.E. AND B.E.E.

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 B.M.E. and B.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 B.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.

5. A FOUR-YEAR COURSE IN ADMINISTRATIVE ENGINEERING, (*IN MECHANICAL ENGINEERING*) LEADING TO THE DEGREE OF B.S. IN A.E.

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.

Freshman Year	*Credit Hours* 1st Term	2nd Term
For schedule see page 46	19	18
Sophomore Year		
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Kinematics, Recitation 3D25	3	0
Kinematics, 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 2	0 or 3	3 or 0
Technical Writing 3A33	2 or 0	0 or 2
Business Statistics 3A41	0	3
Business and Industrial Management 3A23	4 or 0	0 or 4
Public Speaking 1	0 or 3	3 or 0
Total number of hours per term	20	20

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

Junior Year		
Heat Power 3P33, 3P34	3	3
Machine Design, Recitation 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
Graphical Computations 3P55	2	0
Economic Organization 3A21	0	3
Total number of hours per term	17	18
Senior Year		
Industrial Engineering 3I43	3	0
Industrial Relations 3I36	2	0
Cost Accounting 3I47	0	3
Corporation Finance 3A34 or Economics 31	3 or 0	0 or 3
Electives	0 or 4	4 or 0
Engineering Business Law 3A43, 3A46	3	2
Industrial Marketing 3A44	3	0
Mechanical Laboratory 3X41, 3X42	4	4
Heat Power 3P54	0	2
Non-resident Lectures 3G41	0	1
Business and Industrial Problems 3A48	0	2
Human Nature and Management 3A42	0	2
Total number of hours per term	18 or 19	20 or 19

Grand total for the Four-Year Course ..... 150 Hours

NOTE.—Due to curriculum changes, the class graduating in 1939 will take Public Speaking 1 instead of Business and Industrial Problems 3A48 and Human Nature and Management 3A42. These courses can be taken as electives. Engineering Business Law, 3A46, will be a 3-hour course in 1938–1939.

ELECTIVE SUBJECTS IN THE SCHOOL OF MECHANICAL ENGINEERING

	Credit Hours 1st Term	2nd Term
Mechanical Technology 3D51 (not open to seniors)	0 or 2	2 or 0
Advanced Kinematics and Kinetics 3D52	0	3
Materials Handling 3D53	0	2
Dynamics and Vibrations of Machinery 3D54	3	0
Advanced Machine Design 3D55	0	3
Automotive Lectures 3B41, 3B42	2	2
Ordnance Problems 3M53 (one hour a term for two years)	1	1
Hydraulic Power Plants 3M41, 3M42	2	2
Photoelasticity 3M55	3	0
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	2	0
Steam Turbine 3P51	0	2
Internal Combustion Engines 3P52	0	2
Steam Boilers and Boiler Plants 3P53	0	2
Graphical Computations and Representations 3P55	2	0
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
Advanced Industrial Engineering 3I51	1 to 3	1 to 3
Industrial Auditing 3I52	2	0
Advanced Industrial Relations 3I53	0	2
Micro-Motion Laboratory 3I54	2 or 0	0 or 2
Engineering Business Law 3A47	0	2
Industrial Marketing 3A45	0	2

M.E. ELECTIVE SUBJECTS 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	
Advanced Automotive Engineering 3B50	As assigned	
Advanced Machine Design 3D54 and 3D55	As assigned	

ELECTIVE SUBJECTS IN OTHER SCHOOLS AND COLLEGES

Advanced Hydraulics 241	0	3
Advanced Metallography Chemistry 550	0	2
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 466a, b	2	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
Introductory Metallography 545	3	0
Advanced Metallography, Chem. 550	0	3
Gas and Fuel Analysis 250	0	3
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.

Note

Not more than four hours credit for elective work in Advanced Military Science and Tactics will be accepted toward meeting the degree requirements in any Course or Option in the School of Mechanical Engineering.

SCHOOL OF MECHANICAL ENGINEERING
DESCRIPTION OF THE COURSES OF INSTRUCTION

NOTE.—The courses for freshmen in Engineering are described on pages 46 to 50.

COURSES FOR SOPHOMORES, JUNIORS, AND SENIORS

I. COURSES GIVEN IN OTHER SCHOOLS AND COLLEGES

In the following list of prescribed courses, those in Chemistry, 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 Students taking Option G in M.E., see page 100.)

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 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 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 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 545. Introductory Metallography. First term. Credit three hours. Prerequisite or parallel course, Chemistry 530 or Mechanical Laboratory 3X31, or special permission. Fee, $10. Professor MASON and assistant. Lecture, Th 10. Laboratory, M T or Th F 1:40–4; additional sections if warranted. *Baker* 384.

Laboratory practice, lectures, 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 microscopes and their use.

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 Professors B. K. NORTHROP and E. M. STRONG and Dr. 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 instructors.

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 instructors.

CHEMICAL ENGINEERING

750. **Furnace Metallurgy.** Second term. Credit two hours. Prerequisite or parallel course, Chemistry 405. Professor RHODES. T Th 10. *Baker* 377.

Lectures. 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.

To be given in alternate years for all juniors and seniors taking option G, being alternated with Accounting 3A31. (Given in 1938–39.)

ENGLISH AND PUBLIC SPEAKING

English 2. First or second term. Credit three hours. Required of all sophomores in Administrative Engineering. A course in composition with readings mainly from contemporary English and American literature. Professor SIBLEY, Assistant Professor TENNEY and others. Registration in charge of Assistant Professor TENNEY.

Public Speaking I. Repeated in second term. Credit three hours. Required of seniors in Administrative Engineering. Professor WICHELNS, Assistant Professors MUCHMORE and WAGNER, and Mr. STINE.

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 B.M.E. or B.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. Professor GRANTHAM and instructors.

Physics 22. General Physics. Required of candidates for the degree of B.M.E. or B.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. Professor GRANTHAM and instructors.

For elective courses in other schools and colleges of the University, see page 106, 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. First term for M.E. and E.E. sophomores; second term for A.E. juniors. Credit three hours. Lectures, collateral reading, and discussion periods. 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 and Mr. SCHULTZ.

3A23. Business and Industrial Management. Required of all sophomores in Administrative Engineering. Either term. Credit four hours. 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. Required of all A.E. juniors and M.E. juniors or seniors. Given first term for A.E. and second term for M.E. 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; modern mechanical methods of performing the accounting function. Professor BANGS, Assistant Professor HANSELMAN, Mr. WHITE and Mr. SCHULTZ.

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

3A33. Technical Writing. Required of all sophomores in Administrative Engineering. Either term as assigned. Two recitations a week. Credit two hours. A study of the forms of written expression with emphasis on those most frequently used in business and engineering: the writing of technical reports, articles, and editorials; the composition of business letters, such as credit, collection, inquiry, quotation, adjustment, and sales letters. Mr. WHITE.

3A34. **Corporation Finance.** Required of all seniors in Administrative Engineering, elective for upperclassmen in Mechanical Engineering. Second term. Credit three hours. 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. Professor O'LEARY.

3A41. **Business Statistics.** Required of all sophomores in Administrative Engineering. First or second term. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A21.

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 and Assistant Professor LOBERG.

3A42. **Human Nature and Management.** Required of all seniors in Administrative Engineering. Second term. Credit 2 hours. A study of human nature in business and industry involving the psychological approach. Case demonstrations of business and industrial situations are used to illustrate the more important problems. Professor BANGS.

3A43. **Engineering Business Law.** Required of all seniors in Administrative Engineering. First term. Credit three hours. Three lecture-discussion periods per week. A study of the fundamental legal principles which relate to the usual business transactions with emphasis on the law of contracts. 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.** Required of all seniors in Administrative Engineering. First term. 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. Assistant Professor 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. Assistant Professor LOBERG.

3A46. **Engineering Business Law.** Required of all seniors in Administrative Engineering. Second term. Credit two hours. Two lecture-discussion periods per week. A study of fundamental legal principles relating to the usual business transactions with special emphasis on the laws of Sales and Corporations. By the use of adequate case material the student is aided in his application of general legal principles to specific situations. Assistant Professor HANSELMAN.

3A47. **Engineering Business Law.** Elective. Second term. Credit two hours. Two lecture-discussion periods per week. A study of fundamental legal principles relating to common business transactions with special emphasis on the laws of Agency and Negotiable Instruments. By the use of adequate case material the student is aided in his application of general legal principles to specific situations. Assistant Professor HANSELMAN.

3A48. **Business and Industrial Problems.** Required of all seniors in Administrative Engineering. Second term. Credit two hours. Prerequisite courses 3A21, 3A23, 3A31, 3A32, 3A41, 3A43, 3A44. A series of case studies of problems occurring during the launching and conduct of a small manufacturing enterprise. The attempt is made in this way to tie together the work previously taken in economics, statistics, accounting, marketing, business law, and human relations. Professor GARRETT.

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, Assistant Professors HANSELMAN and LOBERG.

AUTOMOTIVE AND AERONAUTICAL ENGINEERING (B)

3B35. **Aerodynamics.** Juniors. Required in Option E. Second term. Credit two hours. Prerequisite courses 3M21 and 3M22a and b. Two recitations per week. Properties of air, airfoil characteristics, drag calculations, engine-propeller characteristics and their relation to airplane performance. Stability calculations, performance estimates, and flight testing. Mr. TERRY.

3B41. **Automotive Lectures.** Seniors and graduates. Required in Option D. First term. Credit two hours. Two lectures a week. Prerequisite courses 3P31 or 3P33, 3D31, 32, 33. The automobile, and the power required for its operation, but not including the power plant (for which see course 3B42). Analysis is made of the relations of the car to the road; functions of steering, driving, braking; mechanical efficiency of chassis; springing for comfort or riding; wind resistance; layout of parts for balanced design. Professor UPTON.

3B42. **Automotive Lectures.** Seniors and graduates. Required in Options D and E. Second term. Credit two hours. Two lectures a week. Prerequisite courses 3P31 or 3P33, 3D31, 3D32, 3D33. Analysis of automotive power plant design and operation; nature of the actual working fluid; preparation for and control of combustion in spark- and compression-ignition engines; volumetric, thermal, and mechanical efficiencies of engines; lubrication, fuels, etc. Professor UPTON.

3B43. **Automotive Computations.** Seniors and graduates. Required in Option D. First term. Credit two hours; two computing periods per week. Must be accompanied by course 3B41, which it parallels, but with more detailed studies to acquaint students with methods of attack on problems in operation or design. Professor UPTON.

3B44. **Automotive Power Computations.** Seniors and graduates. Required in Option D. Second term. Credit two hours; two computing periods per week. Must be accompanied by 3B42, which it parallels, but with more detailed studies in operation and design. Professor UPTON.

3B46. **Airplane Design.** Seniors. Required in Option E. First term. Credit two hours. Prerequisite 3B35. Two recitations a week. Layout procedure, weight and balance estimates, load factors, materials and costs. Principles of stress analysis and airplane computations. Mr. TERRY.

3B47, 3B48. **Airplane Computations.** Seniors. Required in Option E. Throughout the year. Credit two hours a term. Prerequisite course 3B35; and must be accompanied or preceded by 3B46. Two computating periods per week. The student makes calculations and drawings similar to those required by the Department of Commerce for approval of the design of an airplane. Mr. TERRY.

3B50. **Advanced Automotive Engineering.** Elective for qualified seniors and graduates. Either term. Credit two to five hours as arranged. Selected advanced topics and special problems as arranged. Professor UPTON and Mr. TERRY.

DRAWING AND DESCRIPTIVE GEOMETRY

(See under courses offered to Freshmen, page 48.)

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. Professor ROGERS, Assistant Professor BLACK, and Messrs. MORRIS, KINNEY, BARTON and others.

3D23. **Kinematics, 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 devoted to drawing board applications of the theory and principles of course 3D21. Professor ROGERS, Assistant Professor BLACK, and Messrs. MORRIS, KINNEY, BARTON and others.

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 reci-

tation 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. Professor ROGERS, Assistant Professor BLACK and Messrs. MORRIS, KINNEY, BARTON and others.

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. Professor ROGERS, Assistant Professor BLACK, and Messrs. MORRIS, KINNEY, BARTON and others.

3D26. **Kinematics, 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 devoted to drawing board applications of the theory and principles of course 3D25. Professor ROGERS, Assistant Professor BLACK, and Messrs. MORRIS, KINNEY, BARTON and others.

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. Assistant Professor BLACK.

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. Assistant Professor BLACK.

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 machine parts and unit assemblies 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 each problem. Professors ALBERT and ROGERS, and Assistant Professors GARNER and BLACK and Mr. MORRIS.

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 Administrative Engineers. Credit two hours. Must be taken with course 3D34 or in the term following. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M31, and 3M22a. Two drawing periods a week throughout the term. The student for the first time undertakes the design of machine parts and unit assemblies 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 each problem. Professors ALBERT and ROGERS, Assistant Professors GARNER and BLACK, Mr. MORRIS and others.

3D36. **Machine Design, Drawing.** Seniors in Chemical Engineering. Second term. Credit one hour. Prerequisite courses 125, 3X21, 3X22, 3M21, 3M22a, and 3D34. One drawing period a week throughout the term. Design of a unit of equipment peculiar to a chemical industry. Orderly systematic calculations are insisted upon and such layout and detail drawings are made as are found essential to the problem. Professor ALBERT.

3D51. **Mechanical Technology as Related to Design.** An elective for sophomores and juniors in engineering. Second term. Credit two hours. Two one hour periods a week. 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 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.

3D54. **Dynamics and Vibrations of Machinery.** Elective for seniors and graduates. First term. Credit three hours. Prerequisite courses 3D32 or 3D34 and 3M32. Two lecture and discussion periods and one laboratory period a week throughout the term. Balancing of engines. Flywheel design. Transverse and torsional vibrations and critical speeds. Control of vibration and noise in machinery. Assistant Professor BLACK.

3D55. **Advanced Machine Design.** Elective for seniors and graduates. Second term. Credit three hours. Prerequisite courses 3D32 or 3D34 and 3M32. Two lecture and discussion periods and one laboratory period a week throughout the term. Advanced problems in stress analysis of machine parts and structures. Assistant Professor BLACK.

EXPERIMENTAL MECHANICAL ENGINEERING

(See courses listed under letter X on page 120.)

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.** Sophomores, juniors and seniors in Mechanical Engineering are urged to become members of the Student Branch of the American Society of Mechanical Engineers, the meetings of which, however, are open to all. Attendance at any fourteen Branch meetings entitles the member to one hour elective credit. Applications for membership should be made at the Director's Office in October of each year, or to Mr. L. F. Welanetz, Honorary Chairman of the Student Branch.

HEAT-POWER ENGINEERING

(See the courses listed under the letter P on page 118.)

HYDRAULIC POWER ENGINEERING

(See courses listed under letter M on page 117.)

INDUSTRIAL ENGINEERING (I)

3I31. **Industrial Organization.** Required of all juniors in Mechanical and in Electrical Engineering, and of fifth year students in Chemical 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 LEE.

3I43, 3I44. **Industrial Engineering.** Required first term of all Administrative Engineers, and throughout the year of Mechanical Engineers electing the Industrial Option. Throughout the year. Credit three hours each term. One lecture and five hours of laboratory each week. The laboratory work consists of a study of modern production and materials 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, Assistant Professor MILLARD and Mr. MANNING.

3I46. **Industrial Relations.** First term. Credit two hours. Two lectures or recitations a week. 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.** Required of all students in Administrative Engineering and of Mechanical Engineering seniors electing the Industrial Engineering Option. Second term. Credit three hours. One recitation, one lecture and one two and one-half hour computing period each week. Prerequisite, course 3A31, or its equivalent. A detailed study of manufacturing cost systems dealing with order costs, process costs, and standard costs. Professor LEE, Assistant Professor MILLARD and Mr. MANNING.

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. Assistant Professor MILLARD and Mr. MANNING.

3I51. **Advanced Industrial Engineering.** Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a limited number of seniors and graduates. Special problems and investigations which are carried on under the direction of members of the department staff. Professor LEE, Assistant Professor MILLARD and Mr. MANNING.

3I52. **Industrial Auditing.** Elective. For seniors and graduates. Credit two hours. One lecture and one computing period per week, first term. Prerequisite course—Accounting for Engineers 3A31 or its equivalent. A study of auditing theory and practice by the use of illustrative problems pertaining to manufacturing concerns. Assistant Professor MILLARD.

3I53. **Advanced Industrial Relations.** Elective. Two one hour discussion periods each week, second term, credit two hours. Prerequisite course 3I46 or its equivalent. The course consists of studies of problems in industrial relations by the case method. For each period definite cases are assigned and one member of the class is designated to lead the discussion. At frequent intervals cases are assigned, discussions of which are to be written and handed in. The object of the course is to teach the student to apply the fundamentals of industrial relations, studied in course 3I46, to specific situations arising in industry. Professor LEE.

3I54. **Micro-motion Laboratory.** Elective. Credit two hours. Either term. Two, two and one-half hour laboratory periods per week devoted to practical research in the principal phases of Time Study and Motion Economy. Prerequisite courses 3I31 or 3A23. Open to graduates and seniors. Time studies and process charts are made in our own and outside shops. Motion Economy is studied by the development of a specific problem in the laboratory during which motion pictures are made of the operation studied. Through micro-motion analysis of these pictures simo-motion charts are made of the operation before and after improvement. A work place is designed and built, and the improved methods tried out in the laboratory. Assistant Professor MILLARD and Mr. MANNING.

MACHINE DESIGN (D)

(See courses under letter D beginning on p. 112.)

MECHANICAL LABORATORY (X)

(See courses under letter X beginning on page 121.)

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, momentum and impulse; torque and angular momentum. Professor CORNELL, Assistant Professor PERKINS and Messrs. WELANETZ, ARMSTRONG and LEE.

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. Professor CORNELL, Assistant Professor PERKINS, and Messrs. WELANETZ, ARMSTRONG and LEE.

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 SWITZER and CORNELL, Assistant Professor PERKINS and Messrs. WELANETZ, ARMSTRONG and LEE.

3M32. **Applied Mathematics.** Sophomores in Mechanical Engineering. Second term. Credit three hours. Prerequisite course 3M21. 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 Messrs. WELANETZ and ARMSTRONG.

3M33. **Fluid Mechanics.** Juniors in Mechanical Engineering. First term. Credit four hours. Prerequisite courses 3M21 and 3M32. 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 one year, when taken as an elective engineering subject only. Also constitutes classroom requirements of first year of two year advanced course in Ordnance R.O.T.C. Unit. In the latter case, one additional hour per week of military training is required. In either case, credit of one hour each term. Prerequisite courses 3M21 and 3M22. First term covers ammunition and explosives; design and manufacturing methods; ballistics. Second term: other ordnance material, including small arms, artillery, essentials of carriage design, and ordnance vehicles. Major DAVIS.

3M55. **Photo-elasticity.** Elective for seniors and graduates. First term. Credit two hours. One lecture and one laboratory-lecture period each 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 tor 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 and Mr. WELANETZ.

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.

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.

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. Three recitations 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; steam turbines; air-vapor mixtures; and heat transfer. 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 CLARK.

3P33, 3P34. **Heat-Power Engineering.** Required of juniors in Electrical Engineering, Chemical 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 3D25, 3D26, 3M21, 3M22a. The course is an abridged treatment of substantially the same ground as courses 3P31, 3P32, and 3P41, 3P42; it is supplemented in the senior year by course 3P54. The longer courses 3P31, 3P32, and 3P41, 3P42 may be substituted for this one. Assistant Professor HOOK and Mr. FAIRCHILD.

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 periods 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; 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 Mr. FAIRCHILD.

3P43. **Heat-Power Engineering.** Required of seniors in certain Civil Engineering Options. Either term. Credit three hours. Three periods a week. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics 11 and 12 (or the equivalent), Chemistry 102, C.E. 220 and 221. Elementary consideration of behavior of gases and vapors as applied to heat en-

gines; 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 and Mr. FAIRCHILD.

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. 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. Professor MACKEY.

3P49. **Refrigeration.** Elective for seniors. Required in Option B. 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 for 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.

3P54. **Heat-Power Engineering.** Required of A.E. seniors. Elective for E.E. seniors. Not open to M.E. students. Second term. Credit two hours. Two lectures a week. A continuation of courses 3P33, 3P34. Professor BARNARD.

3P55. **Graphical Computation and Representation.** Required of A.E. juniors, and elective for others except freshmen. First term. Credit two hours. Slide rules; construction of net work charts and alignment charts for the solution of equations; and derivation of empirical equations from experimental curve. Professor MACKEY and Assistant Professor MILLARD.

3P57, 3P58. **Heat Engineering.** Throughout the year. M.E. seniors in Option B. Credit four hours a term. Must be accompanied or preceded by 3P41, 3P42, and 3P49. Properties of mixtures, dimensional analysis, fluid flow, heat transmission, selection of fans and pumps, and refrigeration; applications to problems in air conditioning. Professor MACKEY.

3P60. **Advanced Heat-Power Engineering Research.** Elective for graduate students and others qualified for advanced study in this field. Work and credit as arranged with Professors BARNARD, ELLENWOOD, MACKEY 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 47.)

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. Either term. Credit one hour. 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. First term. Credit three hours. 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 MACK.

3S32. **Machine Work.** Required of A.E. and E.E. sophomores. Second term. Credit two hours. Prerequisites 102 and 103. 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 MACK.

3S50. **Extra Shop Work.** Work and credit as arranged with Professor WELLS.

EXPERIMENTAL MECHANICAL ENGINEERING (X)

The work in this department is given in four divisions: (1) Courses in Materials of Engineering and in Materials Testing Laboratory; (2) Courses in General Mechanical Laboratory Practice; (3) Heating, Ventilating and Refrigeration; and (4) Courses in Experimental Mechanical Engineering Research.

1. COURSES IN MATERIALS AND MATERIALS TESTING

3X21. **Materials of Engineering.** Required of M.E. and A.E. in M.E. sophomores, and of Chem. E. juniors. First term. Credit three hours. Prerequisite: Chemistry 102 a and b, or equivalent. An elementary lecture course in engineering materials covering fuels and their combustion, refractories, metallurgy of iron and steel, and the constitution of metals and alloys; with outside reading required on wood, stone, brick, cementing materials and concrete. Assistant Professor JEFFREY.

3X22. **Materials of Engineering.** Required of M.E. and A.E. in M.E. sophomores, and of Chem. E. juniors. Second term. Credit three hours. Prerequisites: Chemistry 102 a and b, or equivalent, and 3X21. A continuation of Course 3X21, the lecture course continuing the study of the constitution of metals and alloys, the metallography of iron and steel, alloy steels, non-ferrous metals and alloys; corrosion; including outside reading on rubber, plastics, leather, rope, etc., and the testing and inspection of materials. Assistant Professor JEFFREY.

3X23. **Materials of Engineering.** Required of E.E. and A.E. in E.E. sophomores. First term. Credit two hours. Prerequisite: Chemistry 102 a and b. An abridgment of Course 3X21 suited to the needs of students in Electrical Engineering. Assistant Professor JEFFREY.

3X24. **Materials of Engineering.** Required of E.E. and A.E. in E.E. sophomores. Second term. Credit two hours. Prerequisites: Chemistry 102 a and b, and 3X23. An abridgment of 3X22 and a continuation of Course 3X23 for students in Electrical Engineering. Assistant Professor JEFFREY.

3X31. **Mechanical Laboratory—Properties of Engineering Materials.** M.E. juniors. First term. Credit four hours. Prerequisite courses 3X21, 3X22, 3M21 and 3M22a. A laboratory course dealing with: the determination of physical properties of materials (principally metals and alloys) by means of tension, transverse, and compression tests; the selection of materials for a given use based upon physical properties; the control of physical properties by various forms of thermal and mechanical treatments with emphasis on the relationship between internal structure and physical properties. A written report is required on each experiment. Professor DAVIS, Assistant Professors JEFFREY and MOYNIHAN, and Messrs. BEBBINGTON and CONTA.

3X33. **Mechanical Laboratory—Properties of Engineering Materials.** E.E. and A.E. juniors and fourth year students in Chemical Engineering. First term. Credit three hours. Prerequisites the same as for Course 3X31. This course is an abridgement of Course 3X31. Professor DAVIS, Assistant Professors JEFFREY and MOYNIHAN, and Messrs. BEBBINGTON and CONTA.

3X52. **Applied Metallography.** Elective. First term. Credit two hours. Prerequisite courses 3X21, 3X22 and 3X31. 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.

Also see courses listed in Option G, Metallurgical Engineering (page 100), and those under Chemistry on page 108.

2. General Mechanical Laboratory Practice

3X32. **Mechanical Laboratory — Introductory Experimental Engineering.** M.E., E.E., A.E. juniors, and fourth year Chemical Engineers. Prerequisite courses: 3X21, 3M23 or 3M33, 3P31 or 3P33, 3P32 or 3P34. All of these courses must either have been completed or taken concurrently with 3X32. A laboratory course dealing with: The calibration and use of engineering instruments; the properties of oils; principles of lubrication; solid, liquid and gaseous fuel analysis and calorimetry; fundamentals of fluid flow; steam engine performance and characteristics; internal combustion engine performance and combustion characteristics. A written report is required on each experiment. Professor DAVIS, Assistant Professors MOYNIHAN and JEFFREY and Messrs. BEBBINGTON and CONTA.

3X33. **Mechanical Laboratory**—See after 3X31 above.

3X41. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and Administrative Engineering in M.E. First term. Credit four hours. Prerequisite courses 3X32, 3P31 or 3P33, and 3P32 or 3P34. Should be taken concurrently with 3P41. One laboratory period and one report each week. Comprehensive tests of internal combustion engines, steam power equipment, hydraulic pumps and turbines, air blowers and wind tunnel. The report of each test must be full and complete, including such items as basic theory of the apparatus, testing method used, original data, computations, results of the test expressed both numerically and graphically and a discussion of the salient points of the test and results. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT and Mr. ERDMAN.

3X42. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and Administrative Engineering in M.E. Second term. Credit four hours. Should follow 3X41. One laboratory period each week alternating with one computing or discussion period. A written report is required for each experiment. Detailed study of the methods of testing and of computation as exemplified by tests of steam engines, air compressors, ice machines and methods of measuring the flow of both liquids and gases. Reports required as in 3X41. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT and Mr. ERDMAN.

3X43. **Mechanical Laboratory—Experimental Engineering.** Required of seniors in Electrical Engineering, Administrative Engineering in E.E. and fifth year students in Chemical Engineering. First term. Credit two hours. Prerequisite courses 3X32, 3P33 and 3P34. Experiments selected by the faculty from course 3X41. Professor GAGE, Assistant Professor ANDRAE, Dr. RUBERT and Mr. ERDMAN.

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. 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 DAVIS, SAWDON, and GAGE, Assistant Professors ANDRAE, JEFFREY and MOYNIHAN, and representatives of the department in which the student is taking his major work.

3X52. **Applied Metallography.** See on page 121.

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 or 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 B.E.E., is offered. (See page 130.)

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. Circuit Analysis

The term circuit is here used in its most general sense to cover electric, magnetic and dielectric circuits. The instruction is planned to include power and communication networks in both the steady and transient states and to furnish a critical analysis of the design and operating features of electric machines.

In the second term of the junior year a study of circuit analysis is undertaken. This covers such mathematical tools as determinants, complex numbers, vectors, sine functions, dimensional analysis, and Fourier's Series. Application of these tools to circuits and networks

possessing constant as well as variable characteristics is then given.

In the first term of the senior year further applications are treated which cover the transient as well as the steady state phenomena in circuits possessing lumped and distributed characteristics.

The second term of the senior year is devoted to the study of electric machines and covers the design and operating features of transformers, synchronous, induction, and commutating machines.

Students interested in advanced circuit analysis are offered a course in Heaviside's Operational Analysis as an elective. This deals with the Laplacian Transform solutions of the transient and steady states in networks comprising lumped and distributed properties.

Other courses offered in this department include studies of the properties of magnetic and dielectric materials, and a seminar in Circuit Analysis.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. Electrical Applications and Control

Courses are given in this department covering the principles of electric railway practice and industrial applications and control.

10. Illumination

The development of lighting equipment and its application are very live and promising fields for the engineer. The electrical engineering student who is fortunate enough to combine strong artistic sensibility with his engineering proficiency is equipped for outstanding achievement in Illumination. Courses in the engineering principles involved are regularly given and special work may be taken by arrangement.

Electrical Engineering Research

The instructing staffs, laboratories, libraries, and other facilities of the various 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 41–43 of this pamphlet. For discussion of graduate research in engineering, see the Announcement of the Engineering Division of the Graduate School beginning on p. 147 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.

Undergraduates who have shown proficiency in the conduct of research will be permitted (at the option of the faculty) to substitute research for some of the senior electives.

Opportunities for Professional Development

During the year Non-Resident Lectures are given to the students on technical and professional subjects, (see list on page 12). Seniors are required to attend a series of these lectures, designed to give them a conception of engineering activities. There are also many scientific lectures given throughout the University, which all students are invited to attend.

The Ithaca Section of the *American Institute of Electrical Engineers* meets frequently, and students are urged to attend and participate in these meetings. There is also a Cornell Branch of the American Institute of Electrical Engineers, with the activities of which practically all electrical students are associated. The Branch, together with other branches in the Northeast District, holds an Annual Convention at which student papers are presented and appropriate prizes are given.

The *Cornell Engineer*, a technical journal published monthly throughout the school year, is managed and edited by undergraduate students in Engineering, (see course 3G52, page 114).

Elective credit hours are given for activity in the A. I. E. E., Student Branch (course 492) and the Cornell Engineer (course 3G52) as indicated on pages 137 and 114, respectively.

COURSES OFFERED IN THE SCHOOL OF ELECTRICAL ENGINEERING

1. THE REGULAR FOUR-YEAR COURSE LEADING TO THE DEGREE OF B.E.E.

	Credit Hours	
FRESHMAN YEAR	*1st Term*	*2nd Term*
See schedule on page 46	19	18
SOPHOMORE YEAR		
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 of Engineering 3X23, 3X24	2	2
Econ. Organization 3A21	3	0
Machine Shop 3S32	0	2
Elec. Engineering 410	0	4
English 2 or Pub. Speaking 1	0	3
Total number of hours per term	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		
Elements of Electrical Engineering 411, 412	4	4
Elec. Engineering Lab. 431	4	0
Electronics 450	0	4
Heat Power 3P33, 3P34	3	3
Mech. Laboratory 3X33, 3X32	3	3
Machine Design, Rec. 3D34	2	0
Industrial Organization 3I31	2	0
Applied Mathematics 420	0	3
Elective	0	2
Total number of hours per term	18	19
SENIOR YEAR		
Electrical Engineering Theory*	5	5
Electrical Engineering Laboratory 433–34	4	4
Mechanical Engineering Laboratory 3X43	2	0
Non-resident Lectures 491	0	1
Electrical Engineering Option**	3	7
Elective	4	1
Total number of hours per term	18	18
Grand total for the Four-Year Course		147 Hours

*A student may select either courses 421, 422, 423 and 424 in "The Theory and Practice of Electrical Engineering" or courses 493 and 494 in "Electric Circuit Analysis".

**A student may select an option in Communication Engineering or Electric Power and Design. Other options as described on page 129 are open to specially qualified students.

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 B.E.E. degree.

ELECTIVE SUBJECTS IN THE SCHOOL OF ELECTRICAL ENGINEERING

	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	3
Elements of Broadcast Engineering 452b	0	2
Elements of Electric Railway Practice 461	2	0
Industrial Applications and Control 462	0	2
Illumination 466a,b	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. Seminar 492	1	1

SOME ELECTIVE SUBJECTS IN OTHER SCHOOLS AND COLLEGES

	Credit Hours 1st Term	2nd Term
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
Elementary Differential Equations 41	0	3
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	0 or 3	3 or 0
Introductory Physical Chemistry (Lab.) 410	3	3
Introductory Chem. Microscopy (Lec. and Lab.) 530	0 or 3	3 or 0
Metallography 545	2	0
Gas and Fuel Analysis 250	0 or 4	4 or 0
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
Modern Physics 41	2	0
Special Topics in Physics 42	0	2
Introduction to Modern Physical Theory (170)	3	3
Human Nature and Management 3A47	0	2
Business and Industrial Problems 3A48	0	2
Elementary Psychology 1	2 or 0	0 or 2
Psychotechnology in Business and Industry 16b	3	0
Advanced Signal Corps Course (see page 50)	1	1

For courses in Mechanical Engineering see page 110.

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

The following courses are required for students taking the Physics Option:

Modern Physics 41	2	0
Special Topics in Modern Physics 42	0	2
Introduction to Modern Physical Theories 170	3	3

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 B.E.E. AND B.M.E.

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 B.M.E. and B.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 B.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 22.

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 B.E.E. course, see page 27.

It is possible by an additional year of study to receive the degree of Bachelor of Electrical Engineering, provided the student signifies this intention at the beginning of the sophomore year.

A FOUR YEAR COURSE IN ADMINISTRATIVE ENGINEERING (*IN ELECTRICAL ENGINEERING*) LEADING TO THE DEGREE OF B.S. IN A.E.

FRESHMAN YEAR	*Credit Hours* 1st Term	2nd Term
See schedule on page 46	19	18
SOPHOMORE YEAR		
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Kinematics, Rec. 3D25	3	0
Kinematics, Drawing 3D26	2	0
Materials of Engineering 3X23, 3X24	2	2
Machine Shop 3S23	0	2
English 2	3	0
Technical Writing 3A33	0	2
Economic Organization 3A21	3	0
Business and Industrial Management 3A23	0	4
Electrical Engineering 410	0	4
Foundry 3S22	1	0
Total number of hours per term	19	19
JUNIOR YEAR		
Heat Power 3P33, 3P34	3	3
Machine Design, Rec. 3D34	2	0
Mechanical Laboratory 3X33, 32	3	3
Money and Banking, Econ. 11	0	3
Accounting 3A31	0	3
Business Statistics 3A41	3	0
Electrical Engineering 411, 412	4	4
Electrical Engineering 431, 450	4	4
Total number of hours per term	19	20
SENIOR YEAR		
Mechanical Laboratory 3X43	2	0
Cost Accounting 3I47	0	3
Industrial Marketing 3A44	3	0
Industrial Relations 3I46	2	0
Corporation Finance 3A34	0	3
Business Law 3A43, 3A46	3	2
Public Speaking 1	0	3
Electrical Engineering Option	4	4
Non-resident Lectures 491	0	1
Electives	4	3
Total number of hours per term	18	19
Grand total for the Four-Year Course	149 Hours	

DESCRIPTION OF THE COURSES OF INSTRUCTION

(A description of the courses of instruction for freshmen is given under the head THE FRESHMAN YEAR, beginning on page 46.)

COURSES FOR SOPHOMORES, JUNIORS, AND SENIORS

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 110.

For description of advanced courses in the Department of Military Science and Tactics, see page 50.

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. First term only. Three hours a week. Two recitations and one laboratory or computing period. 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 and of fifth year students in Chemical 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 and B. K. NORTHROP, Dr. SOHON, Dr. SMITH, Mr. JONES, 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 electrical phenomena and their application to engineering. Aims to provide a solid foundation for further study in electrical engineering. Assistant Professor STRONG and instructors.

411. **Elements of Electrical Engineering.** Required of juniors in Electrical Engineering. First term only. Credit four 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.

412. **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 courses Physics 11, 12 and Mechanics 3M21. Two lectures and one 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 industrial equipment. Emphasis is put on a quantitative study and understanding of basic electrical phenomena rather than on a survey of the characteristics and applications of currently available equipment. Assistant Professor STRONG, Dr. SMITH and Mr. JONES.

417. **Essentials of Electrical Engineering.** Required of seniors in certain Civil Engineering Options. Either term. 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 and instructors.

420. **Applied Mathematics.** Required of all juniors in Electrical Engineering. Second term. Credit three hours. Prerequisites 410, 411 or their equivalent. Two lecture-recitations and one computing period a week. Mathematical introduction covering determinates, complex numbers, vectors, sine functions, dimensional analysis and Fourier Series. Study of circuits and networks subjected to sine and non-sine e.m.f. waves, comprising constant and variable characteristics. Assistant Professor MALTI and instructors.

421, 422. **Electrical Practice.** Throughout the year. Credit two hours a 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 Assistant Professor M. G. NORTHROP.

423, 424. **Advanced Electrical Theory.** Throughout the year. Credit three hours a term. Prerequisite courses 411a, 412a, 420, 431. Two recitations and homework problems a 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 241 and 422, in which practical applications of the advanced electrical theory are considered. Professor KARAPETOFF and Assistant Professor M. G. NORTHROP.

431. **Electrical Laboratory for E.E. Juniors.** Required of juniors in Electrical Engineering. First term. Credit four hours a term. Prerequisite courses, Mechanics 3M21, E.E. 410, and must be accompanied by 411. One laboratory period and report each week. Experimental work on the subjects taken up in 411, 412. Professor CHAMBERLAIN, Assistant Professor B. K. NORTHROP, Dr. SOHON and Mr. BRISTOL.

433, 434. **Advanced Electrical Laboratory.** Required of seniors in Electrical Engineering. Throughout the year. Credit four hours per term. Prerequisite courses, Electrical Engineering 431, 412 and 450. Two recitations, one laboratory period, 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. WOOD.

435, 436. **Electrical Laboratory for M.E. Seniors.** Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, 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, Mr. WOOD and Mr. MANNING.

441. **Electrical Power-Plant Design.** First term only. Credit three hours. Prerequisite courses 411, 412 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. 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, 411, and 431. Two lectures, one laboratory period and one report a 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, one recitation, and one laboratory or computing period a week. Prerequisites, courses 411, 412, 431, 450, and 420. 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 recitation, 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 three 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 reinforcement, 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 411, 412, and 431. 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 411, 412, 431, 450. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

466a, b. **Illumination.** Elective. Throughout the year. Credit two hours. Open to juniors and seniors in the College of Engineering. Prerequisite courses: Physics 11, 12. 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. Assistant Professor STRONG.

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. (Not given in 1938–39).

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. First and second terms. Credit three hours a term. Two lecture-recitations and one computing period a week. Mathematical introduction covering functions of real variables, functions of complex variables, infinite series, some special functions and Laplace and Fourier's Transformations. The classical solution of differential equations. Generalized expansion theorems for differential and difference equations. Application to transient problems in circuits with lumped and distributed parameters, and to ladder networks. 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 BALLARD.

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.

492. **A.I.E.E. Seminar.** Elective for juniors and seniors who are members of the Student Branch of A.I.E.E. Throughout the year. Credit one hour a term. One period a week. Study and practice in the preparation and delivery of professional engineering papers. The organization, conduct and purposes of the professional engineering societies. Assistant Professor STRONG, Counsellor of Cornell Branch A.I.E.E., Professor KARAPETOFF, and others.

493. **Electric Circuit Analysis.** For seniors and graduate students in Electrical Engineering. First term. Credit five hours a term. Four lecture-recitations and one computing period a week. Prerequisite 420 or its equivalent. Analysis of circuits with lumped and distributed parameters, in the steady and transient states. The generalized 2n-terminal network, filter circuits and polyphase circuits. Assistant Professor MALTI and instructors.

494. **Analysis of Machine Circuits.** For seniors and graduate students in Electrical Engineering. Second term. Credit five hours a term. Four lecture-recitations and one computing period a week. Prerequisite 493. Analysis of the design and performance features of electric machines covering transformers, synchronous, induction, and commutating machines. Assistant Professor MALTI and instructors.

495, 496. **Seminar in Circuit Analysis.** For graduate students in Electrical Engineering. First and second terms. Credit two hours a term. One period of two hours a week. Prerequisites general knowledge of Circuit Analysis and of the design and operation features of electric machines. The object of this seminar is to review the developments in the fields of circuit analysis and of electrical machinery and to discuss the research work of graduate students in these fields. Assistant Professor MALTI.

THE SCHOOL OF CHEMICAL ENGINEERING

OUTLINE OF INSTRUCTION

The purpose of the instruction in this School is to provide a broad foundation of training in the fundamental subjects of mathematics, chemistry and physics and in the essential principles and methods of engineering, and professional training in the specific field of chemical engineering. In the required curriculum a certain amount of work in cultural subjects is included. By providing for a certain amount of elective work in the later years, the curriculum makes it possible for the student to take additional courses either in subjects outside the field of his major interest or in special and advanced technical subjects within that field.

FIRST YEAR		*Course*	*First Term*	*Second Term*
Introductory Inorganic Chemistry	Chemistry	110	3	2
Inorganic Chemistry Laboratory	Chemistry	115	3	0
Introductory Qualitative Analysis	Chemistry	203	0	5
Analytic Geometry and Calculus	Mathematics	5a, 5b	5	5
English	English	2	3	3
Introductory Experimental Physics	Physics	11, 12	4	4
			18	19

SECOND YEAR				
Introductory Organic Chemistry	Chemistry	305	3	3
Organic Chemistry Laboratory	Chemistry	310	3	3
Introductory Quantitative Analysis	Chemistry	220	3	0
Quantitative Analysis Laboratory	Chemistry	221	3	0
Gas and Fuel Analysis	Chemistry	250	0	3
General Physics	Physics	21, 22	3	3
German	German	1b	3	3
Drawing	M. E.	125	0	3
			18	18

THIRD YEAR		*Course*	*First Term*	*Second Term*
Introductory Physical Chemistry	Chemistry	405	3	3
Physical Chemistry Laboratory	Chemistry	410	3	3
Inductory Chemical Microscopy	Chemistry	530	0	3
Elementary Mineralogy	Geology	311	3	0
Mechanics	M. E.	3M21	5	0
Strength of Materials	M. E.	3M22	0	3
Hydraulics	M. E.	3M23	0	2
Materials of Construction	M. E.	3X21	3	0
Materials of Construction	M. E.	3X22	0	3
			17	17

FOURTH YEAR

Unit Operations of Chemical Engineering	Chem. E.	705	3	3
Chemical Engineering Laboratory	Chem. E.	710	2	2
Advanced Inorganic Chemistry	Chemistry	130	3	3
Advanced Physical Chemistry	Chemistry	420	3	0
Special Topics in Chemistry	Chemistry	910	1	0
Advanced Quantitative Analysis	Chemistry	230	0	3
Heat Power Engineering	M. E.	3P33	3	0
Heat Power Engineering	M. E.	3P34	0	3
Mechanical Laboratory	M. E.	3X33	3	0
Mechanical Laboratory	M. E.	3X32	0	3
			18	17

No student will be allowed to register for the fifth year of work leading to the degree of Bachelor of Chemical Engineering unless his average grade for the first four years is at least 75.

FIFTH YEAR

		Course	*First Term*	*Second Term*
Electrical Engineering Lectures	M. E.	405	4	0
Electrical Engineering Lectures	M. E.	406	0	4
Machine Design	M. E.	3D34	2	0
Machine Design	M. E.	3D36	1	0
Mechanical Engineering Laboratory	M. E.	3X43	2	0
Industrial Organization	M. E.	3I31	2	0
Chemical Plant Design	Chem. E.	730	3	3
Introduction to Economics	Economics	3	0	3
Electives (hours per term variable)			3	7
			17	17

Students who present two or three units of German at entrance will not be required to take the first term of German 1b. Students who present three units of German may, on recommendation of the Department of German, substitute German 8 for the second term of German 1b. The equivalent number of hours of electives will be substituted for the first term of German 1b, in the above cases.

Elective courses may be taken in any college of the University. The selection must be approved by the student's class adviser.

A student who does not pass at least twelve hours in any term, with a grade of at least 70 in at least six of these twelve hours, may be dropped from the University or placed on probation. The same penalty may be imposed on students in the Summer Session who do not pass at least four hours, with a grade of 70 or better in two hours.

If, in the opinion of the faculty of the School of Chemical Engineering, a student's general record is unsatisfactory, the student will be refused permission to continue his work for the degree of B. Chem. E., even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in these hours.

SCHOOL OF CHEMICAL ENGINEERING
DESCRIPTION OF THE COURSES OF INSTRUCTION

1. COURSES GIVEN IN OTHER SCHOOLS AND COLLEGES

In the following list of prescribed courses, those in Chemistry, Physics, English, Mathematics, Economics, German and Geology are taught in the College of Arts and Sciences. Courses in Mechanics, Strength of Materials, Drawing, Hydraulics, Materials of Construction, Heat Power Engineering, Mechanical Laboratory, Industrial Organization and Machine Design are given in the School of Mechanical Engineering. The courses in Electrical Engineering are given in the School of Electrical Engineering. The various required and elective courses in Mechanical, Electrical and Civil Engineering are described elsewhere in this announcement.

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. Required of candidates for the degree of Bachelor of Chemical Engineering.

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

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. Professor LAUBENGAYER and assistants.

Recitations: one hour a week, to be arranged.

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

130. **Advanced Inorganic Chemistry.** Throughout the year. Credit three hours a term. Prerequisite or parallel courses, Chemistry 405 and 410. 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 Mendeléff, 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.

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 students in the course in Chemical Engineering. Professor NICHOLS, Dr. LONG, and assistants.

Lecture or recitation: M 9. *Baker* 177. One other recitation, to be arranged. Laboratory: M W F 1:40–4. *Baker* 50.

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, 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.

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, 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.

230. **Advanced Quantitative Analysis.** Repeated in the second term. Credit three hours. Prerequisite, Chemistry 220 and 221 or special permission. Deposit, $20. Professor NICHOLS, 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.

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

Laboratory sections: M W 1:40–4; T 10–12:30, 1:40–4:00, 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.

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. MILLER. M W F 9. *Baker* 200.

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

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

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.

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, 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.

420. **Advanced Physical Chemistry.** First term. Credit three hours. Prerequisite, Chemistry 405. Required of candidates for the degree of Bachelor of Chemistry. Dr. HOARD. 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.

530. **Introductory Chemical Microscopy.** Repeated in the second term. Credit three hours. Prerequisite, or parallel courses, Chemistry 405 and Physics 21 and 22, or 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* 378.

Lectures and laboratory practice. The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical characteristics and physical chemistry of crystals; illumination, ultra-microscopy and photomicrography; study of industrial materials such as textile and paper fibers.

Graduate students are advised to take this course the first term.

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

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

Graduate students are advised to take this course before beginning thesis work.

For description of other courses in Chemistry, available as electives in the course in Chemical Engineering, see announcement of the College of Arts and Sciences.

PHYSICS

For description of Physics courses 11 and 12, see page 47 of this announcement. For courses 21 and 22, see page 109 of this announcement. For advanced courses in Physics available as electives, consult the announcement of the College of Arts and Sciences.

MATHEMATICS

Mathematics courses 5a and 5b are described on pages 46–47 of this announcement.

MECHANICAL ENGINEERING

Those courses required for the degree of Bachelor of Chemical Engineering that are given in the School of Mechanical Engineering are described in that section of this announcement that is devoted to a discussion of the work in Mechanical Engineering.

ELECTRICAL ENGINEERING

Courses 405 and 406 in Electrical Engineering are described on page 133 of this announcement.

ENGLISH

2. **Introductory Course in Composition and Literature.** Throughout the year. Credit three hours a term. May not be entered the second term. Professor SIBLEY, Assistant Professor TENNEY, and others. M W F 8, 9, 10, 11, 12; T Th S 8, 9, 10, 11. Rooms to be announced.

The course, open to freshmen who have satisfied the entrance requirements in English, is a training in the reading and writing of English. All those who elect this course must apply as follows for assignment to sections: the first term at the *Drill Hall*; the second term at *Goldwin Smith* A. Registration is in charge of Assistant Professor TENNEY.

GERMAN

1b. **Course for Chemists: Grammar, Reading of Texts in Chemistry.** Throughout the year. Credit six hours on completion of the course, three hours for those taking it only the second term. Professor ANDREWS and Mr. MUELLER. M W F 11, 12. *Goldwin Smith* 177, 190.

2. COURSES GIVEN IN THE SCHOOL OF CHEMICAL ENGINEERING

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

Lectures. 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 fundamental theory upon which the various unit operations are based.

710. **Unit Operations Laboratory.** Throughout the year. Credit two hours a term. Prerequisite, Chemistry 405. Fee, $10. Professor RHODES, Assistant Professor 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 unit operations of chemical engineering, such as agitation, and mixing, filtration, fractional distillation, evaporation, drying, absorption of gases, and heat transfer.

715. **Unit Processes of Chemical Engineering.** Second term. Credit three hours. Prerequisite or parallel course, Chemistry 705. Assistant Professor WINDING. M W F 11. Baker 177.

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

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

Lectures. The chemistry of coal, coke, petroleum tars, and the fuel gases. Particular stress is laid upon the theoretical chemistry involved in the carbonization of coal, the gasification of coal, and the distillation and refining of petroleum and tar.

730. **Chemical Plant Design.** Throughout the year. Credit three hours a term. Prerequisite, Chemistry 705. Deposit, $10. Professor RHODES and Assistant Professor WINDING. Day and hour to be arranged.

One conference and two laboratory periods. Practice in the calculation and design of chemical plant equipment.

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

Visits to plants typical of various chemical industries. Conferences and reports. A trip during spring vacation will be a feature of this course. Fee, covering expenses, to be announced.

The schedules of plant visits are so arranged that a different group of plants is visited each year, over at least a three-year cycle. All students in Chemical Engineering are expected to make at least one of the inspection trips.

740. **Chemical Engineering Computations.** Throughout the year. Credit two hours. Prerequisite or parallel course, Chemistry 705. Assistant Professor WINDING. Hours 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.

750. **Furnace Metallurgy.** Second term. Credit two hours. Prerequisite or parallel course, Chemistry 405. Professor RHODES. T Th 10. *Baker* 377.

Lectures. 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. (Given in alternating years. Will be given 1938–1939.)

795. **Research for Seniors.** Throughout the year. Credit two or more hour a term. Fee variable. Professor RHODES and Assistant Professor WINDING.

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

S. C. HOLLISTER,
Chairman.

WALTER RODNEY CORNELL,
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 (Chem.E., 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 four main subdivisions is as follows:

COMMITTEES ON GRADUATE WORK IN THE ENGINEERING DIVISION

CHEMICAL ENGINEERING.—F. H. Rhodes, *Chairman*, 74 Baker Laboratory; C. C. Winding, *Secretary*, Baker Laboratory; C. W. Mason, Baker Laboratory.

CIVIL ENGINEERING.—P. H. Underwood, *Chairman*, 11 Lincoln Hall; R. Y. Thatcher, *Secretary*, 33-B Lincoln Hall; E. W. Rettger, 33C Lincoln Hall.

ELECTRICAL ENGINEERING.—P. M. Lincoln, *Chairman*, Franklin Hall; W. C. Ballard, jr., *Secretary*, Franklin Hall; Vladimir Karapetoff, 17 Franklin Hall.

MECHANICAL ENGINEERING.—W. N. Barnard, *Chairman*, 18 West Sibley; W. R. Cornell, *Secretary*, 304 West Sibley; G. B. Upton, Mechanical Laboratory.

DIVISION REPRESENTATIVE on the General Committee of the Graduate School, and Chairman of Group E.—George B. Upton.

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 41–43 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. A candidate for an advanced degree is expected to develop the ability to meet new situations, at least in his own field, and to solve them by his own ingenuity. A candidate, especially one for the Doctor's degree, should in addition acquire a feeling of responsibility to add to the sum total of human knowledge and should develop qualities of leadership, particularly in his special field of study.

ADVANCED DEGREES OFFERED

The degrees of Master of Chemical Engineering (M. Chem. E.) 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. For the professional degrees, Chem. E., C.E., M.E., and E.E., see page 16.

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 Faculty of the Graduate School 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.

*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.

The Degrees of M.Chem.E., 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 the degrees of M.Chem. E, M.C.E., M.E.E., M.M.E., and M.S. in 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 four *Committees on Graduate Work*, one for each of the subdivisions (Chem.E., C.E., E.E., and M.E.). See page 146.

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 and the Hooker Fellowship, 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 and Hooker Fellowship. For the latter two awards, 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. Applications should be addressed to the Director of The School of Civil Engineering.

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 GRADUATE SCHOLARSHIPS: Open to candidates for advanced degrees in Chemical, 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 twelve scholarships of an annual value of $1,000. The student must register in the Graduate School and pay the usual fees. The scholarships have not been assigned to any particular school of the college, but will be awarded as conditions dictate. Each holder of one of these scholarships will devote half of his time for eleven months of the year to an assigned research problem. The balance of the time is to be spent in graduate study as candidate for an advanced degree in engineering. Applications will be judged upon the demonstrated ability of the applicant to make satisfactory progress in the problem which might be assigned to him. Correspondence regarding contemplated problems and applications should be addressed to the Dean of the College of Engineering.

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 ordinarily 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. Awards will be made about April 1 each year.

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.Chem.E., 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. See Articles 13 and 19.

(4) A prospective graduate student should write to the office concerned (in schools of Chemical Engineering, Civil Engineering, Electrical Engineering, or Mechanical Engineering) for advice or information concerning the graduate work in Engineering.

(5) Candidacy for the degrees M.Chem.E., 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 candidate's credits, however, the quality of his previous work, his practical experience, if any, and his chosen fields of advanced study will be considered in making adjustments for candidates whose undergraduate courses have not been the exact equivalent of the corresponding undergraduate courses at Cornell.

Candidacy for the degree M.S. in Engineering presupposes graduation from a school or college of recognized standing and thorough and adequate training in the particular fields chosen for advanced work.

(6) A shortage, which does not exceed six university credit hours, may be made up as extra work. If the total shortage exceeds six hours, the applicant may be required to put in extra residence time in the Graduate School, or may be refused admission to the Graduate School.

For a shortage between six and eighteen credit hours, and not in the student's chosen fields of advanced study, extra residence time in the Graduate School will be required. A student with significant shortage in his chosen fields of advanced study may not enter the Graduate School.

(7) The Committees on Graduate Work will recommend for admission to the Graduate School only those applicants who show promise of outstanding ability to pursue graduate study and research, judged by previous record and training.

(8) The minimum language requirement for admission to candidacy for one of the degrees M.Chem.E., M.C.E., M.E.E., M.M.E., or M.S. in Engineering, is two entrance units in one foreign language. When a student's Special Committee considers that a reading knowledge of French or German or both is essential for satisfactory progress in his particular fields of study, the student will be required to demonstrate such knowledge before proceeding with this study.

(9) Applicants who do not care to meet the requirements either for entrance to candidacy for, or graduation with, 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 fields 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 Com-

mittee 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 also 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

(11) 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.

(12) In general, a graduate student should remove his shortages before he enters his chosen fields of graduate work. Since it is not always practicable to do this, the student may receive permission from the Committee on Graduate Work to make up his shortages while doing his graduate work.

Arrangements can sometimes be made for making up language and other deficiencies in the Summer Session. Sometimes graduate work may also be done in the summer, either in the Summer Session or by special arrangement under "personal direction".* To be allowed to work under "personal direction", a student is expected to have spent one year in graduate study, here, or elsewhere.

In making up shortages, a student is under the general supervision of the Committee on Graduate Work.

(13) (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.

*For requirements as to registration and the payment of fees for summer work, see the Announcement of the Graduate School and of the Summer Session.

†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."

(14) A student shall select his program of study and his Special Committee with the advice and approval of the Committee on Graduate work in that subdivision (Chem.E., C.E., E.E., or M.E.), in which his major subject falls. 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.

(15) 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.

(16) If, in the opinion of the Special Committee, a candidate at any time during his residence shows insufficient preparation in any 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.

(17) 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.

(18) 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

(19) A candidate for the Master's degree (M.Chem.E., M.C.E., M.E.E., M.M.E., or M.S. in Engineering) must select his major field in Engineering. He will be allowed considerable latitude in the selection of his minor field or fields, and any field may be chosen which includes a sufficient amount of graduate work, and provided his entire program shows unified purpose. For instance, a student might select some phase of structural engineering as his major field and economics as his minor field if he could show that his study of economics had a definite purpose consistent with well-rounded training as an engineer. The major and minor fields available in the College of Engi-

neering are described in a general way in the following pages. For opportunities in other fields of the Graduate Study, see the Announcement of the Graduate School.

APPROVED MAJOR AND MINOR SUBJECTS

Any of the basic Sciences are also available as Minors.

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 Chemical Engineering

Chemical Engineering **1, 2, 4.**

(Candidates for the degree of Master of Chemical Engineering will be expected to be thoroughly familiar with the general field of Chemical Engineering. Candidates for this degree will be required to select a minor subject in some other field of engineering or in a related science.)

In Civil Engineering

Astronomy
  Geodetic Astronomy **2, 3, 4**
  Geodesy **1, 2, 3, 4**
Highway Engineering **1, 2, 3, 4**
Hydraulic Engineering **1, 2, 3, 4**
Hydraulics
  Theoretical **1, 2, 3, 4**
  Experimental **1, 2, 3, 4**
Management Engineering **1, 2, 3, 4**
Materials of Engineering **2, 3, 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 **1, 2, 3, 4**
  Sewage Treatment **2, 3, 4**
  Water Purification **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, 3, 4**
  Topographic Engineering **1, 2, 3, 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 **2, 4**
Automotive Engineering **1, 2, 4**
Experimental Mechanical Engineering **1, 2, 3, 4**
Fluid Mechanics, **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, 4**

ADMINISTRATIVE ENGINEERING

Professors J. R. BANGS, jr., S. S. GARRETT, G. R. HANSELMAN and H. J. LOBERG.

3A21. *Economic Organization.* Credit 3 hours. Either term.
3A23. *Business and Industrial Management.* Credit 4 hours. Either term.
3A31. *Accounting for Engineers.* Credit 3 hours. Either term.

3A32. **Accounting for Engineers.** Second term. Credit three hours. Prerequisite 3A31.

Continues the work of 3A31, covering the extension of proprietorship; bond and stock issues and valuation; negotiable instruments; income tax; the variable budget; good will; depreciation; reserves, sinking funds, actuarial science; flexible budget; controversial accounting subjects; consolidated statements; statement analysis.

3A34. **Corporation Finance.** Second term. Credit three hours. Prerequisites, 3A21 and 3A31. Professor O'LEARY.

A study of the financial problems of the corporation from the points of view of the management, the investor, and the public.

3A41. **Business Statistics.** First or second term. Credit three hours. Prerequisite course 3A21. Two recitations and one two and a half hour laboratory period a week.

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

3A44. **Industrial Marketing.** First term. Credit three hours. Prerequisite courses 3A21, 3A23, and 3A41. Two recitations and one lecture a week.

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.

3A45. **Industrial Marketing.** Second term. Credit two hours. Prerequisite, course 3A44. One recitation and one two and a half hour laboratory period a week.

The application of the principles of marketing to specific problems. Each student will develop a complete market study and analysis for given industrial products.

3A51. **Business and Industrial Research.** 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.

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.

AERONAUTICAL ENGINEERING

Professor G. B. UPTON.

Problems related to the design and performance of airplanes may be carried on in this field. The laboratories of the department of Experimental Engineering are available for studies on airplane engines. Arrangements may be made with the authorities of the Ithaca airport for flight experiments. Most of the technical reports and notes of the National Advisory Committee for Aeronautics and the Aeronautical Research Committee are available in the library.

3B35. *Aerodynamics.* Either term. Two recitations a week.

3B46. *Airplane Design.* Either term. Two recitations a week.

3B47, 3B48. **Airplane Computations.** Throughout the year. Prerequisite, course 3B35. Two computing periods a week.

Calculations and drawings similar to those required by the Department of Commerce for approval of the design of an airplane.

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 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 3B41, 42, 43 and 44 suitable as a foundation.

3B41, 3B43. **Automotive Design.** First term. Professor UPTON. Two lectures and two computing periods a week.

General study of automotive road vehicles and their functioning; driving, braking, steering, springing, power required for operation.

3B42, 3B44. **Automotive Design.** Second term. Professor UPTON. Two lectures and two computing periods a week.

Power plants of automotive field, particularly internal combustion types. General design and functioning, lubrication, mechanical efficiency, volumetric efficiency, valving, balancing, carburation, ignition, performance.

CHEMICAL ENGINEERING

Professors F. H. RHODES, C. C. WINDING, C. W. MASON and A. W. LAUBENGAYER.

To qualify for admission as a candidate for the degree of M.Chem.E., a student must hold the degree of Bachelor of Chemical Engineering or the equivalent thereof, and must have completed satisfactorily a course substantially equivalent to the course leading to the degree of Bachelor of Chemical Engineering at Cornell University.

The work for the thesis may be in the specific fields of:
Unit Operations.
Unit Processes.
Chemical Engineering Economics.
Chemical Plant Design.

705. *Unit Operations of Chemical Engineering.* Throughout the year. Credit three hours a term.

710. **Unit Operations of Chemical Engineering.** Laboratory. Throughout the year. Credit two hours a term. Professors RHODES and WINDING.

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

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

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

Lectures. The chemistry of coal, coke, petroleum, tars and the fuel gases. Particular stress is laid upon the theoretical chemistry involved in the carbonization of coal, the gasification of coal, and the distillation and refining of petroleum and tar.

730. **Chemical Plant Design.** Throughout the year. Credit three hours a term. Prerequisite, Chemical Engineering 705. Professors RHODES and WINDING. Day and hour to be arranged.

One conference and two laboratory periods. Practice in the calculation and design of chemical plant equipment.

735. **Plant Inspections.** Second term. Credit one hour. Prerequisite or parallel course, Chemical Engineering 705.

Visits to plants typical of various chemical industries. A trip during spring vacation will be a feature of this course. Fee, covering expenses, to be announced.

740. **Chemical Engineering Computations.** Throughout the year. Credit two hours. Dr. WINDING.

750. **Furnace Metallurgy.** Second term. Credit two hours. Prerequisite or parallel course, Chemistry 405. Professor RHODES. T Th 10.

Lectures. 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.

795. *Research for Seniors.* Throughout the year. Credit two or more hours a term.

DESCRIPTIVE GEOMETRY AND DRAWING

(In Civil Engineering)

Professors J. T. PARSON and H. T. JENKINS.

200. *Drawing.* Freshman. First term. Credit three hours.
201. *Drawing.* Freshman. Second term. Credit three hours.
202. *Drawing.* Sophomore. First term. Credit one hour.
203. *Drawing.* Sophomore. Second term. Credit two hours.
204. *Descriptive Geometry.* First term. Credit three hours.

205. **Advanced Drawing.** Either term. Credit, three hours. Professor PARSON.

Perspective drawings (rendered in pencil, ink, and washes) of buildings, bridges, dams, and other engineering works; building details of window frames, cornices, molding, and other simple details; Old English lettering.

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.

RESEARCH: Research in Electrical Engineering may be divided into two general classes (a) theoretical and (b) experimental. Whenever possible the student is required to prove his theoretical deductions by experiment and conversely he is required to explain his experimental results by theoretical considerations.

For theoretical research the facilities of a well-equipped library are available.

For experimental research special equipment and shop facilities are required. The College of Engineering maintains several mechanics and has machine shops

fully equipped to provide shop facilities. The available special equipment required for experimental work along specific lines is given under the general topics outlined below:

GRADUATE COURSES AND TOPICS: Unless otherwise specified graduate courses offered in the School of Electrical Engineering are given either term or both terms as needed. Members of the faculty are prepared to guide students in the *graduate topics* given below. Several seminars are regularly conducted by members of the faculty for groups of graduate students interested in closely related lines of research.

ELECTRIC CIRCUIT THEORY

405-406. *Fundamentals of Electrical Engineering.*
410-411. *Elements of Electrical Engineering.*
415-416. *Principles of Electrical Engineering.*
417. *Essentials of Electrical Engineering.*
420. *Circuit Analysis.*

421-422. **Electrical Practice.** Throughout the year. Prerequisites, 411a, 412a, 420 and 431. Professor KARAPETOFF. Two hours a term.

Practical aspects of the advanced electrical theory, as applied to various types of apparatus and to some manufacturing and operating problems.

481-2. **Engineering Mathematics.** Throughout the year. Prerequisites, elements of electric circuit analysis. Professor KARAPETOFF. Two recitations a week. (Not given in 1938–39).

General methods by which engineering problems are expressed in mathematical form. The course consists of problems taken from mechanical, civil, or electrical engineering, involving analytic geometry, elements of differential and integral calculus, vector analysis, operational analysis, differential equations, and the theory of probabilities. The topic will be selected to suit the class.

493. **Electric Circuit Analysis.** First term. Prerequisite, 420 or its equivalent. Assistant Professor MALTI. Four lecture-recitations and one computing period a week.

Analysis of circuits with lumped and distributed parameters, the generalized 2n-terminal network, filter circuits and polyphase circuits.

486-487. **Heaviside's Operational Analysis.** Throughout the year. Prerequisite, 420 or its equivalent. Assistant Professor MALTI. Two lecture-recitations and one computing period a week.

Mathematical introduction covering functions of real variables, functions of complex variables, infinite series, some special functions and Laplace and Fourier transformations. The classical solution of differential equations. Generalized expansion theorems for differential and difference equations. Application to transient problems in circuits with lumped and distributed parameters, and to ladder networks.

Graduate Topics: General Theory of Circuits and Networks, skin effect, eddy currents in metallic masses, transient phenomena, electro-magnetic oscillations and waves, electric wave filters.

ELECTRICAL MACHINERY

412. *Elements of Electrical Engineering.*
431. *Electrical Laboratory.*
435-36. *Electrical Laboratory.*
450. *Electronics.*

423–424. **Advanced Electrical Theory.** Throughout the year. Credit three hours a term. Prerequisites, 421, 423. Professor KARAPETOFF and Assistant Professor M. G. NORTHROP.

Laws of the magnetic circuit with application to machine design.

442. **Electrical Design.** Second term. Credit four hours. Prerequisites, 421 and 423. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

Fundamental principles underlying the design of direct and alternating current machinery.

433-434. **Advanced Electrical Laboratory.** Throughout the year. Credit three hours first term and four hours second term. Prerequisites, 412, 420, 431, and 450. Professor CHAMBERLAIN and Assistant Professor BURCKMYER. One recitation and laboratory period with a report each week.

494. **Analysis of Machine Circuits.** Second term. Prerequisites, 420, 493 or their equivalent. Assistant Professor MALTI. Four lecture-recitations and one computing period a week.

Analysis of the performance and design of electric machines covering transformers, and synchronous, induction, and commutating machines.

Theory and Characteristics of Electrical Machinery. Prerequisites, General knowledge of the theory and testing of electrical machinery. Professor KARAPETOFF. Advanced theory of electric and magnetic circuits. Mathematical treatment of the physical laws involved in the performance of continuous and alternating current machines. Transient behavior of high-voltage apparatus. Relationship between proportions and operating characteristics. The theory underlying special tests for the determination of machine constants.

Graduate Topics. Advanced study of the *parameters* of revolving machines, special design problems, hunting and stability problems, short circuit phenomena, commutation, armature reaction.

SPECIAL EQUIPMENT. A great variety of direct and alternating current machines is 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, in addition, 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, so arranged that it may be operated either as converter or inverter.

The facilities for testing are well-planned and very complete. For machine testing, there are numerous Prony brakes, an electric dynamometer, and a special apparatus for determining the complete characteristics of fractional-horsepower motors.

ELECTRICAL COMMUNICATION

451. **Electrical Communication Engineering.** First term. Credit three hours. Prerequisites, 412, 420, 450. Professor BALLARD and Assistant Professor MCLEAN.

Theory of alternating currents as applied to telegraph, telephone and radio communication. Theory and application of thermionic devices.

452. **Electrical Communication Engineering.** Second term. Credit four hours. Prerequisite, 451. Professor BALLARD and Assistant Professor MCLEAN.

452a. **Theory of Communication Networks.** Second term. Credit two hours. Prerequisite, 451. Must be accompanied by 452. Assistant Professor MCLEAN.

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.

452b. **Elements of Broadcast Engineering.** Second term. Credit two hours. Prerequisite, 451. Must be accompanied by 452. Professor BALLARD.

Critical analysis and design of equipment used for radio telephone transmission. The laws of acoustics as applied to studio construction and equipment.

Graduate Topics. Electro-mechanical vibrating systems, propagation of electromagnetic waves, thermionic tubes and their applications, design of radio circuits, sound recording and reproduction, electric wave filters, carrier current telephony.

SPECIAL EQUIPMENT. Broadcast transmitter, 1 Kw., complete and up to date in separate building with antenna towers. Complete studio and control equipment. Available to advanced students for special problems. Primary frequency standard, consisting of 100 k. c. temperature controlled quartz crystal oscillator with multivibrator and harmonic amplifier. Laboratory is equipped with 2.5 Kw. 2,000 volt, D.C. power supply and large assortment of power tubes and parts for experimental work on radio transmitters.

Complete type D carrier current telephone equipment, with signalling auxiliaries.

Audible and carrier frequency oscillator, with complete set of resistance, inductance, and capacitance standards for impedance bridge measurements.

Vacuum tube voltmeter-milliammeter and transmission measuring set.

Complete laboratory model 100 line step-by-step dial telephone exchange.

Large assortment of small meters and equipment for studying characteristics of receiving tubes, audio transformers, and telephone equipment.

Standard Signal Generator and Wave Analyzer.

Complete equipment for the manufacture and exhaustion of experimental electron tubes, both of high vacuum and vapor types, is available for the construction of special apparatus.

ELECTRICAL MEASUREMENTS

431. *Electrical Laboratory.*

433-4. **Advanced Electrical Laboratory.**

Graduate Topics. Design of special types of meters and the characteristics of the exponential response meter, development of methods of measurement, characteristics of measuring instruments.

SPECIAL EQUIPMENT. 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.

POWER GENERATION, DISTRIBUTION, AND RATE MAKING

441. **Electric Power Plant Design.** First term. Credit three hours. Prerequisites, 412, 420, and 450. Professor LINCOLN.

Selection and arrangement of Power Plant Equipment.

464. **Electrical Power Transmission and Distribution.** Second term. Credit three hours. Prerequisites, E.E. 421-423 or 493-494 and 433. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

444. **The Economics of Public Utilities.** Second term. Credit two hours. Professor LINCOLN.

A study of the origin and development of Public Utilities, Regulation, Rates and Rate Structures, and Public Relations.

Stability of Electric Power Systems. Prerequisites, general theoretical and experimental study of alternating current circuits and machines. Professor KARAPETOFF.

The method of symmetrical components, positive, negative, and zero-sequence, impedance of stationary apparatus and revolving machines; theoretical and experimental determination of such impedances. Static and dynamic stability of simple and complex aggregates; methods of computation. Means for increasing stability.

Graduate Topics. Circuit breakers and reactor problems.

Sag stress in transmission lines, corona, regulation of long lines, insulator stresses. Valuations, rate structures, accounting methods, rate of return, public ownership, holding companies, depreciation, public regulation, capitalization.

SPECIAL EQUIPMENT. The University Hydroelectric Power Plant, which contains large three-phase alternators, direct-driven by both impulse and reaction water-wheels. This plant is complete in every respect and is used for tests and inspection.

APPLICATIONS OF ELECTRIC POWER

461. **Elements of Electric Railway Practice.** First term. Credit two hours. Prerequisites, 412, 450. Professor CHAMBERLAIN.

A study of the application of electric power to transportation.

462. **Industrial Application and Control of Electricity.** Second term. Credit two hours. Prerequisites, 423 or 493 and 433. Professor CHAMBERLAIN.

Study and selection of motor drives and control, electric welding, and electric heating.

466. *Illumination.*

MATERIALS OF ELECTRICAL ENGINEERING

Solid Dielectrics. Throughout the year. Credit two hours a term. Prerequisites, 421-2-3-4, or 493-494. Assistant Professor MALTI.

A study of anomalous behavior of solid dielectrics under varying conditions of e.m.f., time, frequency, temperature, pressure, humidity and ionizing radiation.

Magnetic Materials. Throughout the year. Credit two hours a term. Prerequisites, 421-2-3-4, or 493-494. Assistant Professor MALTI.

A study of the properties of magnetic materials such as hysteresis, permeability, 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).

Structure of Matter and Applied Electronics. Prerequisites, Physics and Chemistry in the usual scope of undergraduate courses for engineers. Professor KARAPETOFF.

The electron, its charge, mass, diameter, and velocity. Cathode rays. Elements of kinetic theory of gases. Periodic system in terms of orbital electrons. The structure of the nucleus. Photons and electro-magnetic radiation. Ionization and excitation of gases. Applications to gaseous conduction, spark-over, arcs, mercury-vapor apparatus, etc.

Electrical Testing. Prerequisites, 421-2-3-4 or 493-494 and 433. Assistant Professor BURCKMYER.

The testing of the materials of construction for determining their magnetic and electrical properties.

SPECIAL EQUIPMENT. 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. For the study of discharge of electricity through gas a vacuum system is available, and specially designed tubes to show special discharge phenomena.

EXPERIMENTAL MECHANICAL ENGINEERING

Professors A. C. DAVIS, W. M. SAWDON, V. R. GAGE, W. C. ANDRAE, J. O. JEFFREY and J. R. MOYNIHAN.

Numerous laboratories and shops are available for carrying on the many activities in Experimental Mechanical Engineering, as follows:

The Materials Testing Laboratory, for determination of the physical properties of engineering materials under different kinds of stress and heat treatment; the Photo-Elastic Laboratory, for instruction and research in Photo-Elastic work; the Steam Laboratory, for instruction and research involving steam power; the Internal-Combustion Engine Laboratory, for work with this type of power equipment; the M. E. Hydraulic Laboratory, a pump operated laboratory for hydraulic problems; the Lubrication Laboratory for determination of the physical properties of lubricants; the Refrigeration Laboratory, for the study of refrigeration; the Cement Laboratory, for the testing of cement and concrete; the Fuel Testing Laboratory for determination of the composition and calorific value of all types of fuel; the Belt Testing Laboratory, for measurement of belt tension, power transmitted, and slip; the Introductory Engineering Laboratory, for demonstrating the principal operations in forging, welding, soldering, brazing, etc.; the Heat Transfer, Heating, Ventilating, Air Conditioning Laboratories; a series of Research Laboratories; the Forge Shop, Woodworking and Pattern Shop, Machine Shop, Foundry and Boiler House.

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.

3X32. *Introductory Experimental Engineering.* Second term. One laboratory period a week and a written report of the work.

3X41, 3X42. *Experimental Engineering.* Throughout the year. One laboratory period a week and a written report of the work.

3X43. *Experimental Engineering.* First term. Selected experiments from 3X41.

3X51. **Experimental Engineering Research.** Either or both terms. Prerequisites dependent upon field of investigation selected. Professors DAVIS, SAWDON, UPTON and GAGE.

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, but which may be carried on in any department of engineering under the general supervision of this department. The work done may be reported upon in a thesis.

TOPICS SUGGESTED FOR ADVANCED WORK

Mechanical Laboratory Practice.
Instrumentation.
Experimental Research along various lines.
Heat Transfer.
Ventilation.
Refrigeration.
Air Conditioning.
Flow of Fluids.
Fuels.
Power Transmission.
Insulating Materials.

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 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 possibilities. The department and college libraries are liberally provided with reference books, periodicals, transactions of engineering societies, reports, and other material relating to this field.

As prerequisite for this graduate work the student should have had the equivalent of the fundamental courses in heat-power engineering that are required of undergraduates in mechanical engineering at Cornell. These courses are described in the Announcement of the College of Engineering. Those lacking the full equivalent of this training may be required to take one or more of these undergraduate courses or to do specially assigned work to make up the deficiency.

The following courses, which are described in the Announcement of the College of Engineering, are open to both undergraduate and graduate students:

3P31, 3P32. *Heat-Power Engineering.* Throughout the year. Three hours a week.

3P41, 3P42. *Heat-Power Engineering.* Throughout the year. Three hours a week.

3P44, 3P45. **Steam Power-Plants.** Throughout the year. Prerequisites, 3D31, 3D32, 3D33, 3P31 and 3P32 and must be accompanied or preceded by 3P41 and 3P42. Professor BARNARD. Two hours a week.

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.

3P46, 3P47. **Computing and Design.** Throughout the year. Must be accompanied by 3P44 and 3P45. Professor BARNARD. Two three-hour periods a week.

The practical solution of problems discussed in 3P44 and 3P45.

3P48. **Air Conditioning.** First term. Prerequisites, 3P31 and 3P32, or 3P33 and 3P34. Professor MACKEY. Two hours a week.

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.

3P49. **Refrigeration.** Second term. Prerequisite, 3P32, or 3P34. Professor ELLENWOOD. Two hours a week.

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.

3P50. **Power Plant Economics; Equipment Selection.** First term. Prerequisite, 3P32, or 3P34. Professor BARNARD. Two hours a week.

Costs of equipment and plants; energy costs; load curves, station factors; determining characteristics of equipment; selection of best working pressures, temperatures and cycles; 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. By-product power. Other similar topics.

3P51. **Steam Turbines.** Second term. Prerequisites, 3P32 or 3P34. Assistant Professor CLARK. Two hours 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 turbines in engineering practice.

3P52. **Internal Combustion Engines.** First term. Prerequisites, 3D31, 3D32, 3D33, and 3P32 or 3P34. Assistant Professor CLARK. Two hours a week.

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.

3P53. **Steam Boilers and Related Apparatus.** Second term. Prerequisites, 3D31, 3D32, 3D33, and 3P32 or 3P34. Professor BARNARD. Two hours a week.

Fuels, combustion, combustion apparatus; furnaces and boiler types, proportions, materials, design of details; superheaters, economizers, air heaters; accessories; equipment, arrangement and operation of steam generating plants.

3P55. **Graphical Computations and Representations.** First term. Prerequisites, 3D31, 3D32, 3D33 and 3P32 or 3P34. Professor MACKEY. Two hours a week.

Slide rules; construction of net work charts and alignment charts for the solution of equations; and derivation of empirical equations from experimental curve.

3P56. **Advanced Heat-Power Engineering and Research.** Prerequisites dependent upon the work to be done. Professors BARNARD, ELLENWOOD and others. Hours and work to meet the individual needs of each student.

3P57, 3P58. **Heat Engineering.** Throughout the year. Prerequisite, 3P32. Must be accompanied or preceded by 3P41 and 3P42. Professor MACKEY. Two lectures and two computation periods a week.

Properties of mixtures, dimensional analysis, fluid flow, heat transmission, selection of fans and pumps and refrigeration; applications to problems in air conditioning.

The following group offerings for seniors may be used as minors by graduate students: **Option A**—Power-Plant Engineering: 3P44, 3P45, 3P46, 3P47, 3P50.

Option B—Heat Engineering: 3P57, 3P58, 3P49.

TOPICS SUGGESTED FOR 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.
Power and Heating Projects.

HIGHWAY ENGINEERING

Professor W. L. CONWELL.

The laboratories for the examination of non-bituminous and bituminous materials and their utilization, soils, subgrade stabilization problems, etc., are located in the School of Civil Engineering. The other laboratories of the School of Civil Engineering, equipped for examining the properties of engineering materials, and the Ceramic Laboratory of the Department of Geology are also available for graduate work in Highway Engineering.

In addition to the scheduled courses for the graduate student, there is much graduate work of an independent character which requires investigation by the student and frequent conferences with staff members. Occasional field trips are also made.

Note: For courses in design of highway structures such as large bridges, see Structural Engineering.

265. *Highway Engineering.* Credit three hours. Either term.

265-A. **Low Cost Roads.** Either term. Credit three hours. Prerequisite, course 265 or its equivalent. Professor CONWELL. Elective for seniors and graduate students.

Study of economic importance of routes and selection of farm to market roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage and drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low cost roads. Design, construction and maintenance of road mixes, plant mixes, etc.

266. **Highway Laboratory.** Either term. Credit three hours. Prerequisite, Course 265 or its equivalent; may be taken concurrently with Course 265. Professor CONWELL.

Examination of the properties and use of non-bituminous and bituminous materials, soils, bituminous mixtures; also problems in subgrade stabilization.

266-A. **Advanced Highway Laboratory.** Either term. Credit three hours. Prerequisites, Courses 265 and 266. Professor CONWELL. Hours to be arranged.

Special investigations of materials and their use; special problems in design of paving mixtures and their properties; research in subgrade soils and subgrade stabilization, etc.

267. **Advanced Highway Engineering.** Second term. Credit three hours. Prerequisite, Course 265 or its equivalent. Professor CONWELL. This course is conducted as a seminar, meeting once a week.

Students are assigned topics in the field of Highway Engineering. Reports are written on the assigned topics; the student is required to speak at the seminar on the assignment.

268. **Modern Highway Planning and Design.** Second term. Credit three hours. Prerequisite, Course 265 or its equivalent. Professors CLARKE and CONWELL. Elective for seniors and graduate students.

Study of geographical, political, and economic divisions of communities with particular reference to highway transportation requirements; analysis of regional plans chiefly concerning the classification of roads and the selection of routes to be abandoned or improved, based upon their economic justification. Design of regional systems of highways, freeways, and parkways, including the consideration of the economic, safety, and aesthetic aspects. Traffic studies, legislation, financing, and zoning. Design of intersections and grade separations. Problems and reports required.

291. (g) **Design in Highway Engineering.** Either term. Credit three or more hours. Prerequisites, Courses 265, 270, 271, and 280. Professor CONWELL. Conferences to be arranged.

Economic selection of routes, location, design of highways and highway structures, etc.

297. (g) **Research in Highway Engineering.** Either term. Credit three or more hours. Prerequisites, Courses 265 and 266. Professor CONWELL. Hours to be arranged.

Traffic investigations and analyses, economics of highway engineering including contracting, etc.; laboratory investigations of soils, subgrade stabilization, highway materials and their use, etc.

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 selected from the subjoined list, 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 Master's or Doctor's degree 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 (including laboratory), 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.

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. The tendency is to underestimate the time required for preliminary thesis work and that necessary for a thorough digestion of results. Consequently the work should be begun, if possible, early in the first term of residence.

240. *Hydraulics.* Either term. Credit four hours.

241. **Advanced Hydraulics.** Second term. Prerequisite, Hydraulics 240 or the equivalent. Professor Schoder. Three hours a week.

Broader theoretical treatment of some of the topics in elementary hydraulics; backwater and variable flow; the hydraulic pump; water hammer and surges; viscous flow; water wheels; centrifugal pumps.

242. **Hydraulic Measurements.** First term. Prerequisite, Hydraulics 240 (including the laboratory) or the equivalent. Professor Schoder. Three two and one half-hour periods a week.

Field and testing laboratory methods of measuring rates of flow, coefficients, slopes, characteristics, etc.; experimental studies on Pitot tubes in pipes; current meters and floats in open channels; ordinary water meters; special losses of head; fire hose and nozzles; Venturi meters; weirs. The determination of efficiency, capacity, and characteristics of hydraulic machinery by tests.

297 c. **Research in Hydraulics,** either theoretical or experimental.

Hydraulic Engineering

Professor F. J. Seery.

For the master's degree with major work in Hydraulic Engineering, the thesis requirement of the Graduate School may 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. The requirement may not be satisfied by the so-called descriptive type of thesis with only rather vague design based on assumed data.

Ordinarily candidates for the Ph.D. degree who elect most of their work in the general fields of hydraulic engineering and hydraulics are required to select their thesis in experimental or theoretical hydraulics. Only when the candidate has an adequate background of practical experience and mature judgment will a doctor's thesis in hydraulic engineering be permitted.

230. *Water Supply.* Either term. Credit three hours.

231. **Hydraulic Construction.** Second term. Credit three hours. Prerequisite, course 230 or the equivalent. Professor Seery. Computing and designing.

Problems in Water Storage including the design of structures associated with stream regulation; preliminary investigations; economics; estimates; design of dams, etc.

232. **Water Power Engineering.** Usually first term. Prerequisite, courses 240 and 230, or the equivalent. Professor Seery. Three hours a week. Given only if a sufficient number elect the course.

Hydraulic problems involved in the planning for and the design of water power developments.

233. **Hydraulic Engineering.** Either term if a sufficient number elect the course. Prerequisite, course 230 or the equivalent. Professor Seery. Three hours a week.

Problems in Water Supply not covered in Course 230; theory of groundwater flow, wells, methods of development, earthen dams, masonry dams, spillways and other appurtenances of dams.

234. **Conservancy and Reclamation Engineering.** Either term. Prerequisite, Courses 230 and 240, or the equivalent. Professor SEERY. Three hours a week. Given only if a sufficient number elect the course.

Flood flow estimates; flood protection; irrigation and drainage.

236. **Hydraulic Power and Pumping Plant.** First term. Prerequisite, course 232. May be taken concurrently with 232. Professor SEERY. Computing and designing. Credit three hours. Given only if a sufficient number elect the course.

Problems relating to power and pumping plants.

291C. **Design in Hydraulic Engineering.**

In Mechanical Engineering

Professor F. G. SWITZER.

The hydraulic laboratory, under the direction of the Department of Experimental Engineering, is available for the investigation of turbine and draft tube problems, centrifugal pump performance, measurement of water, etc.

The libraries of the University have a very complete collection of treatises relating to mechanics, hydraulics, hydro-electric engineering, and to similar subjects. In addition, these libraries contain the more representative engineering periodicals and the transactions of the leading engineering societies of the world.

3M41, 3M42. **Hydraulic Power Plants.** Throughout the year. Prerequisites, 3M21, 3M22a, 3M22b and 3M23, or 3M33. Professor SWITZER. Two lectures a week.

Power Developments, Hydraulic Turbines, Power study, water power legislation and the Federal Power Commission. Interconnection of power plants, hydraulic and thermal.

3M43, 3M44. **Hydraulic Power Plant Problems.** Throughout the year. Must be accompanied by courses 3M41, 3M42. Professor SWITZER. Two computing periods a week.

Problems involving the principles taken up in courses 3M41, 3M42.

3M52. **Special Hydraulic Power Plant Problems.** Either term. Prerequisites, 3M41, 3M42, 3M43 and 3M44. Professor SWITZER.

Topics relating to design, operation, and economics of hydraulic power plants, selected to meet the individual needs of each student.

TOPICS SUGGESTED FOR ADVANCED WORK

Hydraulic Turbines.
Draft Tube Design and Performance.
Centrifugal Pumps.
Economics of Water Power Plants.

INDUSTRIAL ENGINEERING

Professors M. A. LEE and C. I. MILLARD.

The departmental library of literature on Industrial Engineering subjects is available for the use of graduate students. In the micro-motion laboratory 16 mm. motion picture cameras and projectors with the necessary auxiliary apparatus are available for motion and process studies as well as the necessary tools and work places for setting up and studying various operations.

The courses offered include a consideration of the organization, administration and selection and location of equipment for industrial enterprises.

Formal graduate courses are offered and facilities are available for original work in the field of Industrial Engineering.

To take advanced work in this department the student must have had the equivalent of the undergraduate courses 3I31, 3I43, 3I44, and 3A31. Students desiring to take a minor in this field may enroll in any of the following courses for which they have had the necessary prerequisites.

Undergraduate Courses

3I31. *Industrial Organization.* Either term. Two lectures a week.

3I43, 3I44. *Industrial Engineering.* Throughout the year. One lecture and two computing periods a week.

3I46. *Industrial Relations.* First term. Two lectures a week.

3I47. *Cost Accounting.* Second term. One lecture, one recitation, and one computing period a week.

3I48. *Industrial Engineering.* Second term. Two recitations or discussion periods a week.

Graduate Courses

3I52. **Industrial Auditing.** First term. One lecture and one computing period a week.

3I53. **Advanced Industrial Relations.** Second term. Two discussion periods a week.

3I54. **Micro-motion Laboratory.** Either term. Two laboratory periods a week.

TOPICS SUGGESTED FOR ADVANCED WORK.

Micro-motion analysis.
Investigations for motion and process economy.
Practical economic and production investigations in near-by industries.

MACHINE DESIGN AND DRAWING

Professors C. D. ALBERT, F. S. ROGERS, C. E. TOWNSEND, E. F. GARNER, S. F. CLEARY and F. H. BLACK.

Under this head is included advanced work in descriptive geometry, kinematics and dynamics, machine design and design methods, and special design problems and investigational work.

There are eight well-equipped drawing rooms and a very complete collection of Kinematic models. The Department Library, the Library of the School of Mechanical Engineering, and the University Library have a very complete collection of books on drawing, kinematics, machine design and construction, mechanical technology, structural design, and other books on related subjects.

120. *Descriptive Geometry.* First term. Credit three hours.

121. *Mechanical Drafting.* Second term. Credit three hours.

3D21. *Kinematics, Recitations.* First term. Credit two hours.

3D23. *Kinematic Drawing.* First term. Credit two hours.

3D24. *Kinematics, Recitations and Drawing.* Second term. Credit three hours.

3D25. *Kinematics, Recitations.* First term. Credit three hours.

3D26. *Kinematic Drawing.* First term. Credit two hours.

3D31. *Machine Design, Recitations.* First term. Credit two hours.

3D32. *Machine Design, Recitations.* Second term. Credit two hours.

3D33. *Machine Design, Drawing.* Second term. Credit three hours.

3D34. *Machine Design, Recitations.* First term. Credit two hours.

3D35. *Machine Design, Drawing.* Either term. Credit two hours.

3D36. *Machine Design, Drawing.* Second term. Credit one hour.

3D51. *Mechanical Technology.* Either term. Credit two hours.

3D52. **Advanced Kinematics and Kinetics.** Second term. Prerequisites, 3D21, 3D23, and 3D24 or 3D25 and 3D26. Two lecture and discussion periods and one laboratory period a week. Professor ROGERS.

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.

3D53. **Materials Handling.** Second term. Prerequisites, 3D21, 3D23 and 3D24, or 3D25 and 3D26. Two lectures a week.

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.

3D54. **Dynamics and Vibrations of Machinery.** First term. Credit three hours. Prerequisite courses 3D32 or 3D34 and 3M32. Assistant Professor BLACK. Two lecture and discussion periods and one laboratory period a week.

Balancing of engines. Flywheel design. Transverse and torsional vibrations and critical speeds. Control of vibration and noise in machinery.

3D55. **Advanced Machine Design.** Second term. Credit three hours. Prerequisite, courses 3D32 or 3D34 and 3M32. Assistant Professor BLACK. Two lecture and discussion periods and one laboratory period a week.

Advanced problems in stress analysis of machine parts and structures.

TOPICS SUGGESTED FOR ADVANCED WORK

Descriptive Geometry.
Kinematics and Dynamics.
Special Design Problems.
Vibrations and Critical Speeds.
Investigational Work.

MANAGEMENT ENGINEERING

In Civil Engineering

Professors F. A. BARNES, J. E. PERRY, CARL CRANDALL and R. Y. THATCHER.

The study of methods of construction is neglected in some colleges and the graduate student who is not familiar with them may well take course 264. Books and periodicals on construction methods for various types of work, on management of construction work and laws and practices governing it are available in the Library of the School of Civil Engineering.

264. *Engineering Construction.* Either term. Three hours a week.
290. *Engineering Law.* Either term. Three hours a week.
293. *Engineering Management.* Either term. Three hours a week.

290-A. **Advanced Engineering Law.** Second term. Credit three hours. Prerequisite, Course 290.

An extension of various legal topics treated in Course 290, with particular attention to construction contracts; also a study of laws relating to insurance, suretyship, conditional sales, bailments, trusteeship and taxation; reading of cases illustrating the application of legal rules. Professor BARNES and Assistant Professor THATCHER.

293-B. **Cost Accounting.** Second term. Credit three hours. Required of seniors in Administrative Engineering Option and the B. S. in A. E. Course, 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.** Second term. Prerequisite, courses 264 and 290. Three hours a week. May be taken concurrently with 290.

Valuations and appraisals of properties for rate making, purchase or sale, condemnation, merger, assessment, investment or management purposes, with special attention to rulings and decisions of the courts in rate and valuation cases.

297 (h). **Research in Management Engineering.** Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals. Professor BARNES.

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 investigation and researches as the results find their way into print.

The laboratory equipment is selected to make all ordinary and many special tests and investigations of the materials of construction. 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.

225. *Materials of Construction.* Either term. Credit three hours.
226. *Materials Laboratory.* Either term. Credit three hours.
297b. **Engineering Research in Materials.**

In Mechanical Engineering

Professors A. C. DAVIS, J. R. MOYNIHAN, J. O. JEFFREY and G. B. UPTON.

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.

The Materials Testing Laboratory. This laboratory is equipped for tension and compression tests, a Riehlé 100,000-lb. 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. There are an Olsen torsion machine of 200,000 inch-pounds capacity, two Upton-Lewis fatigue testing machines, and an Amsler-Charpy-Izod impact testing machine. The small equipment includes hardness testing machines, extensometers, a cathetometer, gas and electric furnaces, tempering baths, 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.

3X21, 3X22. *Metallurgy and Properties of Materials.* Throughout the year. Three lectures a week. Assistant Professor JEFFREY.

3X31. *Materials Testing Laboratory.* First term. One laboratory period a Three lectures a week. Assistant Professor JEFFREY.

3X52. **Applied Metallography.** First term. Professor UPTON. Two lectures a week.

Theories and technique of metallography critically reviewed; applications to practice of control of properties of metals. This course will be modified to suit especially the interests of graduate students taking it.

TOPICS SUGGESTED FOR ADVANCED WORK

Properties of Engineering Materials.
Thermal Qualities of Quenching Liquids.
Control of Properties of Engineering Materials.

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. The shops are also available for use in the building of equipment for research in any department. Arrangements for the construction of new equipment should be made in advance with the head of the department.

102. *Wood Work.* Either term. Three hours a week.
103. *Introductory Engineering Laboratory.* Either term. Three hours a week.
3S21. *Pattern-making.* Either term. Three hours a week.
3S22. *Foundry.* Either term. Three hours a week.
3S31. *Machine Shop.* Either term. Nine hours a week.
3S32. *Machine Shop.* Either term. Six hours a week.

TOPICS SUGGESTED FOR ADVANCED WORK

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, 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 and German, and an ability to read technical works in these languages is extremely valuable.

220. *Mechanics of Engineering.* Either term. Credit five hours.
220A. *Mechanics Laboratory.* First term. Credit two hours.
221. *Mechanics of Materials.* Second term. Credit four hours.
221A. *Mechanics Laboratory.* Second term. Credit one hour.

222. **Advanced Mechanics.** First term. Prerequisite, Courses 220 and 221. Professor GEORGE or RETTGER. Three hours a week.

Advanced mechanics of materials; induced and combined stresses; Mohr's diagram; a survey of experimental methods for localized stresses; special cases of flexure; Castigliano's Theorem of Least Work, with applications.

223. *Engineering Problems.* Either term. Credit two hours. Prerequisite, Courses 220, 221 and 240. Two computing periods a week.

224-A. **Engineering Mathematics.** First term. Credit three hours. Prerequisite, Mathematics 5b. Professor RETTGER.

An elementary course in ordinary Differential Equations with applications to Engineering problems. The purpose of this course is to lay the foundation for the more advanced courses in Engineering Mathematics. Algebra, Trigonometry and the Calculus are dealt with in so far as this is necessary for a clear understanding of the treatment of Differential Equations.

224-B. **Advanced Engineering Mathematics.** Second term. Credit three hours. Prerequisite, Course 224-A. Professor RETTGER.

This course is an introduction to the mathematics used in the solution of advanced engineering problems. Partial differentiation. Fourier Series. Line integrals. Vector notation. Conformal representation.

224-C. **Advanced Differential Equations.** First term. Credit three hours. Prerequisites, Courses 224-A and 224-B or their equivalents. Professor RETTGER.

A systematic study of Differential Equations. Partial differential equations and their solutions are emphasized.

224-D. **Special Mathematical Topics.** Second term. Credit three hours. Prerequisites, Courses 224-A and 224-B. Professor RETTGER.

The content of this course depends largely upon the needs and the interests of those enrolled. Generalized Coordinates, Vector Analysis, and the Calculus of Variation are three subjects to be considered.

228. **Theory of Elasticity.** Second term. Prerequisite, 224-A. Professor RETTGER. Three hours a week.

Theory 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 applications to solutions of Engineering problems in elasticity.

228-A. **Engineering Physics of Metals.** Elective. Primarily for graduate students. Second term. Credit 3 hours. An introduction to the physical basis of matter in relation to its elastic and plastic behaviour. Topics for discussion include: Atomic basis of generalized Hooke's Law, atomic cohesive forces and potential troughs, the yield value, primary bonds, dipole and Van der Waal's forces, influence of temperature on elastic properties, thermoelastic basis of internal friction, experimental and theoretical strength of crystals, distortion of the lattice, Smekal's criticism of Born's lattice theory of metals, evidence of submicroscopic structure, elementary concepts of the cooperative phenomena in metals. Dr. CUYKENDALL.

229-A. **Elastic Foundations and Thin Structural Shells.** Dr. HAWKINS. Three hours a week. First term.

Study of the properties of elastic foundations and the application of the elastic foundation theory to the analysis of large diameter, low head tanks, hemispherical domes, hemispherical headers on large pipes, and thin shell pipes under flexure.

297. **Research in the field of Advanced Mechanics.**

In Mechanical Engineering

Professors F. G. SWITZER, W. R. CORNELL and H. C. PERKINS.

In addition to the regular laboratory equipment, there are also available facilities for the study of balancing problems, and for photo-elastic investigations. The equipment includes a Bausch and Lomb polariscope with five-inch diameter beam; bakelite; polishing tables; annealing oven; a 2,000-lb. Olsen Universal hydraulic testing machine arranged for tension, compression and transverse loading; mercury arc for monochromatic light source.

3M21. *Theoretical and Applied Mechanics.* Either term. Five hours a week.

3M22a. *Strength of Materials.* Five hours a week for nine weeks of second term.

3M22b. *Strength of Materials, continued.* Five hours a week for six weeks of second term. Repeated in first term, two hours a week.

3M23. *Hydraulics.* Five hours a week for six weeks of second term.

3M32. *Applied Mathematics.* First and second term. Three hours a week.

3M33. *Fluid Mechanics.* First term, three recitations and one lecture a week.

3M55. **Photoelasticity.** First term. Prerequisite, 3M22b. Professor SWITZER. Two lectures, or laboratory periods and report a week.

The optics of photoelasticity, the stress-optical effect, plane and circularly polarized light, white and monochromatic. Elements of elasticity required for the analysis of observations and the determination of principal stresses.

TOPICS SUGGESTED FOR ADVANCED WORK

Vibration problems.
Theory of Elasticity.
Photo-elastic stress analysis.

RAILROAD ENGINEERING

Professors F. A. BARNES, W. L. CONWELL, J. E. PERRY, CARL CRANDALL and R. Y. THATCHER.

The Library of the School of Civil Engineering contains an excellent collection of books, periodicals and publications of railway or other technical societies dealing with the location, construction, maintenance and operation of railroads.

Books and other publications on transportation are available either in this collection or in the University Library. Maps and profiles are available for studies of the economics of location, and special plans provide for studies of signal layouts, interlocking and yard and terminal design. Instrumental equipment is available for securing data for special problems in relocation and for designs of structures.

260-A. *Location Surveying.* See Course 213. Credit one hour. One week during summer vacation.

260-B. *Route Surveying and Drawing.* Second term. Credit three hours.

261. **Railroad Maintenance of Way.** First term. Prerequisite, courses 260-A and 260-B. Professor PERRY. Three hours a week.

Drainage, track materials, design, track-laying and maintenance; separation of grades, and improvement in grades and alinement.

262. **Railroad Operation and Management.** Second term. Prerequisite, courses 260-A and 260-B. Professor BARNES. Three hours a week.

Railroad history and development. Principal departments and their interrelations, i. e., organization. Freight and passenger traffic, freight houses and yards, shops, car service, signaling, interlocking and train rules.

263. **Route Location.** Second term. Prerequisite, courses 260-A and 260-B. Professor BARNES. Three hours a week.

Transportation history and development. Economic principles governing the location of new railroads and highways and revision of existing ones to produce the most efficient transportation agencies.

269. **Transportation.** Second term. Professors BARNES and CONWELL.

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.

291e. **Railroad Engineering Design.**

Either term. The problems are those encountered in the location, construction and maintenance of railroads. The field is so broad that the interest of the student is given consideration in assigning problems. Professor BARNES and Assistant Professor PERRY.

297e. **Railroad Engineering Research.**

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.

In addition to the above courses, the student may take courses in other departments if time permits; such as courses in transportation in the College of Arts and Sciences, or in applications of electricity in transportation in the School of Electrical Engineering.

Note: For the larger railway structures see STRUCTURAL ENGINEERING.

SANITARY ENGINEERING

Professors C. L. WALKER, W. E. STANLEY and H. N. OGDEN.

Courses offered to graduate students may be divided into two classes: those fundamental studies in Chemistry, Biology, and Bacteriology, which the undergraduate student in Civil Engineering has not had an opportunity of pursuing; and those dealing with the design, construction and operation of sewage treatment and water purification plants. The sewage treatment and water purification plants in the City of Ithaca and in neighboring communities offer opportunity for experimental study.

A well-equipped sanitary laboratory established in the School of Civil Engineering provides an opportunity for students to acquire laboratory technique in

water and sewage analyses, and also a practical training in interpretation. The Kuichling Library for Hydraulic and Sanitary Engineering, and the main library of the School are well provided with the literature dealing with Sanitary Engineering topics.

250. *Sanitary Biology.* Second term. Credit three hours.

251. *Sanitary Biology.* First term. Credit two hours.

252. *Municipal Sanitation.* Either term. Credit four hours.

253. **Purification and Control of Water Supplies.** Second term. Credit three hours. Prerequisite, Water Supply, Course 230. Professors WALKER and STANLEY. Two recitations and one laboratory period a week.

254. **Sewerage Works.** First term. Credit three hours. Prerequisite, Course 252. Professors WALKER and STANLEY. Two recitations and one laboratory period a week.

255. **Treatment of Wastes.** Second term. Prerequisite, Course 252. Professor WALKER. Three hours a week.

256. **Municipal Engineering.** First term. Credit three hours.

256A. **Public Health Engineering.** Second term. Credit three hours.

257. **Purification of Water.** Either term. Prerequisite, Course 253. Professor STANLEY. Three hours a week.

258. **Conference on Present Methods of Sewage Disposal.** Either term. Prerequisite, Course 254. Professor STANLEY. Three hours a week.

259. **Laboratory Course.** Second term. Prerequisite, Courses 253 and 254. Professor WALKER.

291d. **Design in Sanitary Engineering.**

297d. **Research in Sanitary Engineering.**

SOIL MECHANICS

Professors 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. There is also a shop for use in the building of new equipment.

As a prerequisite for work in this field, students should have had Physics of Soil Phenomena (Physics 431) or its equivalent.

287. *Soil Mechanics.* Either term. Credit three hours. Two lectures and one laboratory period a week.

228. **Theory of Elasticity.**—See page 72.

287-A. **Applied Soil Mechanics.** Second term. Credit three hours. Prerequisite course 287 or its equivalent. Advanced application of soil mechanics, based on the principles and physical studies of course 287. The plastic flow theory; the consolidation theory; stability of earth slopes; flow of water through earth structures; theories of earth pressure on retaining walls, caissons and tunnels. Review of modern soil mechanics research.

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.

The department is equipped with a Beggs Deformeter for the Mechanical Analysis of Structures. The facilities of the testing laboratories are available to graduate students.

To qualify for graduate work in structural engineering a knowledge of theoretical mechanics, strength of materials, engineering construction, and elementary courses in stresses and design in timber, steel, and concrete are required.

270. *Bridge Stresses.* Either term. Credit four hours.

271. *Structural Design.* Either term. Credit three hours.

272. **Higher Structures.** Either term. Prerequisite, courses 270 and 271, or their equivalents. Professor URQUHART or O'ROURKE. Three hours a week. Required of all graduate students whose major or minor is in Structural Engineering.

Statically indeterminate structures; continuous beams and trusses; arches and rigid frames.

273. **Steel Buildings.** First term. Credit three hours. Prerequisite, courses 220, 221, and 271, or their equivalents. Assistant Professor BURROWS. Computing and Drawing, six hours a week.

Design of steel framework for buildings of the prevailing type used in power house or shop construction; provision is made for an electric crane moving the full length of the building.

274. **Bridge Design.** Second term. Credit three hours. Prerequisite, course 271 or the equivalent. Assistant Professor BURROWS. Computing and Drawing, six hours a week.

Computations and Drawings for the complete design of a railway bridge of six or seven panels, or a heavy highway bridge.

275. **Investigation of Existing Bridges.** Second term. Credit three hours. Prerequisite, course 271 or the equivalent. Assistant Professor BURROWS. Computing, six hours a week.

Inspection of an existing bridge for the determination of the sizes and condition of plates and shapes, followed by computations to determine either the unit stresses under a specified load or the safe load according to standard specifications.

280. *Concrete Construction.* Either term. Credit three hours.

281. *Foundations.* Either term. Credit three hours.

282. **Reinforced Concrete Building Design.** First term. Credit three hours. Prerequisite, course 280, or the equivalent. Professors URQUHART and O'ROURKE. Computing and drawing, six hours a week.

Complete design and detail drawings for a reinforced concrete flat-slab building including stairway, elevator shafts, penthouses, etc.; investigation of other types of floor systems.

283. **Fixed Arches.** First term. Credit three hours. Prerequisite, courses 270, 271, and 280. Professor URQUHART and Professor O'ROURKE.

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.

284. **Concrete Highway Bridges.** Second term. Credit three hours. Prerequisite, course 280, or the equivalent. Professors URQUHART and O'ROURKE. Computing and drawing, five hours a week.

Design of short span bridges; a slab bridge; a beam bridge; a through-girder bridge; abutments; complete detail drawing of one bridge.

285. **Reinforced Concrete Design.** Either term. Credit three hours. Prerequisite, course 280, or the equivalent. Professors URQUHART and O'ROURKE. Computing, six hours a week.

Theory and design of retaining walls, multiple column footings, bins, tanks, swimming pools, covered reservoirs.

286. **Building Construction.** First term. Professor URQUHART and non-resident lecturers. Three hours a week. Given in alternate years.

One lecture a week by a non-resident engineer or architect who is well known in the field of building construction; one lecture by a member of the University staff; followed by a quiz on the lectures.

291f. **Design in Structural Engineering.**

297f. **Research in Structural Engineering.**

TOPOGRAPHIC AND GEODETIC ENGINEERING

Professors 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.

For courses in Geodetic Astronomy and Geodesy see pages 68 and 70.

110. *Elementary Surveying.* Either term. Credit three hours.

182. *Elements of Field Astronomy.* Either term. Credit two hours. (Given in Department of Astronomy.)

211. *Advanced Surveying.* First term. Credit three hours.

213. *Summer Survey: Topographic, Hydrographic,* and *Geodetic Survey: Camp.* Five weeks during last of summer preceding first term. Credit four hours.

214. *Mapping.* Second term. Credit two hours.

215. *Problems in Adjustment of Observations.* Second term. Credit one hour.

216. **Least Squares: Adjustment of Observations.** Second term. Prerequisite, Calculus and Physics. Professor UNDERWOOD. Two hours a week.

Applications are made to problems in physics, astronomy, mechanics, hydraulics, surveying, etc., with some attention given to the derivation of empirical formulae.

217. **Advanced Topographic Surveying.** Second term. Prerequisite, course 213. Professor UNDERWOOD. Two hours a week.

Economics of surveying methods; surveys for special purposes: storage and distribution of water for irrigation, earthwork on a large scale, lines of communication, etc.; photographic surveying.

219. **Photographic and Aerial Surveying.** Second term. Prerequisite, Advanced Surveying, course 211. Professor UNDERWOOD. Three hours a week.

The principles of photographic surveying; surveys with camera stations on the ground; stereoscopic methods and apparatus; aerial surveys.

297i. **Engineering Research.** Either term.

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NOTE: Pages numbered below 145 apply primarily to undergraduate work, and pages above that relate to graduate work.