UNIVERSITY OF MICHIGAN
UNIVERSITY BULLETIN—NEW SERIES
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COLLEGES OF ENGINEERING AND ARCHITECTURE

GENERAL ANNOUNCEMENT
1921-1922

ANN ARBOR
PUBLISHED BY THE UNIVERSITY
1921

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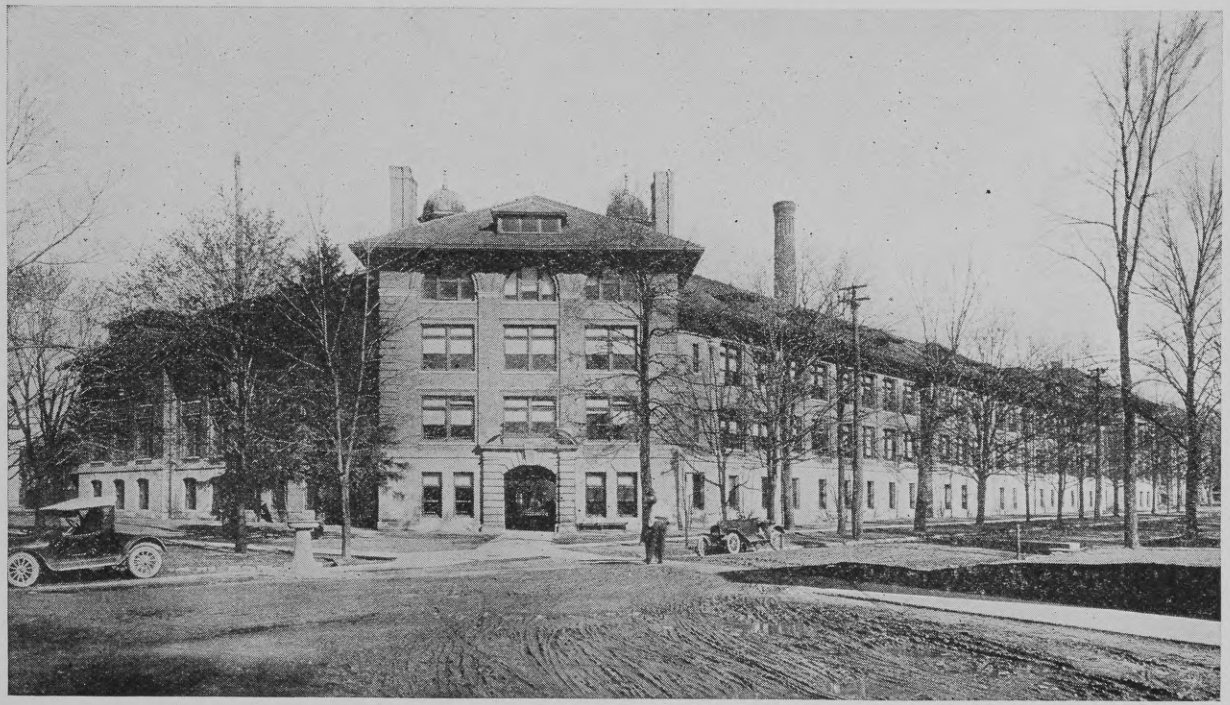

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UNIVERSITY OF MICHIGAN

COLLEGES OF ENGINEERING AND ARCHITECTURE

GENERAL ANNOUNCEMENT

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1921

Announcements

	1921	
June	13	Semester Examinations Begin.
June	30	COMMENCEMENT.
July 5 to Aug.	26	Summer Session.
July 5 to July	7	*Examinations for Admission.*
September	20	Applicants for Admission present themselves.
Sept. 19 to Sept.	23	*Examinations for Admission.*
September 22, 23,	24	Examinations for the Removal of Conditions.
September 24,	26	Classification of All Students.
September	27	FIRST SEMESTER BEGINS.
November	24	Thanksgiving Day.
December	16	(Evening) Holiday Vacation Begins.
	1922	
January	3	(Morning) Exercises Resumed.
January 6, 7, 13,	14	Examinations for the Removal of Conditions.
January	30	Semester Examinations Begin.
February	10	(Evening) First Semester Closes.
February	9-11	*Examinations for Admission.*
February	13	SECOND SEMESTER BEGINS.
February	22	Washington's Birthday.
April	7	(Evening) Recess Begins, Ending April 17 (Evening).
April 21, 22, 28,	29	Examinations for the Removal of Conditions.
May	30	Holiday, Memorial Day.
June	5	Semester Examinations Begin.
June	19	COMMENCEMENT.
June	26	Summer Session Begins.
June	27-29	*Examinations for Admission.*
August	19	Summer Session Closes.
September	18-22	*Examinations for Admission.*
September	26	FIRST SEMESTER BEGINS.

1921

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Colleges of Engineering and Architecture

GENERAL INFORMATION

1. The University of Michigan is a part of the educational system of the State, and derives from the State the greater part of its revenue. The University comprises the Colleges of Literature, Science, and the Arts, of Engineering, of Architecture, of Pharmacy, of Dental Surgery, the Medical School, the Law School, the Homœopathic Medical School, and the Graduate School, each of which publishes a separate annual announcement. The various Faculties include about six hundred officers of instruction, besides nearly one hundred assistants, some of whom participate in the work of teaching. Over 9,800 students, representing all the States and Territories and many foreign countries, are in attendance.

In the legislative act under which the University was organized in 1837, provision was made for instruction in engineering and architecture. There are few older technical schools in the United States. Work was begun in this subject in 1853, and the first degrees were conferred in 1860. The engineering courses were included in the College of Literature, Science, and the Arts, until the close of the collegiate year 1894-95. At that time the College of Engineering was established by the Board of Regents as a separate Department of the University.

Instruction in Architecture was organized as a subdepartment of the College of Engineering in 1906. In

1913 the College of Architecture was given control of its courses of study and, in general, charged with the administration of its affairs.

There are enrolled at present in the College of Engineering 2,029 students, pursuing work in different engineering lines. In the College of Architecture there are one hundred and eighty-three students.

The aim of these colleges is to lay a foundation of sound theory, sufficiently broad and deep to enable their graduates to enter understandingly on a further investigation of the several specialties of the engineering and architectural profession; and at the same time to impart such a knowledge of the usual professional practice as shall make the students useful upon graduation in any subordinate position to which they may be called. While the adaptation of theory to practice can be thoroughly learned only by experience, there are many matters in which the routine work of an engineering field party, office, or drafting room can be carried out, on a greater or less scale, in a training school. *The technical branches are under the direct charge of those who have had professional experience as well as a full scientific training.* The instruction fits the students, as far as possible, for the requirements of active practice. The Department of Engineering Research was established in 1920. The general function and purpose of this department is to coöperate in every proper manner with the industries of the State.

THE ACADEMIC YEAR

2. The academic year extends from September 27, 1921, to June 19, 1922. The Summer Session, between the student's first and second, second and third, or third and fourth years, extends eight weeks, from Monday fol-

lowing Commencement, July 5, to August 26, 1921, and from June 26 to August 19, 1922.

Copies of the University Catalogue describing the different Colleges and Schools, and containing a catalogue of all the students, will be mailed by the Secretary of the University, on request.

SUGGESTIONS AND DIRECTIONS

3. New students should plan to reach Ann Arbor about September 20, 1921, for the first semester, or about February 9, 1922, for the second semester, in order that such preliminaries as finding a room and boarding place may be settled before the opening of the regular session.

Students on arriving in Ann Arbor can obtain information in regard to rooms and board by calling at the Students' Christian Association and the Michigan Union, whose secretaries are actively interested in assisting newcomers to find rooms and boarding places and conduct free employment bureaus for the benefit of students.

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

ADMISSION

4. The requirements for admission are the same for all students in Engineering and Architecture.

Applicants must be at least sixteen years of age, and must present satisfactory evidence of good moral character. The record of work done in the preparatory school must be presented on a form to be obtained from the Secretary of the Colleges.

Students may be admitted on certificate, by examination, on credits from another college, or by a combination of these. They may also be admitted as special students.

ADMISSION REQUIREMENTS

5. The requirements for admission are stated in terms of units, a unit being defined as a course covering an academic year that shall include in the aggregate not less than the equivalent of one hundred and twenty sixty-minute hours of classroom work, two hours of manual training or laboratory work being equivalent to one hour of classroom work.

Group I. Absolute Requirements—10 Units

English ..... 3 units
Grammar, Composition, Classics, History of English Literature.
Mathematics ..... 3 units
Algebra, through quadratics; Geometry, Plane, Solid, Spherical.
Physics ..... 1 unit
History ..... 1 unit
Greek, Latin, German, French, Spanish—One of these..... 2 units

Group II. Alternative Requirements—1 1-2 or 2 Units

Chemistry ..... 1 unit
Trigonometry, Plane ..... ½ unit
Greek, Latin, German, or French..... 1 or 2 units
Manual Training ..... 1 unit

Group III. Optional Requirements—3 1-2 or 3 Units

The remaining 3 or 3½ units may be presented in any subjects for which credit toward graduation is given by the accredited school and which are taught in a manner approved by the University; but no more than three of the fifteen units required for admission will be accepted in vocational subjects and no more than two units in any one of them.

The most favorable combination of courses to offer for admission to the College of Architecture is the following: English, 3 units; Mathematics (including plane trigonometry), 3½; Physics, 1; Chemistry, 1; History, 1 or more; Modern Languages, 2 or more; Freehand Drawing, 1 or more; Manual Training, 1.

Chemistry and Plane Trigonometry are placed in the Alternative Group, with German, French, Greek, Latin, and Manual Training, so that all high schools with three or more teachers may offer full preparation for the Colleges of Engineering and Architecture even if they cannot teach Chemistry and Trigonometry. A student who presents the full requirements for admission without Chemistry or Trigonometry must take Chemistry 1 and 1*a* and Mathematics 1*a* in his first year, receiving credit for the same as cultural studies. These courses are offered in the Summer Session to accommodate

those students who wish instruction in them before entering one of the colleges.

Some modifications of the language requirement may be allowed in the case of students whose native tongue is other than English. These cases will be considered individually.

Under English are included Grammar, Composition, reading of English Classics, and History of English Literature. The History of English Literature may form part of the work of either the third or fourth year. Four units in English should always bs presented whenever it is possible to do so.

Biology is defined at one-half year of Botany and one-half year of Zoölogy: hence Biology cannot be accepted from an applicant who offers at the same time a unit in either, or both, of those subjects.

VOCATIONAL UNITS

6. In Drawing and Manual Training, a unit means the equivalent of at least 360 periods, not less than forty-five minutes each.

All applicants must send courses of study or letters from instructors describing the work done when credit is asked in the vocational subjects,—Manual Training, Drawing, Agriculture, and Commercial Branches. In general, the standards set up by the Commission on Accredited Schools and Colleges of the North Central Association of Colleges and Secondary Schools will be recognized in adjusting high school credits in vocational studies.

The Manual Training accepted in the Alternative Group must be of such a character as to excuse the students from Shops 1 and 2 (Wood Shop and Forge Shop, § 209) in the University.

Drawing.—1. *Free-hand Drawing.*—One-half unit allowed. The student should show that he can represent correctly in outline and in light and shade, geometric and simple natural or decorative form. Accuracy of proportion and perspective are essential. The pencil, charcoal, or brush may be used.

2. *Mechanical Drawing.*—One-half unit allowed. This work should cover:

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

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

(c) Exercises in line shading, shade lining, and cross hatching, together with a reasonable skill in lettering.

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

Students who intend to study architecture are advised to offer one unit in drawing. This may consist of work in free-hand drawing, mechanical drawing, design, or a combination of two of these.

Manual Training.—Students may present one or two units. The work accepted may be:

1. Bench work, wood turning, cabinet making, and pattern making in the wood shop.

2. Forging, chipping and filing, sheet-metal construction, tool making, turning and spinning in metals.

Commercial Branches.—Not more than a total of two units will be accepted in these subjects, to be selected from the following list:

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

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

Commercial Geography.—One-half unit. The amount and character of work accepted in this subject is indicated by the scope of the best text-books in the subject.

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

Elementary Economics.—One-half unit. The applicant should have a knowledge of the leading facts and principles in Economics, including such subjects as division of labor, the factors of production, the law of diminishing returns, demand and supply, value and

prices, and international trade. One of the better elementary texts in use will serve as a basis. This should be supplemented with discussions and problems.

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

ADMISSION ON CERTIFICATE

7. Applicants presenting graduate certificates from any of the schools officially approved by the Committee on Diploma Schools will be admitted without examination to the Colleges of Engineering and Architecture, if they are recommended by the principal of the school in the units required for admission.

The approved schools of the University of Michigan do not necessarily include those accredited to or affiliated with other universities or colleges.

It is recommended that graduates from preparatory schools enter at once. If they do not, they must present evidence that they are, at the time of admission, prepared to do the work of the Colleges. They must show satisfactory preparation especially in mathematics, in English, and in the modern language presented for admission. This preparation may be shown by certificates of work done since graduation, by examinations at Ann Arbor, September 19 to 23, 1921, or by attendance at the Summer Session, July 5 to August 26, 1921, with a satisfactory record in eight hours of work, a part of which must be mathematics.

College credit may be given for studies presented in excess of the fifteen units required for admission, if these subjects are deemed equivalent to similar courses in the University. Such credit will be adjusted after consulta-

tion with the professor in charge of the department concerned.

Students, who for any reason have failed to secure certificate of graduation from an approved school and his principal's recommendation, will be required to pass the regular examinations for entrance in all subjects.

Those desiring to enter on certificate should present their credentials at Room 255, or for Architecture at Room 209, Engineering Building, not later than September 20, if desiring to enter the first semester, or February 9, if desiring to enter the second semester. It is better to mail the credentials, as long before these dates as practicable, to the Assistant Dean, or, for Architecture, to Professor E. Lorch. They will be examined, placed on file, and the applicant will be informed whether they satisfy the requirements or not. Certificates from schools other than those officially approved by the University do not excuse an applicant from the admission examinations.

ADMISSION BY EXAMINATION

8. Before entering upon the examination, each applicant must present his credentials to the Assistant Dean of the College of Engineering at his office, Room 255, or, for Architecture, to Professor Lorch, Room 209, in the Engineering Building.

Specimen entrance examination questions are not furnished.

Fifteen units are required for admission. Eleven and one-half or twelve units are prescribed. The other three and one-half or three units may be presented in the subjects mentioned in § 5. In general, applicants will not be admitted with deficiencies in more than one and one-half of the prescribed units.

An outline of the preparatory work which a student should cover before presenting himself for examination in any one of these subjects is given at length in the University Catalogue. This will be mailed upon application to the Secretary of the University.

EXAMINATIONS FOR ADMISSION

9. All examinations are held at the University. The principal examinations for admission to the Colleges of Engineering and Architecture will be held July 6-8, 1921, and September 19-23, 1921. Another opportunity is afforded on February 9-11, 1922. Applicants will not be examined at any other time except on payment of a special fee of *five dollars* for examination in one or more subjects.

It is necessary for all applicants for admission on examination to present their credentials a day before the entrance examination to the Assistant Dean of the College, at his office, Room 255, or, for Architecture, to Professor Lorch, Room 209, in the Engineering Building, between the hours of 9 and 4, and receive from him papers admitting to the examinations.

An applicant who fails in some part of the examination may, at the discretion of the Faculty, be admitted conditionally; but any condition so imposed must be removed within one year, and no student who has an admission condition outstanding at the beginning of his second year of residence will be allowed to enter his classes until such condition is removed, unless for valid reason an extension of time is granted for its removal.

SCHEDULE OF EXAMINATIONS FOR ADMISSION, SEPTEMBER, 1921

	Monday Sept. 19	Tuesday Sept. 20	Wednesday Sept. 21	Thursday Sept. 22	Friday Sept. 23
8-11		Geometry	Algebra	History	English Composition
1-3:30	English Literature	Physics	German Greek	French Spanish	Botany
3:30-6	Zoology	Physiography Geology	Latin Physiology	Trigonometry Introductory Science	Chemistry Astronomy

SCHEDULE OF EXAMINATIONS FOR ADMISSION, FEBRUARY, 1922

	Thursday, Feb. 9	Friday, Feb. 10	Saturday, Feb. 11
8-10	English Composition	Algebra Trigonometry	Geometry
10-12	Botany Zoology	Physiography Geology	Chemistry
2-4	History	Physics Introductory Science	Latin Greek
4-6	Physiology	French German Spanish	English Literature Zoology

The examinations July 6-8, 1921, will be given in the same order as in the February Schedule.

All examinations are held in Room 203, Tappan Hall

ADMISSION TO ADVANCED STANDING

10. *a.* Graduates of this University and of other approved colleges are admitted without examination to advanced standing as candidates for a degree in engineering or architecture.

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

The remaining requirements for students of Engineering can usually be completed in two years, if the student takes as electives, while an undergraduate,* the mathematics required of engineering students and Courses 4 and 5 in Drawing (see § 193).

Those students who hope to complete the program in Architecture in two years should also complete the equivalent of Drawing 4a, 5a, 21, 22, and 23, and Architecture 1, 4, 5, 6, and 21.

b. A student who has completed at least one year of work in an approved college may be admitted to advanced standing without examination, except such as may be necessary to determine what credits he is entitled to receive.

An applicant must present a letter of honorable dismissal from college, an official copy of his college record, and an official record of his preparatory studies, similar to those required of students admitted on certificate. (See § 7.)

* A student enrolled in the College of Literature, Science, and the Arts, and desiring to elect any course in the College of Engineering or Architecture, which is not printed in the Announcement of the former College, must obtain the written permission of his classifier and of the instructor in charge of the course. A similar procedure is necessary in case a student of this college wishes to elect work in other Colleges.

c. A student who has not completed a year's college work in an approved college, but before entering these colleges of the University has pursued studies beyond those required for admission, may be admitted to advanced standing. Entrance requirements in such cases may be satisfied by complying with the conditions stated in either § 7 or § 9.

d. No official of these colleges can undertake to say what credit may be received here for work done elsewhere, or what class a person may be able to enter after having attended another college for a specified time.

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

Advanced credit is given by the heads of departments of instruction in studies of the first two years and in surveying and engineering mechanics. All other credits are given by the head of the department in which the student secures his degree.

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

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

Applicants should apply in person at Room 255, for Engineering, and at Room 209, for Architecture, Engineering Building, September 24 or February 13. Credentials should be sent on in advance as much before these dates as practicable. Students desiring advanced standing in drawing must bring all drawings completed previous to entrance.

Advanced credits must be secured upon entrance, on blanks furnished by the Assistant Dean, or by the Professor of Architecture, and the records must be returned at once to the Secretary of the Colleges with all papers used in securing the credits.

To apply for advanced credit at a later date, students of Engineering must secure the permission of the Assistant Dean, and students of Architecture the permission of the Professor of Architecture, giving a satisfactory reason for the delay in making the application.

ADMISSION FROM ALBION AND OLIVET COLLEGES

11. A combined course with Albion College has been arranged whereby a student may obtain the degree of Bachelor of Arts from that institution and the degree of Bachelor of Science in Engineering from the College of Engineering. The required work, covering a period of five years, is outlined in § 146. Students entering from Albion College will present a statement of their preparatory work, as well as a transcript of credits from that institution. Similar arrangements have recently been made with Olivet College. See § 147.

ADMISSION AS GRADUATE STUDENTS

12. Higher degrees in engineering and in architecture are conferred in the Graduate School of the University. See University Catalogue and special announcement of the Graduate School.

ADMISSION AS SPECIAL STUDENTS

13. Students who are pursuing work in these Colleges, and are not candidates for a degree, are designated Special Students.

Students over twenty-one years of age who wish to

pursue particular studies in Engineering or Architecture, and who show by examination or by the presentation of satisfactory certificates that they are prepared to do good work in the selected courses, may be admitted as special students on the recommendation of the heads of the departments of instruction in which they wish to study. The object of this rule is to enable young men who are beyond the high-school age to secure technical training along special lines when they are properly prepared for the work. Two or more years of successful experience as teacher, draftsman, surveyor, engineer, or operative in engineering works will be given considerable weight in determining the fitness of the candidate. In general, a good working knowledge of English, algebra, and geometry is required in order to succeed in engineering studies. Applicants for admission as special students should send as early as possible to the head of the department concerned letters of recommendation, certificates of scholarship, and an exact statement of the courses desired.

A two-year course is provided for special students in Architecture. Such students must be qualified for the courses they wish to pursue and must have the approval of the head of the College of Architecture; they must be 21 years of age; must have had two or more years of experience in architects' offices, or its equivalent, and must have a practical knowledge of architectural drawing. Special students who wish to pursue courses in advanced building construction must present the regular entrance requirements in mathematics.

Students who desire to pursue a special course in Architecture should write to Professor E. Lorch as early as possible in order to learn how best to prepare for the work they may wish to do here. They should spend some time in study parallel with their office work before

taking up university work, thus to review or master essential preparatory subjects and to again acquire the habit of study, the loss of which in certain subjects is often a serious handicap to capable draftsmen otherwise well prepared to profit by some of the academic work. In general, a working knowledge of English, algebra, plane and solid geometry is required. Advanced credit can often be given such students for work done in the field and in offices.

College graduates are also admitted as special students and may take those courses for which their preparation is sufficient.

Candidates for admission as specials in either college should state their age and what their education and experience have been. They should send letters of recommendation from former employers and bring drawings to demonstrate their experience and ability.

Special students pay the same fees as regular students. Their work is assigned and regulated by the heads of the departments of instruction in which they register.

A special student may become a candidate for a degree by fulfilling the regular requirements for admission. (See §§ 5 and 6.)

A student who is a candidate for a degree cannot become a special student without the permission of the Faculty.

SUMMER SESSION

14. The Summer Session of the University of Michigan will open July 5, 1921. Work will be given in the Colleges of Literature, Science, and the Arts, of Engineering, of Architecture, in the Medical School, and in the Law School. The session will close August 26. A

special Announcement can be had by addressing the Secretary of the University.

Every student in the College of Engineering in order to finish his course in four years is expected to attend one Summer Session.

Students enrolled in the College of Architecture must spend four months in an architect's office before graduating, receiving four hours' credit for this practical experience.

Courses Offered.—In the College of Literature, Science, and the Arts, the Summer Session affords opportunity for study in languages, history, mathematics, and the sciences. In the Colleges of Engineering and Architecture all of the courses in shop practice are offered, and a part only of those in English, modern language, mathematics, physics, chemistry, drawing, surveying, mechanics, civil engineering, mechanical engineering, electrical engineering, chemical engineering, and architecture. Students who wish to review studies or make up deficiencies, preparatory to presenting themselves for admission to the Colleges, will find courses directly adapted to meet their wants. Those with deficiencies are strongly urged to make them up before entrance, in order to be able to pursue the regular course.

Courses Required.—Regular students in the Colleges of Engineering and Architecture find it necessary to take certain prescribed courses during one Summer Session in order to complete the prescribed work in four years. These courses are specified in §§ 133-138 and 172.

Tuition Fees.—In the Colleges of Literature, Science, and the Arts, of Engineering and Architecture, the tuition fee is $30, including fee for medical services. There is also in Surveying 3 a camp fee of $10.

FEES AND EXPENSES

15. MATRICULATION FEE.—Every student before entering any college or school of the University is required to pay a matriculation fee. This fee, which for citizens of Michigan is ten dollars, and for those who come from any other State or Country, twenty-five dollars, is paid but once, and entitles the student to the privileges of permanent membership in the University.

16. ANNUAL FEE.—In addition to the matriculation fee, every student has to pay an annual fee for incidental expenses. For men, the annual fee in the Colleges of Engineering and Architecture is, for Michigan students, ninety-seven dollars; for all others, one hundred twenty-two dollars. For women, these fees are five dollars less. These fees cover class instruction, use of libraries, outdoor physical education and admission to all athletic events on Ferry Field, membership in the Michigan Union or Woman's League, as well as medical attention from the University health service and dispensary.

A by-law of the Board of Regents provides that no student or graduate shall be allowed to enjoy the privilege of the University until he has paid all fees that are due.

17. FEE FOR SPECIAL EXAMINATION.—An applicant for admission who desires to take the entrance examination at a time not announced is required to pay to the Treasurer a fee of five dollars before permission to take one or more examinations can be granted him. A supplementary examination given at any other time than that stated in this Announcement will be subject to the same fee.

18. GRADUATION FEE.—The fee for graduation is ten dollars, and the by-laws of the Board of Regents prescribe that no person shall be recommended for a degree until he has paid all dues, including the Graduation Fee. This fee will be received by the Treasurer of the University upon the presentation of a ticket to be secured at the office of the Secretary of the College in which the candidate is enrolled. To receive a degree at Commencement the candidate must be present in person and must have paid the graduation fee at least twenty-five days prior to Commencement Day. Others who have satisfied

all the requirements for graduation, including the payment of the graduation fee, will receive their degrees at a subsequent meeting of the Board of Regents.

19. LABORATORY FEES.—Laboratory fees are abolished, but students in laboratory courses must make a cash deposit to pay for materials used and for breakage. *Camp Fee.*—A fee of *ten dollars,* in addition to the regular tuition for the Summer Session, is required of students who take Course 3 in Surveying. See § 14.

20. OTHER EXPENSES.—There are no dormitories for men and no commons connected with the University. Students obtain board and lodging in private families. Room rent varies from three to five dollars a week for each student. Board varies from five to six dollars a week.

21. ANNUAL EXPENSES.—The annual expenses of students, including clothing and incidentals, are, *on the average,* about seven hundred dollars. By the practice of strict economy, it is possible to complete the four-year course for two thousand dollars. Many students are enabled to complete their course by withdrawing for a year or two to earn money to carry them through the remaining years.

A set of drawing instruments costs about $25, and, if well selected, will be serviceable for many years.

REFUNDING OF FEES

22. The Board of Regents has made the following provisions for students withdrawing from the Colleges and for those entering the second semester:

(1) Any student who withdraws voluntarily and in good standing not more than two weeks after his registration shall be entitled to a refund of his entire annual fee, together with the matriculation fee.

(2) A student who withdraws thus more than two weeks and less than eight weeks after his registration is entitled to a refund of one-half his annual fee.

(3) A student who withdraws thus more than eight weeks after the beginning and not later than the end of the first semester is entitled to a refund of 40% of his annual fee.

(4) A student who registers at the beginning of the second semester is required to pay 60% of the prescribed annual fee. The 40% thus refunded at enrollment shall be included in determining any further refund under (1) and (2).

(5) No refund or reduction of the matriculation fee is made except in case of those withdrawing within the first two weeks after registration.

(6) No refund is made to students expelled, suspended, or requested to withdraw on account of conduct or poor scholarship.

STUDENT EMPLOYMENT

23. The University does not undertake to furnish manual labor to students; yet a considerable number find opportunities in the city to meet a portion of their expenses. The Faculty suggests to such students that they should not attempt to carry the full amount of work outlined. Much more efficient work can be accomplished by taking a longer time to cover the course. Each student doing outside work should notify the Classification Committee of such fact at the time of classification.

Students desiring employment should apply in person or by letter before they come to Ann Arbor, to the Dean of Students, Room 2, University Hall.

FELLOWSHIPS AND SCHOLARSHIPS

24. There are several fellowships and scholarships in the Colleges of Engineering and Architecture. For details, see §§ 127, 128, and 178.

There are also annually appointed about thirty-five assistants at salaries ranging from $100 to $250. For the most part, these assistants are graduate students and seniors who have shown themselves proficient in certain lines.

RELATION OF STUDENTS TO THE CIVIL AUTHORITIES

25. Students are temporarily residents of the city, and, like all other residents, are amenable to the laws. If guilty of disorder or crime, they are liable to arrest, fine, and imprisonment. A rule of the University Senate provides that, if a student is arrested, or is convicted by the civil authorities, he shall be cited to appear before the Faculty of the college in which he is matriculated, and shall be liable to suspension or expulsion.

THE MICHIGAN UNION

26. The University of Michigan Union was organized and incorporated under the laws of the State of Michigan in 1904, to establish a University social and recreational center; to provide a meeting place for faculty, alumni, former students and resident students of the University; to furnish a home for alumni when in Ann Arbor, and a place for wholesome relaxation for students, so that their leisure time, their amusements, and their student interests, through the medium of the University atmosphere of the Union, might become a

component part of their education. The Union, furthermore, seeks to inculcate educational ideals through its student activities, for as a social center it encourages and stimulates activities that are for the welfare and enjoyment of the student body, and the result is a richer, more intense University life, a product of the students' own work. This develops group spirit, a sense of loyalty to the community served, pride in work accomplished, a widened circle of friends, and broadened experience and viewpoint in life. The Union, in emphasizing the social values of education, complements the work of the University in its endeavor to graduate broadly educated men and citizens.

The New Union Building will be practically finished by June, 1921, and will be exceptionally well appointed. Among its many attractions, the building provides a swimming pool, six bowling alleys, a barber shop, a billiard room with twenty-four tables, a lounging room, restaurant service including a cafeteria, a women's dining-room, main dining-room, and an assembly hall adapted to use for banquets, meetings, conventions, smokers, concerts and dances, and forty-nine sleeping rooms accommodating sixty-eight persons for the alumni and guests of members. The building will be the headquarters and gathering place for students, alumni, former students, and faculty.

The Union maintains rooming and boarding lists, and in conjunction with the Dean of Students, assists students in finding employment.

The student annual membership fee is $6, fixed by the Board of Directors and by resolution of the Board of Regents adopted June 28, 1921. This fee is incorporated in the annual tuition of every man student of the University.

HEALTH SERVICE

27. The University attempts to conserve the health of students, and to provide that those who are taken sick may have proper attention. Any student may select his own physician, or he may avail himself of the services offered him by the University. Three competent physicians give their full time to free consultation. Prescriptions are prepared at the University dispensary, free of charge, and all University students sent to the University Hospitals by the Health Service will be cared for free of charge for a period not longer than sixty days.

The Dental clinics are open to all students, the only charge being for materials used. Students must not allow dental engagements to interfere with college work.

A course of lectures on General Hygiene is required of medical students, and is open to students from every college. These lectures extend through one semester, three times a week, and are attended usually by from 300 to 400 students. Special instruction along the lines of sex hygiene is given all students, women and men separately.

FACILITIES FOR PHYSICAL EDUCATION

28. The University is provided with excellent gymnasiums. The Waterman Gymnasium for men has cost about $130,000. The main floor, which is a rectangle with truncated corners and dimensions of 246 by 90 feet, is well equipped with the various kinds of apparatus usually found in the best modern gymnasiums. A number of smaller rooms are devoted to administration, fencing, boxing, and other special purposes, while the basement is given up to baths, lockers, handball, shot-put, and rifle range. The main hall is lighted in the daytime by means

of a large skylight 60 feet above the floor, and in the evening by electricity. A gallery makes room for an elliptical running track, ten laps to the mile, making it one of the largest gallery running tracks in the country.

Every freshman and also upper classmen holding lockers are required to take a medical and physical examination. Appointments for freshmen are made by card at the time tuition fees are paid. Upperclassmen can make arrangements for this by applying to Health Service Office or Director's Office, Waterman Gymnasium. Examinations take place in Waterman Gymnasium. At this time also a measurement of various parts of the body is taken and plotted on an Anthropometric Chart, a comparison with the average measurements can be made in this way, and any existing abnormalities corrected. A second measurement is taken after class work is finished, in order to note what changes have taken place. Abnormal posture conditions are corrected, and special exercises for strengthening weak parts are given. Realizing the fact that most college men have inferior chest development, the character of the class work is arranged to overcome this condition. A mixture of both athletic and gymnastic work is given, however, in order to produce variety and enthusiasm for exercise. An excellent outdoor elliptical board track, adjacent to the Gymnasium, has recently been installed, in order that outdoor exercise can be taken, especially during the periods when classes are being held, whenever weather conditions permit. Men qualifying for All-Fresh and class football, cross-country and hockey teams are given gymnasium credit, while these sports are in progress, after which they are transferred to the regular gymnasium classes. Arrangements for the exchange of this work must be made with the Director of the Gymnasium, otherwise no credit will be given.

The facilities of the Gymnasium, including physical examination and instruction, are free for all students, the only charge being a rental of $2 a year for a locker. Attendance twice a week is required of all first-year students of these Colleges. Classes begin the first Monday in November.

The Ferry Athletic Field of thirty acres has been set apart and equipped for open-air sports. A number of tennis courts are open and much interest is maintained in football, baseball, and track athletics by class and University teams.

MILITARY SCIENCE AND TACTICS

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

The first four semesters of each unit comprise the Basic Course, and the last four semesters comprise the Advanced Course. Elections are for a period of four semesters; that is, for a complete Basic or Advanced Course. Once elected, a course becomes a prerequisite to graduation unless the student is formally discharged from this obligation. During the Advanced Course members of the R. O. T. C. receive payment of commutation of subsistence from the Government.

In each course, Basic and Advanced, there is a sum-

mer camp of six weeks' duration. The Advanced Camp is a prerequisite to graduation for students in the Advanced Course. Equipment is furnished and expenses at the camps are paid by the Government.

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

The courses must be elected in the same manner as any other course, and, in addition the student must enroll in the R. O. T. C. at Room, 239, New Engineering Building.

THE ASSEMBLY AND MENTOR SYSTEM

30. Each class in the College of Engineering has its separate assembly at which the freshman class is brought together once a week and the sophomore, junior, and senior classes once a month. At these meetings faculty members and visiting engineers address the students and the regular business of each class is assured of attention by the class as a whole.

Closely connected with these assemblies is the mentor system by which the students receive reports on each of their studies through their mentors or faculty advisers. These reports reach the mentor six weeks after the beginning of the semester and four weeks before the final examinations, and he is therefore able to give the men in his group not merely general advice but definite information as to how they are getting along in their college work.

As soon as a student enters the College of Engineering he is assigned to a mentor who is to be his faculty adviser throughout his college course, and definite

arrangements are made for him to meet his mentor directly after the first assembly. Both socially and in his advisory capacity, moreover, the mentor is the personal representative of the Dean, so that each student may feel free to call on his mentor at any time with reference to any subject relating to his college life.

THE HONOR SYSTEM

31. The students of the College of Engineering have adopted the following system: All examinations and written quizzes in the College are held under the Honor System, the object of which is to create a standard of honor which is essential to a successful engineer and a good citizen. Students are expected to uphold the system or declare their objections to it, after having been duly instructed in all the rules governing the system. The instructor does not remain in the room during an examination. The students are placed upon their honor to refrain from all forms of cheating and to reprimand a fellow student who acts suspiciously, and, in case he does not take heed, to report him to the Honor Committee, which consists of one student elected annually from each class in the College of Engineering, and one from the College of Architecture, each member to serve two years. Every student is requested to write and sign the following at the end of his examination paper:

"I have neither received nor given aid during this examination."

WOMEN STUDENTS

32. All questions relating to the living conditions of undergraduate women students enrolled in the Colleges of Engineering and Architecture come under the jurisdiction of the Dean of Women of the University. Matters of scholarship and attendance are handled by Assistant Dean Butts for Engineering and Professor Lorch for Architecture. Assistant Secretary Green acts as mentor for the women in Engineering and Architecture.

Applications for rooms should be made to Dean Myra B. Jordan, who has entire charge of the matter of housing conditions for the women students of the University.

RULES GOVERNING ELECTION OF STUDIES

33. (a) No student will be allowed to elect merely a part of a course without special permission of the Classification Committee.

(b) No credit will be allowed to a student for work in any course, unless the election of the work is formally entered on his office classification card.

(c) After the first Saturday of each semester no study can be taken up or dropped without special permission of the Hours Committee.

(d) All requests to the Faculty must be made out on printed forms furnished by the Secretary of the College.

(e) A student is required to drop a part of his work at any time if he appears to be undertaking too much; or to take additional work if he is thought not to be sufficiently employed.

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

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

(h) After matriculation, a student cannot, without special permission of the Faculty, be admitted to examination in any one of the courses given, until he has received in the University the regular instruction in such course.

(i) Students must take the initiative in securing from the Assistant Dean excuses for absences from classes, which excuses must be applied for within five days after their return to classes.

RULES RELATING TO EXAMINATIONS AND CONDITIONS

34. The work of students must be arranged in conformity with the following conditions:

Examinations for admission are held before the beginning of each semester. (See § 9.)

An applicant who fails in some part of the admission examination may, at the discretion of the Faculty, be admitted conditionally, but the removal of entrance conditions shall take precedence of all other work. Any condition so imposed must be removed at one of the next two regular examinations for admission, but the Classification Committee is empowered and instructed to see to it that the students entering this college with conditions remove the same during the first semester of residence as far as possible.

No student who has an admission condition outstanding at the beginning of his second year of residence will be allowed to enter his classes until such condition is removed, unless for valid reason an extension of time is granted for its removal.

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

35. At the end of each semester the quality of the work of every student in any course is reported by the instructor as *a* (excellent), *b* (good), *c* (satisfactory), *d* (deficient), *e* (not passed).

To receive credit in a course the grade reported must be above *d*. A student reported *e* receives no credit for the course and must reëlect it at the first opportunity if the course is required for graduation.

A student reported *d* (deficient) is required to do further work in the course. To ascertain the nature of this work he must see or communicate with his instructor

at the time the deficiency is incurred. The work may, at the option of the instructor, embrace any or all of the following requirements: the completion of set exercises or problems, attendance at designated classes and private study, or the completion of a satisfactory examination at one of the regular examination periods. Deficiencies (*d*) incurred in February must be removed before the beginning of the first semester, the following September; deficiencies (*d*) incurred in June or in the Summer Session must be removed before the beginning of the second semester, the following February. Otherwise the record *d* (deficient) is changed to *e* (not passed).

Students desiring to remove an entrance or other condition or to make up for absence from a semester examination must make application to the Secretary, who will furnish a blank form for presentation to the Instructor in charge of the examination. The blank when filled out must be deposited by the student with the Secretary within one week from the date entered upon it by the examiner.

An examiner may, at the supplementary examination, if showing warrants it, give a student an *e*, thereby making it necessary for the student to pursue the whole course anew.

The supplementary examination will be four hours in length, and will be held three times a year: on the last Thursday, Friday, and Saturday of the Summer vacation, on the first and second Friday afternoons and Saturdays after the Christmas vacation, and on the first and second Friday afternoons and Saturdays after the Spring recess.

36. The regular examination in any course at the end of each semester is an essential part of the work of the course. Absence from examination is reported by the mark X placed before the letter *a, b, c, d,* or *e,* marking

the grade of the student's work. This mark X means that the credit in the course is temporarily withheld. Any student absent from examination is required to report to his instructor as soon thereafter as possible. If a student presents a valid excuse for his absence, he may take the examination at one of the regular supplementary or semester examinations before the beginning of the next semester after his return. If the excuse is deemed unsatisfactory, the record shall be reported as *d* or *e*. If, by the end of the semester following the examinations, no report showing a satisfactory completion of the course is received at the office, the record in the course shall be changed to *e*.

When a student has been prevented by illness or other cause beyond his control from completing any course, the mark I may be placed before the grade to denote that fact. This mark is to be removed in the same manner as a defficiency "d".

Students who present themselves for examination in any subject must present to the instructor in charge, at the time of the examination, a supplementary examination slip obtained from the Secretary.

Students having deficiencies in studies which can be taken during the Summer Session are advised to make up those deficiencies at that time and thus be enabled to devote their entire attention to the studies elected during the regular session.

UNSATISFACTORY SCHOLARSHIP

37. The normal number of hours that students should carry each semester is between sixteen and eighteen. Students who have to do outside work to assist themselves through the University, are strongly recommended

to elect a smaller number of hours than those above. In the event of failure in one-half or more of the hours elected, the student will usually be put on probation. This means that for the next semester following he must pass at least twelve hours of his elected work. In the event of his failure to do so, he will be asked to leave the University. Students who have been on probation twice, and subsequently fail to do satisfactory work, may be asked to leave the University, even though they have not been on probation for the semester immediately preceding. In all cases where failures occur which involve the penalties mentioned the student is given an opportunity to appear before the Committee on Delinquent Students to show cause why such action should not be taken.

WITHDRAWAL FROM THE COLLEGES

38. A student should not withdraw from class even temporarily without obtaining permission.

Leave of absence will be granted to those who expect to return before the end of the year.

Honorable dismissal will be granted to those who wish to transfer to another College of the University and to those going elsewhere, provided in either case they are in good standing.

Engineering students must obtain this permission or dismissal from the Assistant Dean, and Architectural students from the Professor of Architecture.

COLLEGE OF ENGINEERING

DEPARTMENTS OF ENGINEERING

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

Civil Engineering is the oldest and best known of the Engineering courses. It deals especially with the design of static or stationary structures and is divided

into several groups which take up the different classes of problems. These groups are:

Structural Engineering, which deals with problems of design and construction in steel for bridges, roofs, and buildings, masonry, foundations, and plain and reinforced concrete.

Hydraulic Engineering, which takes up the problems of irrigation, drainage, water power development, rivers and harbors, and deals with the measurement of water and design and construction of dams, locks, wharves, irrigation works and all other forms of hydraulic construction.

Railroad Transportation Engineering, which deals with railroads and other forms of transportation; the location, construction, maintenance, operation, and also the history and economics of transportation systems. In connection with the courses in the Department of Economics and in Electrical Engineering the entire field of railroad transportation engineering and economics is well covered.

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

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

villages, and the construction and regulation of street railways and other utilities.

Highway Engineering and Highway Transport, which deal with the administration, organization, and financing of highway improvements; the economics, design, construction, and maintenance of highways, roads, and pavements; the properties and methods of testing of road and paving materials; and the economics, management, regulation, and methods of highway transport.

Mechanical Engineering is the branch of engineering which deals largely with heat, power, design of machinery, and the problems of the manufacturer. This field of engineering has developed very rapidly in recent years because of the growth of our manufacturing industries. Mechanical Engineering may be divided into the following groups:

Steam Power Engineering deals with the design, construction, and operation of the various forms of prime movers using steam as the motive power, and their application in the modern power house.

Internal Combustion Engineering considers the application of the gas, oil, and gasoline engine in the development of power. It includes the design, construction, and operation of the various forms of internal combustion engines, also the use of the various types of gas producers.

Hydro-Mechanical Engineering deals with the design, construction, and installation of the various forms of water turbines and pumping machinery.

Heating, Ventilating, and Refrigerating Engineering. —As the problems of heating and refrigerating are much the same, these are included under one head. This group

of studies deals with the theory, design, and operation of heating, ventilating, and refrigerating plants. Special stress is laid upon the applications of heating and ventilation in architectural work.

Automobile Engineering.—The University of Michigan has a strategic location at the center of the automobile industry in this country, and a special group of eight courses is offered in Automobile Engineering. These courses cover the general principles of operation, the theory and design of the engine and the other chassis units, and laboratory and road tests of the various component parts of the automobile or of the complete automobile itself. An exceptionally complete Automobile Laboratory offers opportunity for advanced Research Work.

Industrial Engineering.—This group of studies is provided for those who wish to prepare themselves for the business side of the manufacturing plant or who wish to follow the profession of production engineers.

Electrical Engineering is sub-divided as follows:

Electric Power Engineering deals with the theoretical and practical phases of power generation, distribution, and utilization, together with the design and construction features of the apparatus applicable thereto, and among other specific applications is studied in its relations to electric railways, lighting, power plants, generators, and motors, and the service of the public in its economic and ethical aspects. This training in the knowledge of the art enables men with engineering ability to profit by later experience, thus leading them to executive and technical positions in manufacturing and service corporations, to technical sales work and other kindred vocations.

Electrical Communication, dealing with the transmission of signals and of speech by electrical means with and without wires, includes telephony, telegraphy, electric signalling, and radio communication. The training in this branch consists in the application of fundamental principles to the problems of these specific industries, its object being to fit the student for ultimate success in technical or executive work. Graduates find a broad field of opportunity with the numerous operating and manufacturing companies of the communication industries.

Illumination Engineering deals with the many and varied special problems arising in relation to the production and utilization of light, economically and in accordance with correct principles of physics, physiology, psychology, art, and architecture. The purpose of the work available to undergraduates in this branch of electrical engineering is to indicate the scope, present and prospective importance, and attractiveness of illumination as a field of professional activity, and to establish firmly by thorough drill the principles upon which progress must be founded.

Chemical Engineering treats of the operation and control of those important industrial operations in which chemical processes play a vital part. It has arisen as a separate division of engineering with the recent wonderful growth of the chemical industries, just as electrical engineering developed a generation ago when electricity became industrially important. The development of chemistry and the growing magnitude of industrial operations require from those who would direct these chemical engineering operations a special training which must include not only chemistry and the older branches of engineering, but also *chemical engineering.*

The industries which offer opportunities to the chem-

ical engineer are many. All metallurgical operations which involve melting or even heat treatment of metals; the manufacture of hydraulic cements, clay products, and glass; the acid and alkali industries; electrometallurgy; all processes connected with the utilization of fuel by combustion, or destructive distillation to form gas, coke, and tar; the processes of water purification; the refining of the fats and oils and their manufacture into soap, paint, and varnish; the manufacture of sugar, paper pulp and paper, and explosives; the bleaching and dying of cotton, wool, and silk—are illustrations of the large industries which involve chemical engineering.

Marine Engineering embraces the design, construction, and operation of ships and other floating structures, and the machinery appertaining thereto, and to the auxiliary construction of drydocks and wharves.

Aeronautical Engineering embraces the general theory of aero-dynamics, the design and construction of airplanes, balloons, etc., and questions relating to engines and propellers for aircraft.

ENGINEERING RESEARCH

In response to a request from the manufacturers of the State for close coöperation with the University, the Department of Engineering Research was established in October, 1920. This department will attempt to serve the research interests of the industries in every proper and fitting manner. It is not believed that it can advantageously serve as a testing bureau, since work of this type can be done much better by control laboratories in the industrial plants proper or in central laboratories in the cities and towns in which the industries are located.

Problems, general in character, truly fundamental in their nature and, where possible, of a coöperative type are the ones on which the department believes it can best function. It places at the disposal of the industries its library, its available laboratory space and equipment. The industry or industries requesting service pay labor charges, provide special equipment, and pay a nominal fee for administrative expense and the use of equipment. As a State institution it cannot grant special privileges. Therefore, work on which patents are desired or special privileges with regard to matters of publicity cannot be accepted.

THE WORK OF THE COLLEGE OF ENGINEERING

40. The studies pursued in the earlier part of the course are practically the same for all engineering students. They comprise, in *Mathematics,* advanced algebra, analytic geometry, and the elements of the differential and integral calculus; in *German, French,* and *Spanish,* the grammar, and reading of narrative prose and current scientific literature; *in English,* courses in literature, composition, and rhetoric; in *Physics,* mechanics, sound, light, heat, electricity, and magnetism; in *Chemistry,* the principles of inorganic chemistry; in *Drawing,* descriptive geometry; in *Shop Practice,* carpentry, pattern-making, and forging.

The more technical subjects follow in the latter part of the course. Some of these are of equal value to all engineering students, such as theoretical and applied mechanics, and the strength and resistance of materials. Other subjects are adapted to the special requirements of the several courses.

The general scope of the courses offered is shown in the following:

41. **English.**—The work in English is based on the assumption that the engineering and architectural student needs to be able to speak and to write. It is further assumed that he needs, as a means of wholesome and sensible enjoyment, as well as a means of extending his fund of ideas, a real and intelligent interest in reading. The general courses have, therefore, naturally grouped themselves under two heads: those which aim to develop the student's ability to express himself (Courses 1, 1*a*, 2, 2*a*, and 3); and those which aim to deepen his natural interest in books, and to make him more discriminating and critical. The latter include Courses 14, 21, 22, 23, 24, studies in prose fiction; Courses 25 and 26, studies in the drama; and Courses 27 and 28, readings in scientific literature.

There are, in addition to these general courses, a number of technical and special courses (Courses 4, 5, 6, 7, 8, 9, 10, 12), which have been designed to meet the particular needs of the engineering student, and Courses 16 and 17, which have been planned to aid the foreign student in his special problem.

42. **English for Foreign Students.**—Students whose native language is other than English are given special help in overcoming the handicap which their inexperience with the vernacular often puts upon them. All such students have laid out for them such a course in English, French, German, or Spanish as shall justify the modern language requirements for graduation. In the case of a foreign student, English may be substituted for another modern language, the maximum assignment being 17 hours, and it is understood that English shall be continued until the English faculty is satisfied that a good working knowledge is possessed of both written and spoken English. The two special courses outlined in § 191 for foreign students can be taken throughout the first year, the work being specially planned to meet the requirements of individual cases. If on completing any of these special courses, the student can satisfy the English department as to his pronunciation, his written idiom, and his ability to take dictation with reasonable accuracy, and if he is no longer hampered by his difficulties with English, he may be excused from the remaining special courses, provided that he take instead one of the regular composition courses offered for American students. This plan aims to economize the time and effort of the foreign student and to make sure that on graduation from an American university he may have a reasonable command of English.

43. **German, French, and Spanish.**—The aim of the instruction in German, French, and Spanish is to help the student to a reading and speaking knowledge of those languages. The elementary courses continue throughout one year, and their object is to familiarize the student with the forms and the construction of the languages and to furnish him with practice in reading and speaking them.

The object of the courses of reading in scientific literature is

to acquaint the student with the terminology and special vocabularies of the various sciences, and thus enable him to consult books and periodicals bearing on his professional work with facility and profit. This reading covers a large range of scientific subjects, such as chemistry, physics, geology, and mineralogy, as well as articles on more technical subjects, dealing with the various branches of engineering and architecture. Many students read, besides the work assigned for the classroom, scientific articles in the numerous German and French periodicals to be found in the University Library. This is of value to the student in the prosecution of much of his advanced work. In some of the more important courses in the College of Engineering a reading knowledge, at least, of one of these languages is required.

Elective courses are offered for the accommodation and benefit of students who have the time and inclination to carry their language work beyond the limits of the required courses.

The courses in Spanish are largely conversational, and are offered chiefly to meet the demands of students looking forward to a professional career in countries where Spanish is the prevailing medium of communication, as in the Philippine Islands, the West Indies, Mexico, and the countries of Central and South America. These courses include considerable practice in business forms and commercial correspondence. Opportunity for advanced work in Spanish is offered to students who desire to make themselves specially proficient in this language.

44. **Mathematics.**—The required work is the same for all students of engineering, except students of chemical engineering, and extends throughout the first two or three years.

It is the object of this course not only to impart to the student the mathematical knowledge requisite for the study of the various branches of engineering, but to train his mind in the methods of precise reasoning and accustom him to the proper application of general principles to particular cases.

The first year is devoted to trigonometry, advanced algebra, plane analytic geometry, and the elements of the differential calculus, the second to solid analytic geometry and the differential and integral calculus, including an introduction to the solution of differential equations.

Much time is devoted to the solution of problems in order to combine a fair knowledge of the elementary principles of higher mathematics with the necessary facility in applying these principles to concrete cases. The classes are divided into sections as small as practicable, so as to make it possible for the instructor to give his individual attention to the students.

Students desiring to pursue their mathematical studies further will find a large list of electives among the courses in pure and

applied mathematics offered in the College of Literature, Science, and the Arts.

45. **Physics.**—The instruction in general physics covers a thorough course with the use of trigonometry and extends throughout an entire year. The first semester is devoted to mechanics, sound, and heat; the second to magnetism, electricity, and light. The subjects are amply illustrated with appropriate experiments accompanying the lectures. One period a week is devoted to laboratory work. The numerous courses, both experimental and theoretical, which the department offers are open to students wishing additional work in physics. § 207.

46. **Chemistry.**—Engineering students who present an approved unit of chemistry for entrance are required to take only one course in chemistry. An examination for admission to advanced standing will be required of all students who present admission units derived three or more years prior to the date at which admission is sought and in other doubtful cases. This course covers briefly, by lectures with demonstrations, recitations, and laboratory exercises, the important facts regarding the metallic and non-metallic elements. Due regard is given to the theory of chemistry and the method of scientific reasoning. In the course some of the methods of qualitative analysis are developed. Additional courses in analytical, theoretical, and organic chemistry are required of Chemical Engineering students and may be elected by other Engineering students.

47. **Astronomy.**—A short course is required of Civil Engineering students, including the elements of General and Spherical Astronomy. Special attention is given to the use of the Ephemeris, to the conversion of time, and to the theory of the problems which occur in engineering practice, such as determination of time, latitude, longitude, and azimuth.

Other elective courses provide for Observatory work with the sextant, transit, meridian circle, equatorial, and other instruments, in which students make complete series of observations and reduce their own data. There are also advanced courses in Practical Astronomy, Theoretical Astronomy or Celestial Mechanics, and Astrophysics.

A course in Navigation is also given in Astronomy 22.

48. **Geology.**—The civil engineering sudents are required to take a brief course in geology, the first two-thirds of which is given over to dynamical and structural geology and the remaining portion to an outline history of the different geological formations. § 200.

49. **Drawing.**—A very complete course in mechanical drawing is given, embracing geometrical drawing, isometric projections, descriptive geometry, and the elementary principles of lettering, dimensioning, coloring and shading, with original problems executed

in the drawing room. Students are required to sketch pieces of machinery and afterward to make working drawings of the same suitable for use in the shop. Instruction is also given in free-hand drawing, topographical drawing, statistical charting, patent office drawing and lettering, and the application of descriptive geometry to the solution of problems in shades, shadows, linear perspective and stone cutting. The work in drawing occupies a large part of the student's time through the course. § 193.

There are large and well-lighted drawing rooms in the engineering buildings as well as special rooms for blue-printing and a dark-room for photography.

For Free-Hand Drawing, see §§ 187, 193.

50. **Mechanical Practice and Shop Work.**—The aim of the instruction in this department is to make the student, as far as time will permit, acquainted with the best mechanical practice; the instructors in all practical work are men of wide experience, selected for their mechanical skill; and the department attempts to keep in touch with the most improved methods of mechanical construction. All courses are under the direction of the Superintendent of Shops, and instruction is given in the various branches by practical men skilled in the craft which they teach.

The courses of instruction all begin with a systematic series of graded exercises, to give the student familiarity with the common tools used in the particular branch of work he is pursuing; and in connection with each course the theory of the process is taught by text and recitations. The student thus becomes fitted to execute an ordinary piece of mechanical work and at the same time acquires familiarity with sources of information bearing upon such work. At a later stage in the course the student is taught to apply the principles previously studied in the classroom, and to combine skill and knowledge in the transformation of crude materials into articles which have a market value. § 210.

In Wood Work, after the student has completed the preliminary series of graded exercises he devotes the remainder of the time, about three-fifths of the whole, to elementary pattern work. Special stress is laid upon this part of the course. The student shapes, forms, and builds up patterns for castings in iron and brass, makes core boxes, and becomes as familiar as possible, in the time allowed, with all the details of practice. The first course in wood work is taken by all the engineering students.

In the Foundry the student learns to mould in green and dry sand, both for brass and for iron castings. Instruction is given in the making of cores and their use in the moulds; and in the art of selecting and mixing metals so as to produce the kind of material desired, careful attention being paid to the making of composition metals for specific purposes. Each student is required to take part

in all the work about the cupola and the brass furnaces, and to assume his share of their management during the periods of melting and casting.

IN THE FORGE SHOP the student is required to make forgings from a variety of irons and steels. In this way he becomes familiar with different kinds and qualities of materials suited for blacksmith work; he learns how to heat, forge, anneal, harden, and temper such tools as are used in machine shops. Instruction is also given here in chipping and filing, and elementary machine-shop practice. The student dresses and tempers his own tools for this latter part of the work. The object of the course is to enable the student to acquire a knowledge of the nature and properties of metals, and at the same time impart to him a knowledge of the principles governing such processes of forging as an engineer is likely to be called upon to direct. This work is required of all regular students.

IN THE MACHINE SHOP the instruction is conducted on the same plan as in the pattern shop. On the completion of the series of graded exercises the student begins the construction of parts of machines or pieces of apparatus; and the work is planned in such a way as to give opportunity for learning general shop manipulation. Advanced students are also allowed to elect extra work and to assist the skilled workmen in the construction of larger machines.

A description of the engineering shops is given in § 106.

In all the above-described courses advanced work can be taken by students who wish to become specially skilled in certain lines, or who desire to fit themselves for instructors in Manual Training Schools.

IN PATTERN WORK the student is taught the shaping and construction of patterns for both iron and non-ferrous metals and learns the meaning of and prevention of shrinkage, draft, shape, and straining of molds, etc.

51. **Surveying.**—(a) Courses 1, 2, and 3 in surveying are prescribed for students of Civil Engineering. Courses 1 and 2 are given on the campus, while Course 3 is conducted at Camp Davis on Douglas Lake during the Summer Session following the junior year. Courses 1 and 2 embrace the fundamental theory of surveying, and sufficient field work is required in each to illustrate the lectures and text and to enable the student to become familiar with surveying instruments. All instruments necessary for this work are provided. Reference texts dealing with surveying are accessible to the students. Course 3 is of a practical nature.

(b) Course 4 is offered for other students of engineering. Instruction is given in the fundamental theory of surveying. Field work is prescribed and notes are carefully kept.

(c) Students in Forestry require fundamental courses of slightly

different character. Course 12 is given during the first semester, and Course 13 during the second semester only. Students completing Course 13 are prepared for the work offered in Course 3.

(d For students qualified in surveying and astronomy, Course 6 in geodesy is offered. This course embraces lectures, reference reading, written class reports dealing with geodetic methods with special reference to modern practice. Some consideration is given to notable surveys and constant use is made of government reports and standard works of reference. Students are also given practice in adjusting observation and computing triangulation systems.

(e) *Municipal Surveying.*—Course 7 is offered as an advanced course for all students who have completed Courses 1, 2, and 3. It comprises lectures, text, field, and drawing room work, street surveys for the following purposes,—location, fixing grades, paving, sewers, curbs and minor street details, the location of property lines and the planning and laying out of new subdivisions and additions. Special attention is given to the state laws governing surveys of this nature.

(f) *Railway Surveying.*—Course 9 is a special, advanced course open only to students who have completed Courses 1, 2, and 3, and who are taking the Transportation Engineering Courses. The course embraces the theory of easement and transition curves, turnouts and railroad maintenance surveys, and the work is covered by lectures, texts, field and laboratory work.

(g) *Engineering Photography and Camera Surveying.*—Course 10, dealing with the application of photography to surveying and miscellaneous engineering work, is offered students who have completed Course 1, or Course 4, in Surveying, and who are qualified in physics, chemistry, and drawing. The course embraces the history of photography, the chemistry of the dark-room, testing of lenses, design of photographic laboratories, developing plates, making prints, enlargements and lantern slides, color work, map making, landscape sketching,—all from the standpoint of the engineer.

(h) *Least Squares.*—Course 5 embraces the theory of least squares together with applications of the theory to engineering problems. Particular attention is paid to problems which have come from actual field and laboratory exercises of the student.

(i) *The Surveyor and the Public.*—Course 8 is designed to provide some elementary instruction in matters which have troubled many surveyors in time past. The surveyor generally learns the law governing his work as his experience grows in breadth. He often finds ignorance of the law an embarrassing handicap.

52. **Engineering Mechanics.**—A course of four recitations a week is devoted to the elements of applied mechanics and is required of all students in Engineering. Thorough drill is given in the fundamental principles of mechanics, especially statics, by analytical and

graphical methods, centers of gravity, moments of inertia and friction. This is followed by a course in the dynamics of moving bodies and machinery, a course in the strength and elasticity of materials subjected to stress, and an introductory course in hydrodynamics to prepare the student for further study of the science of hydraulics in its applications to water power development and hydraulic machinery. § 195.

53. **Testing Materials.**—The courses in testing materials include the use of the laboratory and the testing machines for commercial and other tests of cement, concrete, wood, steel, and other structural materials. Special stress is laid on the importance of careful study and full written discussion of results of all tests, and much time is spent in studying the published results of other investigators. Tests made for private individuals, especially in reinforced concrete, afford occasional opportunities for research along these lines. § 195.

Advanced courses, primarily for graduates, are given in Engineering Mechanics, particularly in research work. (See Announcement of Graduate School.)

54. **Structural Engineering.**—Course 1, covering preparatory practice in making engineering drawings; Course 2 and 2*a*, Theory and Design of Structures; Course 3, Masonry, including reinforced concrete, and Course 6, Advanced Masonry and Foundations, are required of all civil engineering students. Courses 4, 5, and 7 are advanced courses in theory and design of steel and masonry structures, including reinforced concrete, and are open only to senior and fifth-year students.

In connection with the courses offered by the Civil Engineering department, courses in testing materials, metallography, and political economy are open to students electing this group. § 192.

55. **Hydraulic Engineering.**—Course 10, which is required of all Civil Engineering students, includes three or four exercises in gauging the flow of the Huron River and practical problems in preparing continuous records of stream discharge. It also covers the theory of the measurement of water, the relation of precipitation to run-off; the effect of seepage, evaporation, and temperature on run-off; fluctuations in discharge of streams; the storage of water; the mass curve; and the study of floods. Course 11, an advanced course in hydraulics, is required only of students taking the hydraulic group.

These fundamental courses are followed by Course 12, Development of Water Power; 14, Irrigation and Drainage; 16, Design of Hydraulic Structures, and 18, Rivers and Harbors.

Fourth and fifth-year students electing these courses may, if they have completed the prerequisites, elect work in the Mechanical and Electrical Departments dealing with water turbines, pumps, and electrical machinery.

Special courses for graduate students are offered as follows: Course 61, Irrigation and Drainage; Course 62, Advanced Hydraulic Design, and Course 64, Hydraulic Engineering Research. Considerable latitude in the line of investigation to be followed is allowed in these courses. § 192.

56. **Railroad Transportation Engineering.**—Course 20, Railroad Location, and Course 23, Railroad Design, are open only to students of the College of Engineering. Course 21, Railroad Engineering, is designed for both students of the College of Engineering and students in the Railroad Administration Course in the Department of Economics, and takes up the subjects of location, design, construction, and maintenance of track and structures in a less technical way.

Course 22, Transportation, is designed for both students of the College of Engineering and students of the Railroad Administration course, and treats of the history and economics of the various methods of transportation.

The Economics Department offers courses in Economics, Elements of Accounting, Railway Operation, Railway Finance, Railway Tariffs, Railway Accounts, and Railroad Transportation Problems, which are open to Engineering students electing Transportation Engineering.

These offerings, together with those in the department of Electrical Engineering, constitute a most complete course in Railroad Transportation Engineering, designed to give the student a grasp of the economic problems and the relation of other railroad departments to the engineering department as well as the purely technical courses.

None of the work included in the Railroad Transportation group is required of all students. § 141E.

57. **Sanitary and Municipal Engineering.**—Course 30, Water Works, deals with the general problem of supplying water of suitable quality and sufficient in quantity for all the various municipal uses, and is required to be taken by all Civil Engineering students. It is logically followed by Course 31, Water Purification, which treats fully of acceptable methods and devices for improving the quality of waters intended for municipal supplies.

Course 32, a first course in sewerage, deals with the general problem of the sewerage and drainage of urban areas, and is a required course for all Civil Engineering students; while Course 33, Sewage Disposal, treats of proper methods of disposal and deals with various processes and devices for the purification of sewage.

In Course 35, Sanitary Engineering Design, the classroom courses are supplemented by lectures and problems and drawing-board work in the designing of structures related to sanitary engineering. Course 34, Municipal and Industrial Sanitation, considers briefly the great body of observed data and other facts upon which

the practice of public sanitation is based. Course 36, Municipal Engineering, covers the subjects of street cleaning, the collection and disposal of garbage and other city wastes, and certain other administrative problems properly belonging to the city engineering office. Course 26, Engineering Contracts and Specifications, rounds out the program with a consideration of the duties and responsibilities of the city engineer in his relation to public works contracts.

Opportunities for graduate study in the purification of water and sewage and in certain other lines of investigation related to public sanitation are afforded by the Sanitary Experiment Station and the facilities offered in the Engineering Library. § 192.

58. **Highway Engineering and Highway Transport.** — Course 40, Highway Engineering, which treats of the fundamentals of economics, administration, legislation, preliminary investigations, highway transport surveys, economic design of highways, and the construction and maintenance of the different types of roads and pavements, is required to be taken by all Civil Engineering students. Course 41, Highway Transport Surveys and the Theory and Economics of Highway Improvements, is the theory course in this group. In Course 42, Highway Engineering Laboratory, the various non-bituminous and bituminous materials used in the construction and maintenance of roads and pavements, are studied in the laboratory. Course 43, Highway Engineering Design, covers design problems pertaining to roads and streets and discussions of field methods of reconnoisance and surveying, and office methods used in mapping, estimating, and recording. Course 44, Highway Transport Economics, Methods, Legislation, and Management, treats of the fundamentals of the transportation of passengers and commodities over highways.

Students electing the highway engineering and highway transport group in the senior year are advised to elect, in addition to the above courses, as many courses as practicable from the following group: Civil Engineering 22, Transportation; Civil Engineering 26, Specifications and Contracts; Civil Engineering 27, Public Utility Problems; Mechanical Engineering 29, Automobiles and Motor Trucks; English 6, Report Writing; Political Economy 1E, Elements of Economics. Students electing the highway engineering and highway transport group, and who have obtained the written approval of the Professor of Highway Engineering and Highway Transport, may elect for credit not more than two of the graduate short period courses.

Special opportunities for graduate work in highway engineering and highway transport are offered through the medium of Civil Engineering 66, Highway Engineering and Highway Transport Research, and the graduate short period courses in highway engineering and highway transport, Civil Engineering 67 to 83, and Mechanical Engi-

neering 40, which are given during the months of December to March, inclusive.

59. **Steam Power Engineering.**—Course 9 is required of all mechanical engineers, and includes lectures and text-book work covering the theory, economics, design, and construction of steam power plants. This course is followed by Course 9*a*, in which the student designs a power plant to fit the need of a special problem assigned to him. In this group there are also given Courses 11 and 11*a* in the design and construction of steam boilers; Courses 12 and 12*a* in the design of reciprocating engines, and Course 13 in steam turbines. Courses 20 and 20*a* consider the problems involved in the handling of coal and ashes in power house design.

Special courses are offered in the laboratory in the experimental examination of power plants to determine their operating efficiency.

60. **Internal Combustion Engineering.**—All Mechanical Engineering students are required to take Course 5, which deals with the laws of thermodynamics underlying the principles of the internal combustion engine as a heat engine, and Courses 2 and 6, in which are taken up the fundamental laws of machine parts as are used in the design of internal combustion engines. This is followed by Course 15, which covers the theory, design, and construction of various types of gas, oil, and gasoline engines and their auxiliaries. Course 15*a* follows, in which the student designs a standard type of internal combustion engine. The methods of testing of internal combustion engines are studied in Courses 7 and 8. The theory, design, and testing of automobile gas engines are taken up in Courses 29, 30, 30*a*, and 32.

Students, especially graduates, engineers with several years of experience, and officers of the army or navy who desire to do research work in any branch of internal combustion engineering are offered an opportunity in Courses 37, 38, and 39.

61. **Hydro-Mechanical Engineering.**—Course 4, which is required of all students of Mechanical Engineering, takes up in a general way the theory, design, and operation of all principal hydraulic machines, particularly the water turbine, centrifugal pumps, and reciprocating pumps. In addition to the classroom work the students perform a number of experiments in the hydraulic laboratory.

Course 4 may be followed by Course 17, in which the complete theory of the reciprocating and centrifugal pump is given. In Course 17*a* the student may design either a centrifugal pump or a reciprocating pump.

Course 16 gives the complete theory of water turbines. In conjunction with 16, students may take 16*a*, in which they design a water turbine.

Course 23 offers the students a possibility for advanced laboratory work, and post-graduate students a chance for research work in hydro-mechanical engineering.

Students who desire to specialize in hydro-mechanical engineering can take suitable courses in hydraulic engineering offered in the department of Civil Engineering, and also courses in Electrical Engineering.

62. **Heating, Ventilating, and Refrigerating Engineering.**—Course 25 is a general course in heating and ventilation in which the design, construction, and operation of the various types of heating and ventilating plants are considered. Course 25*a* takes up the design and construction of complete heating systems.

The laboratories are equipped with special machines for the investigation of some of the more important problems in heating and ventilation.

The theory and construction of refrigerating plants is given in Course 19. The laboratory is equipped for special research work in refrigeration.

63. **Automobile Engineering.**—A series of eight courses is given in Automobile Engineering: One general course, five design courses, and two laboratory and road testing courses. Course 29 is a general course covering the fundamental principles of automobile operation and design, and their application in current automobile practice. This is followed by Courses 30 and 30*a*, which cover the theory and design of the engine, and Courses 31 and 31*a*, which cover the theory and design of the rest of the automobile chassis. In these courses the students make calculations and complete designs for the principle automobile units. Course 32 includes experimental laboratory and road study of modern automobiles and their component parts, including engine tests, transmission tests, and road tests upon the complete automobile. Course 33 is an advanced course in automobile testing and research, covering special problems involved in some automobile unit or in the complete automobile. Course 34 affords an opportunity for advanced design and research upon special critical problems in the design of some automobile unit or of the complete automobile or motor truck. Course 41 is seminar work, taking up current topics.

64. **Industrial Engineering.**—The general subject of shop management is given in Course 35. This course includes both the theory of the subject and experimental work in the University shops, including motion study. Course 36 is a continuation of Course 35. There are also special courses in the Economics department in Business Administration which are closely associated with the engineering courses, and these courses are taken by students doing special work in these lines.

65. **Electrical Measurements.**—Adequate courses in electrical measurements are provided in the Department of Physics.

66. **Dynamo-Electric Circuits and Apparatus.**—Five courses are offered, three of them designed for students who are candidates for a degree in Electrical Engineering, and two for other students. Courses 2, 3, and 4 are required for candidates for the electrical degree and cover, respectively, the principles and practical calculations of circuits and machines using direct-current electricity, the principles and practical calculation of circuits carrying alternating-current electricity, and the operating characteristics of alternating-current machinery. These courses in fundamental principles are followed for students in electrical engineering by more advanced courses, some required and some elective. Courses 2, 3, and 4 form a close knit group and should be taken in close sequence. Courses 2a and 3a, the former prescribed and the latter elective, are for students other than those candidated for a degree in electrical engineering, and cover together in a brief fashion about the same ground as Courses 2, 3, and 4, the emphasis being placed perhaps more on the applications than on theory. Course 2a covers circuits and machines using direct current and circuits carrying alternating current. Course 3a is devoted to characteristics and applications of machines using alternating current. A non-electrical student thus receives thorough but by no means exhaustive instruction which should equip him with at least rudimentary training in the application of electrical principles to his specialty.

67. **Design of Electrical Machinery.**—Two courses in electrical design are offered. It is not possible nor is it desirable to try in these courses to turn out finished professional designers. The courses are intended to do two things: First, to clarify and fix the student's knowledge of dynamo machinery by means of calculations applied to actual machines. Second, to induce him to think as an engineer, rather than as a physicist, by imposing upon him the limitations encountered in practical work, by making him consider factors of cost of materials, possibility of economical manufacture, physical limitations of the materials used, the possibility of selling the machines at a profit, etc. The first course deals primarily with direct-current apparatus, the second with alternating-current machinery. Assembly drawings and a few detail drawings of machines are made.

68. **Power Generation, Transmission and Distribution.**—In the three courses covering this subject effort is made to apply fundamental economic principles to the selection and location of standard apparatus, including the financial phases of design, and to cultivate an analytic engineering judgment through the study of the operative functions of generating and transmitting devices.

69. **Electrical Communication.**—In this subject the principles developed in the preceding courses are studied from a new viewpoint. The aim is to broaden the student's electrical training by applying these principles to new apparatus and circuits. Many new ideas are introduced, such as the simultaneous transmission of several telephone or telegraph currents over the same conductor, the production and detection of electro-magnetic waves, the electron theory in its application to the electron tube used in the telephone repeater and in radio apparatus, etc.

The work is divided into three courses and prepares the student for the opportunities on the communication industry or strengthens him for work in other electrical industries as a result of his broadened perspective and better grasp of fundamentals.

70. **Illumination and Photometry.**—The courses offered in this subject are designed to familiarize the student with the fundamental principles of generation and control of light as a commodity, and to that end the significance and use of photometric quantities and the methods of measuring them are thoroughly treated.

71. **Advanced Theory of Electrical Machinery and Circuits.**—A limited number of problems in connection with rotating magnetic fields, electrical oscillations, the propagation of electric waves along wires and in free space, etc., are taken up and studied in detail from the mathematical standpoint. The emphasis is placed upon the formation of the equations representing electrical and mechanical phenomena and upon the interpretation of the results arrived at by the mathematical analysis. An effort is made to get the student to see the theoretical and practical advantages of mathematical analysis, to give him some added facility in the application of mathematics to practical problems, and to inspire him to continue his development along theoretical lines.

72. **Applied Electrical Engineering.**—The courses in Industrial, Railway, and Rate Engineering described in § 194, lay particular stress on the use of engineering judgment and the application to engineering problems of the principles of economics.

73. **Advanced Courses** are described in § 194, and include seminary and research work under the direction of various members of the staff, the problems assigned being such as will develop initiative and analytic power and at the same time contribute to the advancement of the electric art. In addition, there are courses of recitations and lectures on the existing advanced theory.

74. **Chemical Engineering.**—Under this head are grouped the courses which treat of the technical operation and control of the important manufacturing industries in which chemical processes play a vital part. The course of study leading to a degree in Chemical

Engineering is detailed in § 144. The students are trained in chemistry so that they may understand the chemical side of the processes and act as their own chemist if necessary. They are taught mechanism and the operation of machinery that they may understand the problems involved in carrying out these processes on the manufacturing scale and be fitted after proper experience to take charge of the operation of such plants. Further description of specific lines of work in Chemical Engineering is given in succeeding paragraphs.

75. **Engineering Materials.**—A general course is given to all students in the Engineering College. It discusses the properties of the important manufactured materials used in Engineering structures. The processes of manufacture are only studied as throwing light upon the properties of the materials. The course includes: iron and steel, brass and other important non-ferrous alloys, hydraulic cements, brick and other clay products, glass and protective coatings.

76. **Fuel.**—A descriptive study is made of fuels and their utilization. Attention is given to loss of heat in flue gases and to the advantages of gas producers and regenerators in attainment of high temperatures. § 190.

77. **Chemical Technology.**—The first course treats descriptively of industries which involve inorganic chemistry. The manufacture of salt is treated first. The great acid and fertilizer industries, and the manufacture of soda ash with its numerous by-products come next. This leads to the electrolytic production of alkali and bleaching powder, and to the electrochemical industries. In the second course the industries involving organic chemistry are treated in a similar way. The subjects comprise the manufacture of illuminating gas, with recovery of by-products; the fat and oil industry, including the refining of the natural oils and their manufacture into soap, paint, and varnish, with their allied industries; the manufacture of sugar from beets and cane; the manufacture of starch and its conversion into glucose; the brewing and distilling industries; the manufacture of paper; and the bleaching and dyeing of textile fabrics. Subsequent courses allow a more detailed study in the laboratory of a single one of these industries and give opportunity for specialization along any chosen line. § 190.

78. **Iron and Steel.**—A course of instruction by lectures and recitations is given to Engineering students upon the manufacture and properties of iron and steel. Advanced courses afford opportunities both in classroom and laboratory for a detailed study of the effects of heat treatment and mechanical work upon the properties of steel. The laboratory has excellent facilities for heat treatment and microscopic examination of specimens and an exceptionally varied stock of material upon which to work. § 190.

79. **Metallurgy of the Non-Ferrous Metals.**—The metallurgy of copper, zinc, lead, and other non-ferrous metals and alloys is taught by a course of lectures and recitations, followed by an advanced laboratory course on their properties and heat treatment. The principles of ore-dressing are also set forth through a course of lectures and recitations. § 190.

80. **Gas and Fuel Testing.**—This is a combined class and laboratory course involving the ordinary methods of technical gas analysis, and the determination of the heating value of solid fuel and of gas. The calibration of pyrometers is also studied.

81. **Portland Cement and Concrete.**—The changes which Portland cement undergoes as it sets and hardens are studied microscopically and also by delicate measurements of change of volume. Especial attention is paid to the causes of disintegration of concrete and to the efficiency of protective coatings and waterproofing compounds. The effects of variations in temperature of burning and in the composition of cement are studied on products made in a small rotary kiln installed in the laboratory where temperatures may be accurately controlled. § 190.

82. **Paints and Protective Coatings.**—The efficiency of paints is tested in the laboratory and also on exposure frames erected on the roof of the chemistry building. A minute study is made of the changes taking place in paint exposed to the weather. § 190.

83. **Chemical Engineering Machinery.**—Several courses are devoted to a study of the mechanical operations involved in the chemical industries and of the particular types of machines adapted to the work. These are followed by advanced courses in which the student may take some piece of chemical machinery and design it in detail; or take a process and select the types and sizes of machinery for carrying it out. Extensive laboratory study of the principles involved in the design of various types of apparatus. § 190.

Through the generosity of the Swenson Evaporator Company of Chicago, there has been established a laboratory for the study of evaporators, the principle representatives of the special apparatus used in the chemical industries. Studies are made of the effect on the rate of heat transmission of all the factors involved in evaporating apparatus, such as depth or density of liquid, disposition of heating surfaces, differences in steam pressure, etc. The great variety of problems arising in the design of film evaporators are the subject of other lines of investigation. Experiments on the manufacture of particular products on the factory sale are also carried out. The principles underlying other types of apparatus, such as filters, sprays, and cooling systems, etc., are also under investigation. Advanced research courses are offered in this laboratory for graduate students.

84. **Gas Engineering.**—The generation of gas from coal either in the producer or retort, its purification, distribution, and utilization for heating furnaces, or in gas engines, demand a very considerable special training in chemical engineering and mechanical engineering. The course in Chemical Engineering is sufficiently flexible to allow the desired specialization. § 190.

Advanced courses, primarily for graduates, are given in Chemical Engineering, and include seminary and research work. (See Announcement of Graduate School.)

85. **Marine Engineering and Naval Architecture** are subdivided as follows:

86. **Structural Arrangements of Ships.**—This course is devoted to the discussion of the practical details relating to the various parts of a ship's structure, such as keels, framing, plating, preparation of working drawings, ordering material, general methods of construction, and Classification Societies' rules. § 206.

87. **Ship Calculations.**—This course consists of a series of lectures and recitations upon the displacement and buoyancy of ships, and includes discussions of rules for determining areas, volumes, center of buoyancy, metacenters, change of trim, tonnage, freeboard, etc. The theory and use of the planimeter and integrator are also discussed. § 206.

88. **Strength of Ships.**—This course includes a general discussion upon the question of strength and resistance of materials, methods of obtaining curves of weights, buoyancy, shearing force, and bending moment upon ships under various conditions of wave support; general and local stresses, and strength of riveted joints. § 206.

89. **Stability of Ships.**—A series of lectures and recitations is devoted to the various methods of obtaining curves of stability, statical and dynamical, of vessels of different types under varying conditions. The geometrical properties of the surface of buoyancy, flotation, etc., are discussed, together with problems relating to the rolling of vessels in still water and in waves. Methods of reducing rolling are illustrated by models in the experimental tank. § 206.

90. **Resistance and Propulsion of Ships.**—Under this heading are treated all questions relating to the resistance of vessels to motion. Surface friction, wave making, eddy resistance, Froude's law of comparison, progressive trials, etc., are discussed and illustrated in the experimental tank. Investigations of the action and design of various forms of propellers and the analysis of their effect upon the resistance of the vessel are also discussed. § 206.

91. **Ship and Engine Specifications.**—A series of lectures is given which embraces a general discussion of the preparation of specifications. Methods of estimating weights and costs; arrangements of pumping, heating, and ventilation; auxiliary machinery, etc., are also included. In connection with the design of a ship or machinery installation each student is required to prepare a general specification. § 206.

92. **Marine Boiler Design.**—This course covers a general discussion of all details relating to the design, construction, and economy of marine boilers, together with the consideration of various kinds of fuels.

In the drawing course connected with the above, the student designs a marine boiler and all the necessary details. § 206.

93. **Marine Engine Design.**—Courses in this subject include all problems relating to the design and economy of multiple expansion marine engines. The detail design of the various parts, including condensers, air and feed pumps, balancing, etc., is also discussed.

In the drawing course connected with the above, the student designs a marine engine and all the necessary details. § 206.

94. **Steam Turbines, Gas, and Oil Engines.**—Courses in these subjects, which are accepted in Marine Engineering, are given by the department of Mechanical Engineering. § 206.

95. **Ship Drawing and Design.**—The above courses are accompanied by work in the drawing room, which include: Laying off and fairing a set of lines from given offsets; calculations of displacement, center of buoyancy, etc., and plotting results; construction of capacity curves; calculation of change of trim and curves connected therewith; of launching; of strength and determination of curves of weight, buoyancy, shearing forces, and bending moments; calculation of stresses; of curves of stability. § 206.

Later, the student works out a design for a vessel to fulfill given conditions, as, for instance, a fast passenger or cargo steamer, cruiser, battleship, torpedo boat, or steam yacht, and will prepare the lines, general arrangement, midship section, and all calculations connected with the above, and, if time permit, complete set of working plans, together with an order form and specifications.

96. **Experimental Tank Work.**—Students are given an opportunity of assisting in the moulding and preparation of the various models, and afterwards testing the same.

Experiments upon ships' forms are conducted in a systematic manner, and the results of such experiments will give the student an intelligent idea as to the capabilities of any given form.

The action of bilge keels upon the rolling of vessels, and upon the speed, are also subject to investigation. It is proposed in the

near future to install special apparatus for the investigation of the action and properties of screw propellers. § 206.

For description of Experimental Tank, see § 117.

Advanced Work.—Advanced courses, primarily for graduates, are given in Naval Architecture and Marine Engineering, and include seminary, design, and research work. (See Announcement of Graduate School.)

97. **Aeronautics—Theory.**—A series of courses dealing with properties of the atmosphere; principles of theoretical and experimental aerodynamics; aerodynamical properties of the various constructive elements of aeroplanes and airships; structural arrangements, resistance and propulsion, equilibrium and stability, operation and maintenance of all classes of modern aircraft; construction of aeronautical motors; equipment and construction of aerial posts and hangars.

98. **Aeronautics—Design.**—The theoretical courses as given above are followed by courses of lectures and drawing in which the question of strength and all details relating to the structural design of aeroplanes, airships, propellers, aeronautical motors, hangars, etc., are discussed and completed designs are made to fulfill a given set of conditions. § 206.

FACILITIES FOR INSTRUCTION

99. While the College recognizes that the benefits of instruction are far more dependent on the character of the instructors than upon any adjunct in the way of laboratory apparatus or of physical illustration, and with this in view have selected the instructing staff from among those qualified both by technical training and practical experience, nevertheless extensive use is made of the ordinary supplementary aids.

100. **Visits of Inspection.**—The educational value of visits of inspection is well recognized and trips of this sort are regularly made in connection with many of the courses. The wonderful industrial growth of the neighboring cities of Detroit and Toledo as well as other points in Michigan within easy reach of Ann Arbor allows a varied range of modern engineering structures and processes to be visited at small expense and at the time when the subjects are being studied by the class. Week-end trips are frequent, and during the Spring recess several parties are made up for longer trips, to the

Atlantic seaboard on the East and to Chicago and Mississippi river points on the West.

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

101. **Excursions.**—University is well situated for excursions to hydraulic and electrical power plants. In Ann Arbor there are a large modern telephone exchange and a power substation of the electric railroad. The Eastern Michigan Edison Company has four hydro-electric power stations, one at Ann Arbor and the others within a distance of four miles. These stations are of recent construction and illustrate the very latest engineering practice in hydraulic and electrical design.

At Detroit there is much of interest to students of electrical engineering, including the main power house and substations of the Detroit Edison Company, and of the Detroit United Railway, the electrically operated Michigan Central Railroad tunnel under the Detroit River, and the new railroad terminal. Each Spring it is the custom of the College of Engineering to organize parties which visit during the Spring vacation a considerable number of important engineering concerns in the central and eastern states.

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

There are within forty miles two of the most complete modern classification yards in the United States, illustrating all types of humps and other modern sorting, the New York Central freight terminals at Toledo and the Michigan Central passenger terminals at Detroit. The Detroit River tunnel and the street railway properties in both cities afford exceptional opportunities for inspection of important work. The coöperation of the railways with the work of the department extends not only to giving students access to the properties but to giving freely to the University plans of all standard and special structures, for illustrative material, as well as courses of lectures by officers of the companies.

From the standpoint of Automobile Engineering, the University

of Michigan has a strategic location at the very center of the automobile industry of the country. Detroit, Toledo, Flint, Jackson, Lansing, and Indianapolis, with the greatest automobile factories in the world, are within easy excursion distances, and each year an inspection trip is made under the direction of the Automobile Department. These trips, while primarily for Engineering students, are open to any who are interested.

102. **Physical Laboratory.**—The first floor of the physical laboratory is devoted to experimental work in electricity and magnetism, and to research. It contains about 8,000 square feet and is divided into fourteen rooms, including a battery room, an instrument shop, a large room for electrical measurements, and a smaller one for photometry. Two rooms are used for elementary instruction in direct and alternating current machinery and are equipped with various types of machines in common use, with the necessary instruments for testing. The rest of the rooms on this floor are used for research.

The battery room contains two storage batteries; one, consisting of one hundred twenty cells, of ten ampere capacity, and one, consisting of eighteen cells, of twenty-five ampere capacity. A switchboard, wired to all parts of the building, serves for the distribution of current from the batteries as well as the 220 and 110 volt direct current from the University power house and the 110 volt alternating current from the city lines. Compressed air is also available in several rooms.

On the second floor are two lecture rooms, one seating one hundred twenty and the other four hundred students. An apparatus room is adjacent to each lecture room. This floor contains, in addition, a large laboratory for beginners, the library, an office and three research rooms.

The third floor contains eleven rooms, the two largest of which are used as laboratories for beginners. Two rooms are used as classrooms and the rest for the advanced work in electro-chemistry and heat. On account of the crowded condition of the Physics building two rooms in the basement of Tappan Hall have recently been assigned to the Physics department. They are equipped for laboratory work in sound and light.

The laboratory is well supplied with apparatus from the best European and American makers, and the annual budget allows the addition each year of apparatus needed for the work of graduate students and for the illustration of recent advances in physics.

103. **Chemistry Building.**—The Chemistry building provides for the teaching of chemistry to students in all of the various departments of the University and for the technical work in the School of Pharmacy and the course in Chemical Engineering. The whole of an admirably designed, strictly fireproof building erected in 1909 at a cost slightly over $300,000 is devoted to those purposes. The

building is rectangular in shape, 230 x 130 feet, with two central courts, and is four stories high. It contains 125 rooms and has a total floor area of 104,500 square feet. The exterior was designed to give a maximum amount of window space, and artificial illumination by tungsten lamps has been installed on an equally generous scale. Ventilation is cared for by eight fans capable of changing the air in the entire building every eight minutes, and the heating is controlled by thermostats in each room. The hood facilities are excellent. Hydrogen sulphide, high pressure steam, compressed air, and distilled water are piped to the laboratories needing them, and special electric circuits have been freely provided. The store rooms occupy a stack six stories high, including basement and attic, placed in the central crossbar of the building, with provisions for dispensing on three main floors.

The library occupies the center of the south side of the building and is a handsomely finished room with shelf capacity for ten thousand books and seats for 85 readers. The chemical library contains 8,400 volumes and is especially rich in complete sets of journals. One hundred and eleven journals are currently received. The chemical museums on the third floor contain valuable exhibits illustrating chemical manufacturing processes.

In addition to a full supply of routine materials and apparatus for work in general, analytical, organic, physical, pharmaceutical, and technological chemistry, facilities are offered for advanced study along all of these lines.

104. **Equipment for Surveying.**—The equipment for surveying includes transits, levels, rods, tapes, etc., in sufficient number to supply two hundred students. Special equipment is provided for triangulation work. A launch and sounding apparatus is provided for the work in the summer camp. Current meters, barometers, hand levels, sextants, cameras for surveying and engineering photography, plane tables for topographic work, and numerous other small engineering and surveying instruments are provided.

105. **Camp Davis.**—In 1908 and 1909 the Regents of the University came into possession of about 1,600 acres in Cheboygan County, Michigan. A part of this came as a gift from Colonel Charles Bogardus and his wife, Hannah W. Bogardus. Since 1909 the Regents have purchased, from time to time, other tracts which have an area of about 3,200 acres. In recognition of the kindly interest of Colonel Bogardus and his wife, the entire area now owned by the University is called the Bogardus Tract. The surveying camp, situated on these lands, is known as Camp Davis, in memory of Joseph Baker Davis, who established the camp in 1874 and conducted it for over thirty years, many years before other universities followed the example thus set by Michigan. The University lands lie, generally speaking, between Douglas and Burt Lakes,

having a frontage of four and one-half miles on the former and one and three-fourths miles on the latter lake. The camp is six miles east of Pellston on the G. R. & I. Railroad, eight miles northwest of Topinabee on the Michigan Central Railroad, and thirteen miles southwest of Cheboygan. Douglas Lake is a beautiful sheet of water, four and one-half miles long and from one to two miles wide. Burt Lake, one mile to the south, is ten or eleven miles long, and it is one of the chain of lakes which go to make up a part of the famous Inland Water Route of Michigan. The lands have a varied topography. Camp Davis is located on the south shore of South Fishtail Bay, Douglas Lake. The quarters of the students, teaching staff, physician, store, office, etc., are located along the shore in a double row of steel buildings almost parallel with the water line of the lake.

The driveway in the street between them was given a good coat of gravel during the summer of 1916. A good gravel road was completed in 1918. In 1915 a new kitchen, twenty-eight feet square, with a concrete basement, was erected. This, with the mess tents, is located south of the camp on the slope of the hill twenty feet above the lake. The mess is conducted by a committee selected from the members of the student body each week. This committee has an advisor from the teaching staff. A well forty feet deep, near the center of the camp, furnishes an ample supply of pure, cold water, while the lake affords opportunity for bathing and boating. The camp is designed fundamentally to give students practice in surveying, yet they are given opportunity to design simple structures and to help carry out the plans thus made. A good harbor has been provided in this way. A cistern for storing water pumped from the well has been built and a pipe line extends therefrom to the main street of the camp, thus bringing the well water practically to each tent. A 4 H. P. kerosene engine furnishes power for pumping water and running a generator for lighting the camp. Two concrete storehouses have been built and a concrete platform for adjusting instruments has been laid. A complete sewer system with septic tank was installed in 1915.

An instrument building, fourteen feet by twenty-eight feet, was built in 1917, and affords excellent facilities for the storage, care, and issuing of instruments. A concrete sidewalk was laid along the north side of the main street of the camp in 1918.

A physician detailed from the University Health Service is in attendance each year.

The camp has telephone connection with Petoskey and Cheboygan and daily rural mail service from Topinabee. The mail address is Topinabee, Michigan, Camp Davis, R. F. D. No. 1.

106. **Engineering Shops.**—The engineering shops are in a group of connected buildings, and occupy about 30,000 square feet of floor space. Electric power is used throughout.

The *Wood and Pattern Shop,* 40 by 127 feet, is equipped with the tools and machinery usually found in a first-class establishment.

One end of the shop contains wood-benches and tools needed for hand work in wood. The other end contains benches and tools specially adapted for pattern-making. The central portion is occupied by a good variety of wood-working machinery. A lumber and pattern loft, 40 by 120 feet, contains blue-printing apparatus, materials, and a large collection of patterns made by students.

The *Foundry,* 30 by 120 feet, is equipped with two melting furnaces for cast iron, gas and coke furnaces for non-ferrous metals, core ovens, elevator, crane, blowers, molding machines, small tools, and other equipment for a large variety of foundry work. Castings are made weekly or oftener for the use of the different departments of the University. About seventy-five tons of iron are made into castings annually. Instruction is given in the use of green sand, dry sand, and loam work. A new chemical laboratory has been developed for research work in connection with the Foundry.

The *Forge Shop,* 40 by 127 feet, contains twenty-eight downdraft forges with anvils and tools for hand forging; equipment for bench work in metals, a large punching and shearing machine, a power hammer, and other special forging equipment, lathes, drills, planers, and grinders for elementary machine shop work, furnaces and other equipment for the heat treatment of steels, an oxy-acetylene welding outfit, and a large electric-driven fan for supplying blast to fires and for ventilation. The complete equipment is used for instruction in the fundamental principles and processes of metal working.

The *Machine Shop,* 40 by 127 feet, contains one or more of each of the principal types of machine tools now in general use. These comprise engine lathes, turret lathes, planers, sharpers, drilling, milling, and grinding machines, and others of more special types. These comprise a total of 48 power-driven machines. In addition, there are portable electric tools, compressed air equipment, and machines and devices operated by hand. An ample equipment of small tools for machine and hand use is maintained in a well-organized tool-room. The whole is used for instruction in the fundamental processes of machine construction.

In connection with each of these four shops there is a recitation room, in which are collected models, drawings, charts, diagrams, and books which are used in the courses of instruction.

The central portion of the building, 32 by 54 feet, contains lockers and lavatories in the basement, offices, and instrument shop.

The *Instrument Shop* is provided with machinery and tools for making apparatus and instruments for the laboratories of the University.

A good part of the equipment has been designed and built in the shops. New machinery is added from time to time by construc-

tion or purchase. The entire equipment is used in instructing engneering and other students in the use of tools for working in wood and in metals, and in modern workshop methods. Opportunity is afforded to become familiar with the more common materials and form of construction used in engineering structures, buildings, and machinery. In all work an effort is made to follow the practice of the best shops.

107. **The Mechanical Engineering Laboratory** is located in the Engineering building and occupies a floor space of some 13,000 square feet. It is devoted to experimental work in connection with the testing of engines, boilers, pumps, fans, air compressors, hydraulic machinery, and automobile engines. The very complete and modern Washington Street plant of the University is available for use, and a test of this plant constitutes a regular part of the second course in Mechanical Laboratory. Occasionally tests are made of outside plants in the vicinity of Ann Arbor.

The laboratory, as a whole, comprises all the equipment utilized for illustration of the theory involved in Mechanical Engineering and for experimental work of both standard and research nature. Separate laboratory instruction is given along the lines of hydraulic machinery and automobiles, and those parts of the equipment applying especially to these divisions are segregated as far as possible to form the Hydro-Mechanical Laboratory and the Automobile Laboratory. The general laboratory is well equipped with power machines of all kinds, which furnish the means of instruction in the principles of testing. Attention may be called particularly to the 13-ton ammonia refrigerating plant, which is practically new and complete in all respects; the 40 H. P. Stirling boiler; very good facilities for the testing of heating and ventilating apparatus; and very complete and well-selected equipment of instruments and small apparatus.

108. **The Hydro-Mechanical Laboratory** is equipped with a pair of 600-cubic-foot tanks on scales, a large Duplex pump, a Francis turbine, a Doble tangential water wheel, two Rees Roturbo pumps, as well as much other machinery, and all necessary accessories for testing.

109. **The Automobile Laboratory** consists of an engine testing section, a dynamometer room, and a section for the display and demonstration of automobiles, motor trucks, and their component parts. The engine testing section contains a complete equipment of engines, selected with a view to affording the student experience with various typical successful types. This section is equipped with prony brakes, water dynamometers, and one fan dynamometer. The dynamometer room contains a complete Diehl electric dynamometer and a 100 H. P. Sprague electric dynamometer, together with special fuel-

measuring devices, tachometers, air meters, pyrometers, gas analysis apparatus, manograph, and complete accessories necessary for instructional testing and advance research work. In the display and demonstration section are gathered together complete operating and cut-out chasses, various types of engines, cut-out transmissions, rear axles, differentials, clutches, carburetors, ignition systems, and other automobile parts and equipment. This apparatus is especially mounted to show its operation and design, and is used as demonstration study and test equipment for the regular automobile courses. It further serves as a permanent educational exhibit open to the public.

110. **The Physical Testing Laboratory** occupies two adjoining rooms, 29 x 54 feet and 27 x 54 feet, respectively, on the ground floor of the south wing of the building, and is equipped with apparatus especially designed for testing the strength of materials used in engineering work. This equipment includes a 100,000-pound Olsen testing machine and one of 200,000 pounds capacity built by Riehle Brothers. Both of these machines are adapted to tensil, compressive, and transverse tests, and are run by direct-connected electric motors. An Olson torsion machine of 240,000 inch-pounds capacity, also equipped with direct-connected motor, is used in determining the torsional strength of shafts and axles. Impact tests are made on an Olsen impact machine and Upton Lewis toughness testing machine is used for endurance tests. The cement testing laboratory is equipped for making the ordinary tests of cement and concrete. In addition to scales, sieves, briquet molds, and accessories, there are two briquet testing machines made by Olsen, and a uniform load beam testing machine, especially designed for the University of Michigan, with a capacity of 85 tons, and adapted to beams of reinforced concrete, wood, or steel of any span up to 12 feet.

111. **Highway Laboratory.**—The facilities afforded by the laboratory are sufficient to make all tests required to determine resistence to abrasion, hardness, toughness, cementing power, and absorption for rock, slag, and gravel; resistence to abrasion of paving brick; and complete tests of sand, soils, sand-clay mixtures, wood block, stone block, cement, cement-concrete, and bituminous materials. Among the more important pieces of apparatus are a Deval abrasion machine, ball mills, a pressure moulding briquette machine, a Page impact machine, a Dorry hardness machine, diamond core drills, grinding laps, a rock crusher, specific gravity apparatus, an Olsen cement briquette braking machine, a Per Se sieve shaker, a Dulin Rotarex extractor, standard penetrometers, ductility machines, chemical balances, electric ovens, sets of standard sieves and screens, drying ovens, moist closets, and various types of apparatus for the determination of voids in mineral aggregates. A testing machine has been specially designed and built for the testing of full size bridge members, concrete floor slabs, columns, arches, and beams.

The capacity of the machine is 300,000 pounds. The McCabe paving determinator, owned by the City of Detroit, which is designed to wear to destruction the surface of paved roadways, has been installed in this laboratory and is available for research students in highway engineering.

112. **The Sanitary Experiment Station.**—This laboratory in sanitary engineering is located near the campus, with thoroughly up-to-date equipment for the study of problems in public sanitation, more especially those relating to stream pollution and sewage disposal.

113. **Hydraulic Experimental Flume.**—Facilities for experimental work in the measurement of flowing water for discharges up to 250 cubic feet per second are afforded by a flume 138 feet long, 6.5 feet wide, and 8 feet deep. This flume with accompanying equipment is located just below the Argo Dam on the Huron River.

114. **The Electrical Engineering Laboratories** consist of a dynamo laboratory, communication laboratories, and a photometric laboratory.

The DYNAMO LABORATORY contains a full complement of direct and alternating current apparatus of various types and sizes, representative of the leading American manufacturers.

As in all of the electrical laboratory work, special emphasis is here laid upon the development of the student's ability to analyze the phenomena which he observes in the operation of electrical machinery. To this end, and with the aim of developing the personal initiative of the student, a large number of moderate sized machines have been provided in order to give each student intimate contact with the apparatus.

The laboratory is fully equipped with meters and instruments of various ranges, types, and makes. For calibration work there are standard resistances, standard cells, a potentiometer, and meters of the precision type. The equipment also includes a General Electric oscillograph with all accessories.

Distribution of power in the laboratories is controlled through a plug and socket system. This system gives great flexibility and requires that all connections be made by the student himself, but provides the means by which these operations may be quickly and easily performed.

The laboratory has on exhibit several dynamos of very early type which are of historic interest.

The COMMUNICATION LABORATORIES are unusually well equipped for both practical and theoretical experimental study of communication by electrical means.

The University's private branch exchange of some two hundred lines, adjacently located, together with an automatic and magneto

exchange in the laboratory, provides excellent facilities for practical study. As the laboratory is unusually well equipped with special instruments of the highest grade, the facilities for theoretical study are good.

One room is provided for the study of communication by wires, another for the study of radio-communication, and another for special group studies. In addition, there are several small rooms equipped for individual experimental work.

The PHOTOMETRIC LABORATORY is equipped with three fixed bars provided with the most accurate photometers of both equality and contrast types, and suitable auxiliary apparatus, such as lamp rotators; three portable photometers for making surveys of illumination; one precision photometer bar with complete accessories for standardization and investigation; a single mirror selector for making measurements on large light sources. The equipment includes a complete and modern collection of lamps and accessories, including mercury, magnetite, and carbon arcs, refractors, reflectors of all varieties in glass and metal, and head-light and flood-light projectors.

115. **University Power Plant.**—The new University Power Plant, which has recently been completed at a cost of $350,000, is a fine example of modern power plant construction and is available for instruction and for use. There have been installed eight 400 H. P. Wickes water-tube boilers with Murphy stokers, supplying steam at 150 pounds gauge pressure; an Allis-Chalmers cross-compound engine direct connected to a 625 K. V. A. generator producing 3-phase, 60-cycle alternating current at 2,300 volts; a 300 K. V. A. Curtis turbo-generator, equipped with Westinghouse-Le Blanc condenser; a 25 K. W. Allis-Chalmers motor-generator set; a 25 K. W. Allis-Chalmers turbine-driven exciter; a 15-ton engine room crane; a 3½-ton coal-handling crane; a pneumatic ash conveyor; two 2,000 H. P. feed-water heaters; two turbine-driven pumping units; two hot-well pumps; an air compressor; power and lighting transformers; and a distribution system for power and light. It is proposed in the future to obtain a supply of water from the river by means of an electrically-operated pumping station erected near the river. The feed-water heaters supply hot water to the boilers and also for domestic purposes. Coal is brought directly from the Michigan Central Railroad to the plant over an electrically-operated road, delivering the coal to a storage bin; thence it is taken to a coal-crusher and delivered to the steel bunker above the stoker-hoppers. The ashes are carried by a pneumatic conveyor to a bunker over the track, from which they are loaded directly into cars. Tunnels are provided for the underground distribution of steam, hot water, and electrical energy. There is available alternating current at 2,300 volts, 220 volts for lighting, and other voltages for power; also direct current at 220 volts and 500 volts; high and low-pressure steam, and hot water.

116. **Chemical Engineering Laboratories.**—The Chemical Engineering Laboratory occupies twenty-five rooms on the first and second floors of the Chemistry building and the whole south half of the old Campus power house. On the second floor of the Chemistry building are an office, two private laboratories, a laboratory accommodating four advanced students, a general laboratory with desks for twenty students, a balance room, and a fully equipped paint and varnish laboratory. On the first floor, aside from private laboratories for instructors and advanced students, there are facilities for regular instruction and research in gas and fuel analysis and testing, measurement of high temperatures, assaying, Portland cement manufacture, ceramics, metallography, metallurgy, heat treating, electrochemistry and electro-metallurgy, and pulp and paper manufacture. A bituminous materials laboratory is maintained in connection with the Civil Engineering department.

The EVAPORATOR LABORATORY, located in the south half of the old Campus power house, contains the following: A vertical tube evaporator, with a heating surface of from 40 to 100 square feet, equipped with a jet condenser, flat and cone bottoms; salt filter, pumps, and a special device for forced circulation. Provision is made in its design for increasing the heating surface, varying the disposition of the heating surface, increasing the foam space, making temperature and pressure measurements at any point, and adapting the operation to any type of liquor. A horizontal tube evaporator with similar flexibility. A special film type evaporator in which the phenomena in such evaporators are to be studied in the greatest detail possible. A model zeolite water-softening plant with a capacity of 50 gallons per hour. Weigh tanks, scales, condensed water receivers, storage tanks, and measuring apparatus for the most elaborate tests. Other types of equipment are continually being added. An instructor's office and a computing room adjoin the laboratory.

117. **Marine Engineering Laboratory.**—On the first floor of the Engineering building the east wing is devoted to the experimental tank. This tank is 300 feet long, 22 feet wide, with a depth of water of 10 feet. At the south end is a model room and work shop for the purpose of making models of vessels.

The models used in the tank for testing purposes are from ten to twelve feet, and are made of paraffin wax. A clay mould is first made approximately to the shape desired, and a core inserted. The paraffin is then poured into the mould, and after cooling the rough model is taken to the model cutting machine. This machine consists essentially of two moving tables or platforms, upon one of which is placed the model and upon the other the drawing which it is desired to reproduce. The model moves under a pair of rotating cutters, which are made to follow the lines on the drawing. After cutting, it is brought to its final shape by hand, then carefully weighed, and

sufficient ballast added to bring it to any desired draft and displacement.

The tank is spanned by a traveling truck which is driven by a motor and can be run at any desired speed. Upon this truck are mounted the dynamometers for measuring the resistance of the models of various forms at different speeds, and also for experiments upon thrust and efficiency of propellers.

118. **Aeronautics Laboratory.**—For students taking aeronautical courses facilities are provided in various laboratories of the Engineering College for special investigations of strength of materials and parts of aircraft structure, motor testing, comparative study of resistance of bodies in the naval tank; also studies are made of aero-dynamical properties of various bodies and aerofoils in an air current, 3 x 3 feet, velocity 40 miles per hour, provided by an air blower, in connection with which is a dynamometer newly constructed by the department. The dynamometer is of a type enabling a simultaneous determination of lift, drag, and center of pressure.

119. **Astronomical Observatory.**—The University Observatory was founded in 1852, through the liberality of citizens of Detroit, and on this account it was named Detroit Observatory. It is situated about one-half mile northeast from the University Library, at the corner of Ann and Observatory streets.

Its principal instruments are a reflecting telescope of 37⅜ inches clear aperture, equatorially mounted, and designed especially for photographic and spectroscopic work; a refracting telescope of 12¼ inches aperture, arranged for micrometric work; a six-inch meridian circle; a six-inch refractor with camera attached for celestial photography; a three-inch meridian transit with zenith telescope attachment; a comet seeker; mean and sidereal clocks; theodolites; chronometers; chronograph; seismographs; computing machines; sextants, etc.

The meridian circle and larger refractor are installed in the original Observatory building, the west wing of which contains the Observatory Library and connects with the residence of the Director.

A newer building adjoins the original one on the east, and contains the dome for the large reflecting telescope; laboratory, class, and computing rooms; offices, etc. A set of seismographs is installed in the basement of this building.

The small refractor and meridian transit are mounted in a small observatory near the main building, and are used principally for purposes of instruction.

For many years the Observatory has been receiving the principal astronomical publications and its technical library is reasonably complete. It includes nearly all the printed star catalogues, most of the modern publications of observatories and astronomical societies, and nearly complete files of the astronomical periodicals.

120. **Natural Science Building.**—A four-story fireproof building was erected in 1915 for the use of the departments of botany, forestry, geology, mineralogy, psychology, and zoölogy. The approximate measurements are for the north side 243 feet, for the east side 263 feet, for the west side 150 feet; and the south side, with a series of breaks, is made to conform in general to the diagonal walk and trees. A green-house is located on the south side at the east corner. The building encloses a court 120 feet across. A corridor about 700 feet in length runs through the center of each floor. There is a clear span of approximately 23 feet between the corridor and the exterior walls on both the campus and court sides. The form of construction gives unusually large windows, and these, combined with the light court in the center, allow excellent illumination of all rooms. The corridor floors are finished with terrazzo, the floors of the rooms with cement. The building contains 270 rooms. Each department is given a section from roof to basement. At the southwest corner on the diagonal walk is located a lecture room seating 500, with a preparation room attached. The lecture table is built in sections; each section runs on rollers and can be taken to any part of the building for the preparation of material. These sections fasten to stanchions set in the concrete floor; at the stanchions all sorts of plumbing and electric supplies are available, including low-voltage storage battery current. An isolated and well-lighted library for all departments in the building is located above the lecture room. This portion of the building is carried on structural steel.

There is a vacuum cleaning system throughout. Alternating current is used for power and for lighting and is available everywhere. There is a unit system of distribution of direct current at 220 volts and special outlets for direct current at 75 volts are well distributed. Cistern water and filtered water are available at certain places in the building. The building is well ventilated with a complete air supply and exhaust system. A special separate exhaust is provided for the toilets and certain other rooms. Pneumatic switches and diaphragm motors are used to control ventilation. The temperature is controlled by thermostats.

121. **The Mineralogical Laboratory** comprises 36 rooms located in the northeast portion of the Natural Science building. A suite of five rooms, designed especially for research, are located on the first floor. Three of these rooms have light-tight shutters, and are provided with piers equipped with water, gas, compressed air, and alternating and direct currents. The packing, store, and grinding rooms are also on this floor. The mineral collection, lecture room, model and apparatus rooms, and an office are on the second floor. The laboratories for the courses in general mineralogy, blowpipe methods, and mineral and rock analyses, several offices, and a stock room are on the third floor. On the fourth floor are the laboratories

for lithology, petrography, crystal measurements, and physical crystallography, a small lecture room, and offices for the staff and advanced students. A crystallization room is located in the subbasement.

The laboratory is well equipped with crystal models, natural crystals, and lecture and working collections of minerals, rocks, and thin sections. There is an excellent equipment of goniometers, polarization microscopes, and other crystallographic-optical instruments, necessary for the thorough study of minerals. These instruments are all of the most modern and approved types. The blowpipe and chemical laboratories possess every facility for the qualitative and quantitative determination of minerals and rocks. The equipment of the laboratory is such that special attention can be given to graduate work and special investigations in mineralogy and petrology.

122. **The Laboratories for Geology and Geography** are located in the Natural Science building, occupying the northern half of the eastern front and extending through the four floors of the building. They include a general geological laboratory for the work in physical geology, a laboratory for the work in geography and physiography, a paleontological laboratory, and soil laboratories, beside smaller private working laboratories for members of the staff of the department. In addition, there are the Russell seminary room, a departmental library of reference works, and adjoining it the map and folio room. In the southwestern corner of the building there is a larger natural science library room provided for the six science departments which occupy the building.

The several laboratories of the department are equipped with the necessary apparatus, including topographical-geological map models reference and working map collections, globes, charts, and other accessories for comprehensive studies. For the work on soils there are two connecting laboratories served by adjoining balance and stock rooms which are well equipped for a thorough study of the subject. For the work in vertebrate paleontology there is a large mounting room provided with a preparateur, whose time is given up to the mounting of the specimens for the geological museum.

For the use of assistants in the department and for advanced students, a number of special research rooms have been provided.

123. **The Libraries.**—A large new library building erected at the cost of $615,000 was opened in January, 1920. This building has general and special reading rooms for eight hundred students at one time, and is equipped with modern appliances for the housing and serving of books. The University libraries receive over 2,000 periodicals annually.

THE ENGINEERING LIBRARY, comprising about 17,000 volumes, is housed in the Engineering building. The latest and best books on

professional subjects are added yearly to the library, where they are accessible to all; and frequent references are made to them in the classroom as the various subjects are brought forward. Over one-half of the collection consists of files of professional periodicals and proceedings of engineering societies. Funds being now available, extensive additions to the books and periodicals, particularly foreign periodicals, will be made during the coming year.

The number of volumes in the Engineering and Architectural Libraries was 17,067 on June 30, 1919. The number of volumes in the University Library on the same date was 413,880. The accessions during the year should bring the figures up to about 17,500 and 430,000, respectively.

THE DAVIS LIBRARY OF HIGHWAY ENGINEERING, located in Room 407 of the Engineering building, is the most complete collection of work on highway engineering and highway transport in this country. All the most recent books in English, French, and German have been purchased and, in addition, many old volumes, which are of interest from a historic point of view, have been secured. Town, municipal, county, park, state, and government reports and specifications, many monographs and complete files of trade publications also form an important part of this library. All technical periodicals which contain articles relative to highway engineering and highway transport are on file, hence the latest literature on the science and art of highway engineering and highway transport is available.

THE ENGLISH LIBRARY, in Room 8 of the Old Engineering building, contains a collection of reference books for the use of students in English courses.

SOCIETIES

124. The Engineering Society.—The Engineering Society of the University of Michigan is an organization of students formed by the affiliation of sections from each department of the College of Engineering. Membership in the sections is voluntary and is regulated by the constitution of each section. Such membership entitles the students to all the privileges of the general society.

The general society has as its primary purpose the creating of a broader field of vision for the Engineering student. This it attempts to accomplish by providing the opportunity for closer associations and the promotion of a social spirit among the students of the several departments; by securing as speakers at its meetings engineers of prominence in all fields of the profession; and by the publication of articles of general information to the student. As a further means to this end the society publishes quarterly a journal, called *The Michigan Technic,* which contains papers read before the society, abstracts of theses, contributed articles from the alumni and

faculty members, and other matters of interest to the student and the profession. A reading room is also maintained by the society where all the leading magazines and technical papers are accessible.

125. The sections of the general society are as follows:

Civil Engineering Section. This section holds meetings at least once a month at which papers of particular interest to the civil engineer are read and discussed. In the several sections, original papers are presented and the members are encouraged to take active part in the discussions, thus fitting themselves for a broader field of endeavor when they enter into the actual practice of their chosen profession. Helpful criticisms and suggestions are given by faculty members and the student is aided in every way in acquiring the art of public speaking.

Mechanical Engineering Section. This section of the general society is also a **student branch of The American Society of Mechanical Engineers.** Meetings of the section are held at least once a month, at which original papers by the students and the Proceedings of the A. S. M. E. are read and discussed. Each active member of the section receives, in addition to *The Technic,* the monthly *Journal* of the A. S. M. E.

Electrical Engineering Section. This section is a **student branch of The American Institute of Electrical Engineers.** In joining it, the student makes a connection which usually extends throughout his whole professional life after graduation, and which helps him materially by furnishing opportunities for advancement. The meetings which are held twice each month are managed entirely by the students, who procure speakers from among themselves or from professionals in the field, and who derive valuable experience in self-expression as well as technical knowledge from the discussions which they must make for themselves. Each member of the branch receives, in addition to the quarterly *Michigan Technic,* a copy of the Proceedings of the A. I. E. E., which are issued once each month.

Chemical Engineering Section. This section provides in its constitution for at least eight meetings during the academic year. Subjects of particular interest to the chemical engineer are presented.

126. Physical Colloquium.— In the Department of Physics meetings are held every week during the college year, at which the instructors and assistants in the department come together to report on original research and discuss important articles in current physical literature. The meetings are intended primarily for graduate students, but are also open to undergraduates doing advanced work.

FELLOWSHIPS

127. **Roy D. Chapin Fellowship in Highway Transport.**—This fellowship is offered to provide for the investigation of an approved subject relative to Highway Transport. It pays the sum of $250 per semester or winter period, December to March, with an allowance of $50 for expenses.

Roy D. Chapin Fellowship in Highway Engineering.—This Fellowship is offered to provide for the investigation of an approved subject relative to hard-surfaced roads and pavements. It pays the sum of $250 per semester or winter period, with an allowance of $50 for expenses.

Detroit Edison Fellowships in Highway Engineering.—Two Fellowships are offered for the investigation of approved subjects relative to moderate-cost country roads. Each Fellowship pays the sum of $250 per semester or winter period, with an allowance of $50 for expenses.

National Steel Fabric Company's Fellowship in Highway Engineering.—This Fellowship is offered to provide for the investigation of the design of cement-concrete pavements and foundations as structures. It pays the sum of $250 per semester or winter period.

The United States Radiator Corporation's Fellowship in Mechanical Engineering.—The United States Radiator Corporation of Detroit, Mich., has maintained since 1916 a Fellowship with a value of five hundred dollars for the study of problems in Heating and Ventilation.

The Ric-wil Company's Fellowship in Mechanical Engineering.—In January, 1920, the Ric-wil Company of Cleveland, Ohio, established a Fellowship to continue for two years for the investigation of the loss of heat from underground steam and hot water piping.

The Acme White Lead and Color Works Fellowship in Paints.—This Fellowship in the Department of Engineering Research is offered to provide for the investigation of the Settling of Suspensions. It pays the sum of $1,000 per year, of which sum $750 goes to the holder of the Fellowship.

The Detroit Edison Fellowship in Metallurgy.—This Fellowship in the Department of Engineering Research is offered for the investigation of subjects relating to metallurgy. The present problem is "Equilibrium Conditions in Malleable Iron." Eleven hundred and ninety dollars has been made available for use in this Fellowship from January 1 to July 1.

The National Twist Drill and Tool Company Fellowship.—The National Twist Drill and Tool Company of Detroit established two fellowships of $500 each for the University year 1920-1921, in connection with the work in the Engineering Shops.

SCHOLARSHIPS

128. **William James Olcott Scholarships.**—In June, 1916, Mr. William J. Olcott of Duluth, Minnesota, gave to the University the sum of five thousand dollars for the establishment of a Scholarship open to students in the College of Engineering. The amounts awarded, when repaid, shall accumulate towards the foundation of further scholarships.

Paul Wheeler Warriner Scholarship.—A loan fund of $300 given in memory of Paul Wheeler Warriner, a member of the Engineering Class of 1920, who died in his freshman year.

LOAN FUNDS

129. **The Benjamin Sayre Tuthill Fund.**—The Benjamin Sayre Tuthill Fund was established in 1910, in memory of Benjamin Sayre Tuthill of the class of 1909 in Civil Engineering, who died at Albuquerque, New Mexico, May 30, 1910. This fund "is to consist of a sum of money, contributed by his friends, which shall be available to students as a loan fund at a moderate rate of interest. When, through the contributions added from time to time and the earnings of the loans, this fund shall have reached such proportions as will support a scholarship, it may be used if advisable. It is the intent that the Memorial be used in the most practical way possible to aid struggling students." The administration of the Fund is left, by the deed of establishment, in the hands of a Trustee appointed by the Dean.

The John Frank Dodge Loan Fund.—Seniors and juniors of the College of Engineering may borrow from this $10,000 fund to the amount of one hundred dollars for any one year when their records and needs warrant such a loan. The fund is administered by the President of the University, the Dean of the College, and the head of the department in which the applicant for aid is enrolled. All loans must be paid with five per cent interest two years after graduation, the interest being reckoned from date of graduation.

Class Fund of 1914.—A fund of $400 was established by the Class of 1914, to be increased in the future by gifts from members of the class. A senior in the College of Engineering may secure a loan from this fund by applying to the head of his department, to the Dean of the College, or to the President of the University. These loans are payable in two years without interest.

Class Fund of 1915.—A fund of $232 was contributed by the Class of 1915 to be used as a loan fund for senior or junior Engineering students.

Class Fund of 1917.—The Class of 1917 contributed $300 to be used as a loan fund for Engineering students.

George H. Benzenberg Trust Fund.—In the Fall of 1920 Mr. George H. Benzenberg gave in trust to the University $20,000, the interest of which is to be available to loan to Engineering students in need of aid to complete their studies.

DEGREES CONFERRED IN THE COLLEGE OF ENGINEERING

130. The University of Michigan confers on all graduates of the College of Engineering the degree of Bachelor of Science in Engineering, the diploma designating the branch of engineering which the student has pursued.

Graduate Courses Leading to the Degree of Master of Science in Engineering and to the Degree of Civil Engineer, Mechanical Engineer, Electrical Engineer, Chemical Engineer, Naval Architect, Marine Engineer, and Aeronautical Engineer

Candidates for these degrees register in the Graduate School. For particulars, see the annual announcement of the Graduate School, which may be obtained upon application to the Secretary of the University.

131. REQUIREMENTS FOR GRADUATION

To secure a degree in the College of Engineering, a student must meet the following requirements:

1. He must complete the required courses of his department (§§ 141-145).

2. He must complete a sufficient number of group options (§§ 141-145) or other courses of University grade approved by the head of his department to make a total of 140 credit hours.

A student may not, in general, offer as group options advanced credits earned in the preparatory school.

Hours of Work Required for the Degree of Bachelor of Science in Engineering

Subject.	Civ.	Mch.	Elec.	Chem.	Mar.	Aero.
English	6	6	6	6	6	6
Language and Cultural Electives	16	16	16	16	16	16
Mathematics	18	18	18	16	18	18

Physics	10	10	14	10	10	10
Chemistry	5	5	5	30	5	5
Astronomy	2	0	0	0	0	0
Geology	3	0	0	0	0	0
Drawing	4	4	4	4	4	4
Shop Practice	4	12	8	4	4	12
Surveying	15	2	2	2	2	2
Engineering Mechanics	12	12	12	7	12	12
Civil Engineering	22	3	3	0	3	3
Mechanical Engineering	4	29	4	9	26 or 20	23
Electrical Engineering	4	4	32	4	4	4
Chemical Engineering	3	3	3	19	3	3
Marine Engineering	0	0	0	0	15 or 21	0
Aeronautical Engineering	0	0	0	0	0	14
Group Options	12	15	13	13	12	8
*Military Science and Tactics	0	0	0	0	0	0
Total	140	140	140	140	140	140

132. MODERN LANGUAGES AND CULTURAL ELECTIVES

All regular students in the College of Engineering are required to complete the equivalent of Course 4 in French or German as given in the University, or Course 3 in Spanish if preceded by two years of Latin in the high school. Course 2 in Spanish if preceded by at least three units of Latin or Greek, will satisfy this modern language requirement. After completing this requirement, students must elect courses from the following list, until they have 16 hours of college credit in foreign languages and other cultural studies: English, Foreign Languages, Oratory, History, Political Science, Political Economy, Sociology, Philosophy, Fine Arts, Music. Students whose language is other than English may substitute English for French, German, or Spanish, the maximum amount of English being seventeen hours. Plane Trigonometry and Chemistry 1 and 1*a* or 1*b* will be included in this list when college credit is given in these studies.

To secure credit in Music, courses must be chosen from those scheduled in the College of Literature, Science, and the Arts.

English may be substituted for German, French, or Spanish in satisfying the requirements for graduation in the case of students whose native language is other than English. The administration of this rule is left to the professor in charge of English.

Students in the College of Architecture are required to complete Course 3 in French or German.

* May be substituted for other courses, subject to approval of Heads of Departments.

133. PROGRAM I. CIVIL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. (2E) or Engl. 1	5 or 4	Engl. or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom. (Math. 2)	4
Drawing 4	2	Drawing 5	2
Shop 1 or 2	2	Shop 1 or 2	2
Total hours	17 or 16	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus (Math. 3)	5	Calculus (Math. 4*a*)	3
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Chem. Eng. 1	3	Statics (E.M. 1)	4
		Drafting Room Practice (C.E. 1)	2
Total hours	17	Total hours	18

Third Year

Calculus (Math. 4*b*)	2	Astronomy 3E	2
Geology 1	3	Surveying 2	4
Surveying 1	3	Hydromechanics (E.M. 4)	2
Strength, Elasticity (E.M. 2)	3	Theory of Structures (C.E. 2)	3
Dynamics (E.M. 3)	3	Design of Structures (C.E. 2*a*)	2
Elec. App. 1 (E.E. 2A)	4	Heat Engines (M.E. 3)	4
Total hours	18	Total hours	17

Summer Session

To be taken at end of third year
Surveying 3 — 8 hours

Fourth Year

Masonry (C.E. 3)	3	Advanced Masonry (C.E. 6)	2
Hydrology (C.E. (10)	3	English 5, 6, 9, 10, or 14	2
Water Works (C.E. 30)	3	Group Options	9
Sewerage (C.E. 32)	2		
Highway Eng. (C.E. 40)	2		
Group Options	3		
Total hours	16	Total hours	13

* See Sec. 132.

134. PROGRAM II. MECHANICAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. (2E) or Engl. 1	5 or 4	Engl. 1 or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom. (Math. 2)	4
Shop 1 or 2 and Des. Geom.	4	Des. Geom. 5 and Shop 1 or 2	4
Total hours	17 or 16	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus 1 (Math. 3)	5	Calculus 11 (Math. 4)	5
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Eng. Materials (Chem. Eng. 1)	3	Statics (E.M. 1)	4
Machine Draw. (M.E. 1)	2		
Total hours	19	Total hours	18

Summer Session

Elec. Apparatus I (E.E. 2A)	4
Foundry and Pattern Shop (3)	4
Total hours	8

Third Year

Strength, Elasticity (E.M. 2)	3	Machine Shop	4
Dynamics (E.M. 3)	3	Hydromechanics (E.M. 4)	2
El. of Mach. Des. (M.E 2)	3	Thermodynamics (M.E. 5)	3
Heat Engines (M.E. 3)	4	(a) Mach. Design (M. E. 6)	
(a) Mech. Lab. (M.E. 7) and Ch. E. 10, or		(b) Hyd. Mach. and Mech. Lab. (M.E. 4, 8)	4 or 6
(b) Surveying 4	3 or 2	(a) Surveying 4 or	
		(b) Mech. Lab. (M.E. 7) and Ch. E. 10	2 or 3
Total hours	15 or 16		15 or 18

Fourth Year

(a) Hyd. Mach. & Mech. Lab. or		Power Plants (M.E. 9)	3
(b) Machine Des.	6 or 4	M.E. 11a, 12a, 15a, 16a, 17a, 20a, 21a, 30a, or 31a	2 or 3
Machine Movements (M.E. 10)	2	Group Options	12 or 13
M.E. 11, 12, 13, 15, 16, 17, 20, 30, or 31	2 or 3		
English 5, 6, 9, 10, or 14	2		
C.E. 2	3		
Group Options	2		
Total hours	15, 17, or 18	Total hours	17, 18, or 19

135. PROGRAM III. ELECTRICAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. or Eng. 1	5 or 4	Eng. 1 or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom. (Math. 2)	4
Drawing 4	2	Drawing 5	2
Shop 1 or 2	2	Shop 2 or 1	2
Total hours	17 or 16	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus 1 (Math. 3)	5	Calculus 11 (Math. 4)	5
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Machine Shop (4)	4	Surveying 4	2
		Elementary Electrical Design E.E. 1)	2
Total hours	18	Total hours	18

Summer Session

Eng. Materials (Chem. Eng. 1)	3
Statics (E.M. 1)	4
Total hours	7

Third Year

Strength, Elasticity (E.M. 2)	3	Elec. Measurement (Phys. 5E)	2
Dynamics (E.M. 3)	3	Theory of Structures (C.E. 2)	3
Hydromechanics (E.M. 4)	2	Elec. App. II (E.E. 3)	4
Heat Engines (M.E. 3)	4	English 5, 9, 10, or 14	2
Elect. App. I (E.E. 2)	4	Group Options	3
Illum., Photometry (E.E. 7)	2	Mechanism of Electrical Machines (E.E. 14)	3
Total hours	18	Total hours	15 to 18

Fourth Year

Elec. Measurements (Phys. 6E)	2	Electro-Mechanics (E.E. 17)	4
Elec. App. III (E.E. 4)	4	Group Options	6 to 9
Design of Elec. Mach. (E.E. 5)	4	English 6	2
Power Plants, Trans. and Distribution (E.E. 11)	5		
Group Options	3		
Total hours	18	Total hours	12 to 15

136. PROGRAM IV. CHEMICAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. or Engl. 1	4 or 5	Engl. or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom (Math. 2)	4
Drawing 4	2	Drawing 5	2
Shop 1 or 2	2	Shop 1 or 2	2
Total hours	16 or 17	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus I (Math. 3)	5	Calculus II (Math. 4*a*)	3
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Qual. Analysis (Chem. 3)	5	Quant. Analysis (Chem. 5) or Chem. Eng. 1, 2, and 9	5 or 6
Total hours	19	Total hours	17 or 18

Summer Session

Theoretical Chem. 8E	3
Chemistry 5, or Chem. Eng. 1, 2, and 9	5 or 6
Total hours	8 or 9

Third Year

Organic Chem. (Chem. 7)	5	Organic Chem. (Chem. 7*a*)	5
Quant. Analysis (Chem. 28)	3	Mat. of Const. (E.M. 2 or 6)	3
Statics (E.M. 1)	4	Mach. Draw. (M.E. 1)	2
Heat Engines (M.E. 3)	4	Salts, Acids, etc. (Ch.E. 4)	2
Metal. of Iron and Steel (Ch.E. 6)	2	Group Options	7
Total hours	18	Total hours	18

Fourth Year

Carbon Comp. (Ch.E. 5)	4	Elect. App. I (E.E. 2A)	4
Special Problems (Ch.E. 12)	5	Surveying 4	2
Elem. Mach. Des. (M.E. 2)	3	Group Options	2
English 5, 6, 9, 10, or 14	2		
Group Options	4		
Total hours	18	Total hours	8

137. PROGRAM V. MARINE ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. (2E) or Engl. 1	5 or 4	Engl. or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom. (Math. 2)	4
Shop 1 or 2 and Des. Geom. 4	4	Des. Geom. 5 and Shop 1 or 2	4
Total hours	17 or 16	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus 1 (Math. 3)	5	Calculus 11 (Math. 4)	5
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Surveying 4	2	Statics (E.M. 1)	4
Machine Drawing (M.E. 1)	2		
Total hours	18	Total hours	18

Summer Session

Dyn. Elec. Mach. (E.E. 2A	4
Elective	4
Total hours	8

Third Year

Strength, Elasticity (E.M. 2)	3	Hydromechanics (E.M. 4)	2
Dynamics (E.M. 3)	3	Thermodynamics (M E. 5) or	
El. Mach. Des. (M.F. 2)	3	Ship Drawing Design (N.A. 6)	3
Heat Engines (M.E. 3)	4	Machine Design (M.E. 6)	4
Structural Design (N.A. 1)	1	Mech. Laboratory (M.E. 7)	2
Structural Drawing (N.A. 5)	2	Eng. Materials (Ch.E. 1)	3
		Ship Calculation (N.A. 2)	3
Total hours	16	Total hours	17

Fourth Year

Hyd Machinery (M.E. 4)	3	English 5, 6. 9, 10, or 14	2
Mech. Laboratory (M.E. 8)	2	Resistance, Propulsion (N.A. 4)	3
Internal Com. Eng. (M.E 15) or		Marine Engines (Mar. E. 9)	2
Stability of Ships (N.A. 3)	3	Group Options	8
Marine Boilers (Mar.E 8)	1		
Draw. and Des. (Mar E. 10)	3		
Theory of Structures (C.E. 2)	3		
Total hours	15	Total hours	15

138. PROGRAM VI. AERONAUTICAL ENGINEERING

First Year

FIRST SEMESTER		SECOND SEMESTER	
*Modern Language	4	*Modern Language	4
Gen. Chem. (2E) or Engl. 1	5 or 4	Engl. or Gen. Chem. (2E)	4 or 5
Alg. and Anal. Geom. (Math. 1)	4	Alg. and Anal. Geom. (Math. 2)	4
Shop 1 or 2 and Des. Geom. 4	4	Des. Geom. 5 and Shop 1 or 2	4
Total hours	17 or 16	Total hours	16 or 17

Second Year

*Language	4	*Language	4
Calculus 1 (Math. 3)	5	Calculus 11 (Math. 4)	5
Mech., Sound, Heat (Phys. 1E)	5	Magn., Elect., Lt. (Phys. 2E)	5
Surveying 4	2	Statics (E.M. 1)	4
Machine Drawing (M.E. 1)	2		
Total hours	18	Total hours	18

Summer Session

Shop 3	4
Elect. App. I (E.E. 2A)	4
Total hours	8

Third Year

Shop 4	4	Hydromechanics (E.M. 4)	2
Strength, Elasticity (E.M. 2)	3	Thermodynamics (M.E. 5)	3
Dynamics (E.M. 3)	3	Machine Design (M.E. 6)	4
El. Mach. Des. (M.E. 2)	3	Eng. Materials (Ch.E. 1)	3
Heat Engines (M.E. 3)	4	Theory of Structures (C.E. 2)	3
General Aeronautics (Aero. 1)	2	Theory of Aviation (Aero. 2)	2
Total hours	19	Total hours	17

Fourth Year

Mech. Lab. (M.E. 7)	2	English 5, 6, 9, 10, or 14	2
Internal Com. Eng. (M.E. 15)	3	Mech. Laboratory (M.E. 32)	2
Theory and Design of Propellers (Aero. 3)	3	Aerodynam. Lab. (Aero. 5)	1
Aeropl. Design (Aero. 4, 4*a*)	4	Design of Aeronaut. Motors (Aero. 6)	2
Group Options	3	Group Options	5
Total hours	15	Total hours	12

139. COURSES COMMON TO THE DIFFERENT PROGRAMS IN THE COLLEGE OF ENGINEERING

The following required studies are common to all the programs in the College of Engineering:

English 1, Theme-writing and Oral Expression	4 hours
English 5, 6, 9, 10, or 14	2 hours
Modern Language and Cultural Electives	16 hours
Mathematics 1, Algebra, and Analytic Geometry	4 hours
Mathematics 2, Algebra and Analytic Geometry	4 hours
Mathematics 3, Differential Calculus	5 hours
Mathematics 4a, Integral Calculus	3 hours
Physics 1E, Mechanics, Sound, and Heat	5 hours
Physics 2E, Magnetism, Electricity, and Light	5 hours
Chemistry 2E, General and Inorganic Chemistry	5 hours
Drawing 4 and 5, Descriptive Geometry	4 hours
Shop 1, Wood, and 2, Forge Shop	4 hours
Eng. Mech. 1, Statics	4 hours
Eng. Mech. 2, Materials of Construction	3 hours
Mech. Eng. 3, Heat Engines	4 hours
Elect. Eng. 2, Electrical Apparatus I (or 2A)	4 hours
Chem. Eng. 1, Engineering Materials	3 hours
	79 hours

The following studies are common to most of the programs:

Math. *4b*, Diff. Equations (except Chemical)	2 hours
Surveying 4, Use of Instruments (except Civil)	2 hours
Eng. Mech. 3, Dynamics (except Chemical)	3 hours
Eng. Mech. 4, Hydromechanics (except Chemical)	2 hours
Civil Eng. 2, Theory of Structures (except Chemical)	3 hours
Mech. Eng. 1, Machine Drawing (except Civil and Electrical)	2 hours
Mech. Eng. 2, Elements of Mach. Design (except Civil and Electrical)	3 hours

140. THE GROUP SYSTEM OF ELECTIVE STUDIES

In July, 1912, there went into effect a complete revision of all the programs in Engineering by which it was made possible for a student in his senior year to have a much wider range of elective work than formerly. The new system provides that of the 140 hours of credit required for graduation, 125 to 128 hours only are prescribed and 12 to 16 hours may be elected. These elections may be made from the groups of studies outlined

below or from other courses approved by the head of the department.

The group system allows the student to receive his instruction in the advanced subjects from a specialist. It also permits a student desiring to take up a fifth year of study to specialize in some particular branch of engineering. A student in any group will be allowed to elect work in the other departments of engineering or in the other colleges or schools of the University, subject to the approval of the head of his department. A student desiring to obtain special scientific knowledge or special business training by building on the fundamental subjects of engineering may be allowed to elect scientific courses or courses in economics or business administration under the direction and approval of the head of his department.

The groups of studies and the scope of the work which they cover are given in the following:

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141. CIVIL ENGINEERING

1. *Outline of Required Courses.*

a. Preparatory Courses.

English 1, and choice of English 5, 6, 9, 10, or 14	6 hours
Modern Language or Cultural Electives	16 hours
Mathematics 1, 2, 3, 4*a*, 4*b*	18 hours
Physics 1E, 2E	10 hours
Chemistry 2E	5 hours
Drawing 4 and 5, Descriptive Geometry	4 hours
Astronomy 3	2 hours
Geology 1	3 hours
Shop Work 1 and 2	4 hours
	68 hours

b. Secondary and Technical Courses

Chem. Eng. 1, Engineering Materials	3 hours
Surveying 1, 2, 3	15 hours
Eng. Mech. 1, Statics	4 hours
Eng. Mech. 2, Materials of Construction	3 hours
Eng. Mech. 3, Dynamics	3 hours

Eng. Mech. 4, Hydromechanics	2 hours
Civil Eng. 1, Drafting Room Practice	2 hours
Civil Eng. 2, Theory and Structures	3 hours
Civil Eng. 2*a*, Design of Structure	2 hours
Civil Eng. 3, Masonry	3 hours
Civil Eng. 6, Advanced Masonry	2 hours
Civil Eng. 10, Hydrology	3 hours
Civil Eng. 30, Water Works	3 hours
Civil Eng. 32, Sewerage	2 hours
Civil Eng. 40, Highway Engineering	2 hours
Mech. Eng. 3, Heat Engines	4 hours
Elec. Eng. 2A, Electrical Apparatus I	4 hours
	60 hours

Summary:

Preparatory Courses	68 hours
Secondary and Technical Courses	60 hours
Group Options	12 hours
Total	140 hours

2. *Outline of Group Options.*

In the selection of his 12 hours of elective work, the student may choose his studies from the groups as outlined below:

Every student is required to elect one of the design courses, either C. E. 5, 7, 16, 25, 35, or 43, together with the accompanying theory course.

A. Structural Engineering.
B. Hydraulic Engineering.
C. Transportation Engineering.
D. Sanitary and Municipal Engineering.
E. Highway Engineering and Highway Transport.
F. General Engineering Science.

A. STRUCTURAL ENGINEERING.

Eng. Mech. 5, Testing Materials	2 hours
Civil Eng. 4, Higher Structures	2 hours
Civil Eng. 5, Design of Structures	3 hours
Civil Eng. 7, Advanced Design of Reinforced Concrete Structures	3 hours
Civil Eng. 8, Analysis and Design of Arches	2 hours
Civil Eng. 26, Specifications and Contracts	2 hours
Civil Eng. 27, Public Utility Problems	1 hour
Civil Eng. 42, Highway Engineering Laboratory	2 hours
Mech. Eng. 20, Mechanical Handling of Materials	2 hours
Chem. Eng. 6, Iron and Steel	2 hours
Chem. Eng. 8, Metallography	2 hours
Political Economy 1E, Elements of Economics	3 hours

Students electing Group A are required to elect Design Course 5 and Course 4, the accompanying theory course.

B. HYDRAULIC ENGINEERING.

Civil Eng. 11, Hydraulics	2 hours
Civil Eng. 12, Development of Water Power	3 hours
Civil Eng. 13, Administration of Water Resources	2 hours
Civil Eng. 14, Irrigation and Drainage	2 hours
Civil Eng. 16, Design of Hydraulic Structures	3 hours
Civil Eng. 18, Rivers and Harbors	1 hour
Civil Eng. 26, Specifications and Contracts	2 hours
Civil Eng. 27, Public Utility Problems	1 hour
Civil Eng. 61, Irrigation and Drainage, Advanced	2 hours
Civil Eng. 62, Hydraulic Design, Advanced	2 hours
Civil Eng. 64, Hydraulic Engineering Research	———
Mech. Eng. 4, Hydraulic Machinery	3 hours
Mech. Eng. 16, Water Turbines	3 hours
Mech. Eng. 20, Mechanical Handling of Materials	2 hours
Elec. Eng. 3a, Alternating Current Apparatus	4 hours
Elec. Eng. 11, Power Plants, Transmission and Distrib.	5 hours
Elec. Eng. 33, Industrial Electrical Engineering	2 hours
Elec. Eng. 36, Rates and Cost Analysis	1 hour
Math. 57, Graphical Methods	2 hours
Math. 58, Empirical Formulae	2 hours
Political Economy 1E, Elements of Economics	3 hours

Students electing Group B are required to elect Design Course 16 and Course 12, the accompanying theory course.

C. RAILROAD TRANSPORTATION ENGINEERING.

Surveying 9, Railway Surveying	2 hours
C.E. 20, Railroad Location	2 hours
C.E. 21, Railroad Engineering	2 hours
C.E. 22, Transportation	2 hours
C.E. 23, Railroad Design	3 hours
C.E. 26, Specifications and Contracts	2 hours
C.E. 27, Public Utility Problems	1 hour
E.E. 8, Electric Railways	2 hours
E.E. 11, Electric Generating Stations and Substations	2 hours
E.E. 13, Telephones	4 hours
E.E. 36, Rates and Cost Analysis	1 hour
Pol. Ec. 1E, Elements of Economics	3 hours
Pol. Ec. 6, Transportation Problems	3 hours
Pol. Ec. 15, The Corporation Problem	3 hours
Pol. Ec. 38E, Elements of Accounting	3 hours

Students electing Group C are required to elect Design Course 23 and Courses 20 and 21, accompanying theory courses.

D. SANITARY AND MUNICIPAL ENGINEERING.

Surveying 7, Municipal Surveys..... 2 hours
Civil Eng. 17a, Concrete and Steel Highway Bridge Design..... 3 hours
Civil Eng. 11, Hydraulics ..... 2 hours
Civil Eng. 26, Specifications and Contracts..... 2 hours
Civil Eng. 27, Public Utility Problems..... 1 hour
Civil Eng. 31, Water Purification ..... 2 hours
Civil Eng. 33, Sewage Disposal ..... 2 hours
Civil Eng. 34, Municipal and Industrial Sanitation.... 2 hours
Civil Eng. 35, Sanitary Engineering Design..... 3 hours
Civil Eng. 36, Municipal Engineering ..... 2 hours
Civil Eng. 41, Highway Transport Surveys and the Theory and Economics of Highway Improvements. 2 hours
Civil Eng. 42, Highway Engineering Laboratory..... 2 hours
Mech. Eng. 20, Mechanical Handling of Materials.... 2 hours
Mech. Eng. 25, Heating and Ventilation..... 2 hours
Elec. Eng. 7, Illumination and Photometry..... 2 hours
Bacteriology and Phys. Chem. 3E, Practical Bacteriology 3 hours
Bacteriology and Phys. Chem. 5E, Water Analysis..... 2 hours
Pol. Ec. 1E, Elements of Economics..... 3 hours
Pol. Ec. 38E, Elements of Accounting..... 3 hours
Mineralogy 1, Elements of Mineralogy..... 2 hours
Mineralogy 9, Lithology ..... 2 hours
Geology 15, Soil Geology..... 3 hours

Students in Sanitary and Municipal Engineering electing Group D are required to elect Design Course 35 and Courses 31, 33, or 34.

E. HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT.

Civil Eng. 22, Transportation ..... 2 hours
Civil Eng. 26, Specifications and Contracts..... 2 hours
Civil Eng. 27, Public Utility Problems..... 1 hour
Civil Eng. 41, Highway Transport Surveys and the Theory and Economics of Highway Improvements. 2 hours
Civil Eng. 42, Highway Engineering Laboratory..... 2 hours
Civil Eng. 43, Highway Engineering Design..... 3 hours
Civil Eng. 44, Highway Transport Economics, Methods, Legislation, and Management..... 2 hours
Mech. Eng. 29, Automobiles and Motor Trucks..... 3 hours
English 6, Report Writing..... 2 hours
Political Economy 1E, Elements of Economics..... 3 hours

Students electing Group E are required to elect the Design Course 43 and the accompanying Theory Course 41. Students having a conflict of a required course with Civil Engineering 41 may substitute Civil Engineering 44 by obtaining the written approval of

the Professor of Highway Engineering and Highway Transport. Students electing Group E are advised to elect Civil Engineering 26 and 42 during the first semester, and Civil Engineering 41, 43, and 44 and as many courses as practicable from the following group during the second semester: Civil Engineering 22 and 27, Mechanical Engineering 29, English 6, Political Economy 1E. Students electing the Highway group may elect for credit, with the written approval of the Professor of Highway Engineering and Highway Transport, not more than two of the graduate short period courses.

F. GENERAL ENGINEERING SCIENCE.

Mathematics.
Physics.
Chemistry.
Astronomy.
Mechanics.
Mineralogy.
Geology.

This group is arranged to permit students to take advanced work in any of the above subjects. Courses elected in this group must be in advance of the last required course in the subject chosen. Students electing twelve hours' work in any one of these subjects will not be required to elect a design course.

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142. MECHANICAL ENGINEERING

1. *Outline of Required Courses.*

a. Preparatory Courses.

English 1, and choice of English 5, 6, 9, 10, or 14	6 hours
Modern Languages or Cultural Electives	16 hours
Mathematics 1, 2, 3, 4	18 hours
Physics 1E, 2E	10 hours
Chemistry 2E	5 hours
Drawing 4 and 5, Descriptive Geometry	4 hours
Shop 1, Wood Shop	2 hours
Shop 2, Forge Shop	2 hours
Shop 3, Pattern Making and Foundry	4 hours
Shop 4, Machine Shop	4 hours
Total	71 hours

b. Secondary and Technical Courses.

Surveying 4, Use of Instruments	2 hours
Eng. Mech. 1, Statics	4 hours
Eng. Mech. 2, Materials of Construction	3 hours
Eng. Mech. 3, Dynamics	3 hours
Eng. Mech. 4, Hydromechanics	2 hours
Mech. Eng. 1, Machine Drawing	2 hours
Mech. Eng. 2, Elements of Machine Design	3 hours

Mech. Eng. 3, Heat Engines	4 hours
Mech. Eng. 4, Hydraulic Machinery	3 hours
Mech. Eng. 5, Thermodynamics	3 hours
Mech. Eng. 6, Machine Design	4 hours
Mech. Eng. 7, Mechanical Laboratory, First Course	2 hours
Mech. Eng. 8, Mechanical Laboratory, 2nd Course.	3 hours
Mech. Eng. 9, Power Plants	3 hours
Mech. Eng. 10, Theory of Machine Movements	2 hours
Civil Eng. 2, Theory of Structures	3 hours
Elec. Eng. 2a, Electrical Apparatus I	4 hours
Chem. Eng. 1, Engineering Materials	3 hours
Chem. Eng. 10, Tech. Examination of Gas and Fuel.	1 hour
Total	54 hours

Summary:

Preparatory Courses	71 hours
Secondary and Technical Courses	54 hours
Group Options	15 hours
Total	140 hours

2. *Outline of Group Options.*

In this selection of his 16 hours of elective work the student may choose from the following groups and from courses offered in the other departments of the College of Engineering and in the other Schools and Colleges of the University, subject to the approval of the head of this department.

A. Steam Power Engineering.
B. Internal Combustion Engineering.
C. Hydro-Mechanical Engineering.
D. Heating, Ventilation, and Refrigerating Engineering.
E. Automobile Engineering.
F. Industrial Engineering.
G. General Engineering Science.

In selecting his 16 hours of elective work the student must elect one design course, either M.E. 11*a*, 12*a*, 15*a*, 16*a*, 17*a*. 20*a*, 21*a*. 30*a*, or 31*a*, together with the accompanying theory course.

A. STEAM POWER ENGINEERING.

Mech. Eng. 9*a*, Design of Power Plants	3 hours
Mech. Eng. 11, Steam Boilers	3 hours
Mech. Eng. 11*a*, Design of Steam Boilers	3 hours
Mech. Eng. 12, Steam Reciprocating Engines	2 hours
Mech. Eng. 12*a*, Design of Steam Reciprocating Engines	3 hours
Mech. Eng. 13, Steam Turbines	3 hours
Mech. Eng. 17, Pumping Machinery	3 hours

Mech. Eng. 17*a*, Design of Pumping Machinery..... 3 hours
Mech. Eng. 19, Refrigeration ..... 2 hours
Mech. Eng. 20, Mechanical Handling of Materials.... 2 hours
Mech. Eng. 20*a*, Design of Hoisting and Conveying Machinery..... 3 hours
Mech. Eng. 22, Research Work in the Mechanical Laboratory..... 3 hours

B. INTERNAL COMBUSTION ENGINEERING.

Mech. Eng. 9*a*, Design of Power Plants..... 3 hours
Mech. Eng. 15, Internal Combustion Engines and Gas Producers..... 3 hours
Mech. Eng. 15*a*, Design of Internal Combustion Engines ..... 3 hours
Mech. Eng. 17, Pumping Machinery ..... 3 hours
Mech. Eng. 20, Mechanical Handling of Materials.... 2 hours
Mech. Eng. 20*a*, Design of Hoisting and Conveying Machinery..... 3 hours
Mech. Eng. 22, Research Work in the Mechanical Laboratory..... 3 hours
Mech. Eng. 37, Special Topics on the Internal Combustion Engine..... 2 hours
Mech. Eng. 38, Laboratory Research Work on Internal Combustion Engines ..... 3 hours
Mech. Eng. 39, Research Design of Internal Combustion Engines ..... 3 hours

C. HYDRO-MECHANICAL ENGINEERING.

Mech. Eng. 16, Water Turbines ..... 3 hours
Mech. Eng. 16*a*, Design of Water Turbines..... 3 hours
Mech. Eng. 17, Pumping Machinery ..... 3 hours
Mech. Eng. 17*a*, Design of Pumping Machinery..... 3 hours
Mech. Eng. 23, Advanced Hydraulic Laboratory..... 3 hours

D. HEATING, VENTILATING, AND REFRIGERATING ENGINEERING.

Mech. Eng. 19, Refrigeration and Air Compression.... 2 hours
Mech. Eng. 25, Heating and Ventilation..... 2 hours
Mech. Eng. 25*a*, Heating and Ventilation Design..... 3 hours
Mech. Eng. 22, Research Work in Mechanical Laboratory..... 3 hours

E. AUTOMOBILE ENGINEERING.

Mech. Eng. 20, Mechanical Handling of Materials.... 2 hours
Mech. Eng. 22, Research Work in the Mechanical Laboratory.....2 or 3 hours
Mech. Eng. 29, Automobiles and Motor Trucks..... 3 hours
Mech. Eng. 30, Automobile and Motor Truck Engines. 3 hours

Mech. Eng. 30*a*, Design of Automobile and Motor Truck Engines..... 3 hours
Mech. Eng. 31, Automobile and Motor Truck Chasses. 3 hours
Mech. Eng. 31*a*, Design of Automobile and Motor Truck Chasses ..... 3 hours
Mech. Eng. 32, Automobile Testing ..... 2 hours
Mech. Eng. 33, Advanced Automobile Testing and Research..... 3 hours
Mech. Eng. 34, Advanced Automobile Design and Research.....Hours arranged
Mech Eng. 36, Scientific Shop Management..... 3 hours

F. INDUSTRIAL ENGINEERING.

Mech. Eng. 20, Mechanical Handling of Materials.... 2 hours
Mech. Eng. 21*a*, Design of Machine Tools..... 3 hours
Mech. Eng. 25, Heating and Ventilation..... 2 hours
Mech. Eng. 25*a*, Heating and Ventilating Design..... 3 hours
Mech. Eng. 35, Scientific Shop Management..... 3 hours
Mech. Eng. 36, Scientific Shop Management, Advanced Course.....2 or 3 hours

G. GENERAL ENGINEERING SCIENCE.

Mathematics.	Astronomy.
Physics.	Mechanics.
Chemistry.	Mechanism
Civil Engineering.	Chemical Engineering.
Mechanical Engineering.	Political Economy.
Electrical Engineering.	Sociology.

Eight hours to be taken from the advanced courses in the above subjects. By "advanced course" is meant one following the last required course. The remaining eight hours are free electives.

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143. ELECTRICAL ENGINEERING

1. *Outline of Required Courses.*
   a. Preparatory Courses.
      English 1, and choice of English 5, 6, 9, 10, or 14... 6 hours
      Modern Language and Cultural Electives..... 16 hours
      Mathematics 1, 2, 3, 4..... 18 hours
      Physics 1E, 2E..... 10 hours
      Chemistry 2E ..... 5 hours
      Drawing 4 and 5, Descriptive Geometry..... 4 hours
      Shop 1 and 2, Wood and Forge shop..... 4 hours
      Shop 4, Machine Shop..... 4 hours

      Total..... 67 hours

b. Secondary and Technical Courses.

Physics 5E and 6E, Electrical Measurements	4 hours
Surveying 4, Uuse of Instruments	2 hours
Eng. Mech. 1, Statics	4 hours
Eng. Mech. 2, Materials of Construction	3 hours
Eng. Mech. 3, Dynamics	3 hours
Eng. Mech. 4, Hydromechanics	2 hours
Civil Eng. 2, Theory of Structures	3 hours
Mech. Eng. 3, Heat Engines	4 hours
Elec. Eng. 1, Elementary Elec. Design	2 hours
Elec. Eng. 2, Elec. Apparatus I	4 hours
Elec. Eng. 3, Elec. Apparatus II	4 hours
Elec. Eng. 4, Elec. Apparatus III	4 hours
Elec. Eng. 5, Design of Electrical Machinery	4 hours
Elec. Eng. 7, Illumination and Photometry	2 hours
Elec. Eng. 11, Power Plants, Transmission and Distribution	5 hours
Elec. Eng. 14, Mechanism of Elec. Machines	3 hours
Elec. Eng. 17, Electro-Mechanics	4 hours
Chem. Eng. 1	3 hours
Total	60 hours

Summary:

Preparatory Courses	67 hours
Secondary and Technical Courses	60 hours
Group Options	13 hours
Total	140 hours

Choice of Elective Work

In the selection of his elective work the student will do well to guide his choice by the general philosophy controlling the work of the department. The aid of the staff in Electrical Engineering is to help the student toward the development of a sense of proportion, to ability to observe, visualize, and analyze rather than to impart specific and ephemeral information.

It is felt that fundamental courses in other branches of Engineering will accomplish this better than will highly advanced and specialized courses in Electrical Engineering. The latter should be deferred to a graduate year. It is advisable that strong students spend a fifth year working toward a Master's degree, offering therefor the more specialized courses in Electrical, Mechanical, and Civil Engineering, in Economics, and in the physical sciences.

As a broad election of technical subjects is advised in preference to the special work of the Electrical Department, so it is suggested

that Engineering courses might well make way for elections of pure science, Economics, History, Philosophy, and the Liberal Arts.

Such broad elections will fit the Engineering graduate to take his place in organized society and will aid him to an unusually broad perspective of his profession in its relations to the world of which it is a part. It is the belief of the staff that such preparation should fit the student for an ultimate position of leadership in his profession.

Guided by these general principles, the student may select his elective courses from among the courses offered in any departments of the University. As an aid to his selection the student is encouraged to consult freely with the members of the staff.

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144. CHEMICAL ENGINEERING

1. *Outline of Required Courses.*

a. Preparatory Courses.

English 1, and choice of English 5, 6, 9, 10, or 14	6 hours
Modern Language and Cultural Electives	16 hours
Mathematics 1, 2, 3, 4*a*	16 hours
Physics 1E, 2E	10 hours
Chemistry 2E, 3	10 hours
Drawing 4 and 5, Descriptive Geometry	4 hours
Shop 1 and 2, Wood and Forge Shop	4 hours
Total	66 hours

b. Secondary and Technical Courses.

Chemistry 5, Quantitative Analysis	5 hours
Chemistry 7, Organic Chemistry	5 hours
Chemistry 7*a*, Organic Chemistry	5 hours
Chemistry 8E, Theoretical Chemistry	3 hours
Chemistry 28, Advanced Quantitative Analysis	3 hours
Surveying 4, Use of Instruments	2 hours
Eng. Mech. 1, Statics	4 hours
Eng. Mech. 2, Materials of Construction, or Eng. Mech. 6, Strength of Materials	3 hours
Mech. Eng. 1, Machine Drawing	2 hours
Mech. Eng. 2, Elements of Machine Design	3 hours
Mech. Eng. 3, Heat Engines	4 hours
Elec. Eng. 2A, Electrical Apparatus I	4 hours
Chem. Eng. 1, Engineering Materials	3 hours
Chem. Eng. 2, Technology of Fuels	1 hour
Chem. Eng. 4, Technology of Salts, Acids, and Alkalis	2 hours
Chem. Eng. 5, Technology of Carbon Compounds	4 hours

Chem. Eng. 6, Metallurgy	2 hours
Chem. Eng. 9, Technical Examination of Gas and Fuel	2 hours
Chem. Eng. 12, Special Problems	5 hours
Total	61 hours

Summary:

Preparatory Courses	66 hours
Secondary and Technical Courses	61 hours
Group Options	13 hours
Total	140 hours

2. *Outline of Group Options.*

In the selection of his 13 hours of elective work the student may choose his studies from the following groups:

A. Metallurgical Group.
B. Gas Engineering Group.
C. Organic Industrial Group.
D. General Manufacturing Group.
E. Pulp and Paper Manufacturing Group.

A. METALLURGICAL GROUP.

Mineralogy 1, Elements of Mineralogy	2 hours
Mineralogy 2, General Mineralogy	5 hours
Mineralogy 4, Determinative Mineralogy	2 hours
Geology 1, Elements of Geology	3 hours
Geology 16, Economic Geology	3 hours
Geology 17, Metamorphosis and Ore Deposits	2 hours
E. M. 5, Testing of Materials	2 hours
M. E. 7, Mechanical Laboratory	2 hours
Ch. E. 7, Metallurgy of Non-Ferrous Metals	2 hours
Ch. E. 8, Metallography	2 hours
Ch. E. 13, Chemical Engineering Machinery	2 hours
Ch. E. 14, Chemical Engineering Machinery	2 hours
Ch. E. 17, Ore Dressing	2 hours
Ch. E. 18, Non-Ferrous Metallography	5 hours
Ch. E. 24, Pyrometry and Furnace Design	2 hours
Political Economy 1E, Elements of Economics	3 hours

B. GAS ENGINEERING GROUP.

E. M. 4, Hydromechanics	2 hours
C. E. 26, Specifications and Contracts	1 hour
C. E. 27, Valuation and Estimating	1 hour
M. E. 5, Thermodynamics	3 hours
M. E. 7, Mechanical Laboratory	2 hours
M. E. 9, Power Plants	2 hours

M. E. 15, Gas Engines and Gas Producers..... 3 hours
E. E. 7, Illumination and Photometry..... 2 hours
E. E. 3, Alternating Current Machinery..... 2 hours
Ch. E. 13, Chemical Engineering Machinery..... 2 hours
Ch. E. 14, Chemical Engineering Machinery..... 2 hours
Ch. E. 16, Gas Manufacture ..... 2 hours
Ch. E. 23, Chemical Plant Design..... 2 hours
Ch. E. 24, Pyrometry and Furnace Design..... 2 hours
Ch. E. 27, Design of Chemical Machinery..... 2 hours
Pol. Econ. 1E, Elements of Economics..... 3 hours
Pol. Econ. 32, Business Organization..... 3 hours
Pol. Econ. 38E, Accounting ..... 3 hours
Free Electives ..... 4 hours

C. ORGANIC INDUSTRIAL GROUP.

Chemistry 43, Organic Laboratory ..... 5 hours
Chemistry 45, Advanced Organic Chemistry..... 2 hours
Mineralogy 1, Elements of Mineralogy..... 2 hours
C. E. 31, Water Purification ..... 2 hours
C. E. 33, Sewage Disposal ..... 2 hours
C. E. 34, Sanitary Science ..... 1 hour
Ch. E. 13, Chemical Engineering Machinery..... 2 hours
Ch. E. 15, Seminar .....
Ch. E. 16, Gas and Motor Fuels.....
Ch. E. 27, Design of Chemical Machinery..... 2 hours
Ch. E. 23, Chemical Plant Design..... 2 hours
Ch. E. 31, Dyes, Textile and Dyeing..... 2 hours
E. M. 4, Hydromechanics..... 2 hours
Pol. Econ. 1E, Elements of Economics..... 3 hours
Pol. Econ. 38E, Principles of Accounting..... 3 hours
Bacteriology ..... 5 hours
Free Electives ..... 8 hours

D. GENERAL MANUFACTURING GROUP.

E. M. 4, Hydromechanics ..... 2 hours
M. E. 5, Thermodynamics ..... 3 hours
M. E. 6, Machine Design ..... 4 hours
M. E. 7, Mechanical Laboratory ..... 2 hours
M. E. 9, Power Plants ..... 2 hours
M. E. 20, Handling Materials ..... 2 hours
E. E. 3, Alternating Current Machinery..... 4 hours
C.E. 26, Specifications and Contracts..... 2 hours
Ch. E. 13, Chemical Engineering Machinery..... 2 hours
Ch. E. 14, Chemical Engineering Machinery..... 2 hours
Ch. E. 23, Chemical Plant Design..... 2 hours
Ch. E. 27, Design of Chemical Machinery..... 2 hours
Ch. E. 24, Pyrometry and Furnace Design..... 2 hours

Pol. Econ. 1E, Elements of Economics..... 3 hours
Pol. Econ. 32, Business Organization and Management. 3 hours
Pol. Econ. 38E, Principles of Accounting..... 3 hours
Free Electives ..... 8 hours

E. PULP AND PAPER MANUFACTURING GROUP.

This group contains options from the courses in pulp and paper manufacture and the courses in chemical engineering machinery in the department of Chemical Engineering; from courses in identification of woods in Forestry and in the microscopic study of woody plants in Botany; from courses in Electrical or Mechanical Engineering; in hydraulics in Civil Engineering; and in Economics.

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145. NAVAL ARCHITECTURE, MARINE ENGINEERING, AND AERONAUTICS

1. *Outline of Required Courses.*
   a. Preparatory Courses.

English 1, and choice of English 5, 6, 9, 10, or 14...	6 hours
Modern Language and Cultural Electives.....	16 hours
Mathematics 1, 2, 3, 4.....	18 hours
Physics 1E, 2E.....	10 hours
Chemistry 2E	5 hours
Drawing 4 and 5, Descriptive Geometry.....	4 hours
Shop 1 and 2, Wood and Forge Shop.....	4 hours
Total.....	63 hours

   b. Secondary and Technical Courses (Naval Architecture and Marine Engineering).

Surveying 4, Use of Instruments.....	2 hours
E. M. 1, Statics	4 hours
E. M. 2, Materials of Construction.....	3 hours
E.M. 3, Dynamics	3 hours
E. M. 4, Hydromechanics	2 hours
M. E. 1, Machine Drawing	2 hours
M. E. 2, Elements of Machine Design.....	3 hours
M. E. 3, Heat Engines	4 hours
M. E. 4, Hydraulic Machinery	3 hours
M. E. 6, Machine Design	4 hours
M. E. 7, Mechanical Laboratory	2 hours
M. E. 8, Mechanical Laboratory	2 hours
Elec. Eng. 2A, Electrical Apparatus I.....	4 hours
Chem. Eng. 1, Engineering Materials.....	3 hours
N. A. 1, Structural Design	1 hour
N. A. 2, Ship Calculations	3 hours

N. A. 4, Resistance and Propulsion of Ships	3 hours
N. A. 5, Structural Drawing	2 hours
Mar. Eng. 8, Marine Boilers	1 hour
Mar. Eng. 9, Marine Engines	2 hours
Mar. Eng. 10, Marine Boiler Design	3 hours
C. E. 2, Theory of Structures	3 hours
Total	59 hours

c. Secondary and Technical Courses (Aeronautics).

Shop 3 and 4, Pattern-making, Foundry, and Machine-Shop	8 hours
Surveying 4, Use of Instruments	2 hours
E. M. 1, Statics	4 hours
E. M. 2, Materials of Construction	3 hours
E. M. 3, Dynamics	3 hours
E. M. 4, Hydrodynamics	2 hours
C. E. 2, Theory of Structures	3 hours
M. E. 1, Machine Drawing	2 hours
M. E. 2, Elements of Machine Design	3 hours
M. E. 3, Heat Engines	4 hours
M. E. 5, Thermodynamics	3 hours
M. E. 6, Theory of Machine Design	4 hours
M. E. 7, Mechanical Laboratory	2 hours
M. E. 15, Internal Combustion Engines	3 hours
M. E. 32, Mechanical Laboratory	2 hours
E. E. 2, Elec. Apparatus and Circuits I	4 hours
Ch. E. 1, Engineering Materials	3 hours
Total	55 hours

Summary:

Preparatory Courses	63hours
Secondary and Technical Courses	55 hours
Group Options	22 hours
Total	140 hours

2. *Outline of Group Options.*

Three groups of studies may be followed in this department, viz.:

Group A, which is arranged for those who wish to devote the principal part of their studies to the design and construction of ships; and,

Group B, for those who wish to specialize more in the design of propelling machinery and other machinery connected with ships.

Group C contains not only aeronautical courses but also certain courses given in other departments which are of particular interest for students specializing in Aeronautical Engineering.

A. NAVAL ARCHITECTURE.

N. A. 3, Stability, etc.	3 hours
N. A. 6, Ship Drawing and Design	3 hours
N. A. 7, Ship Drawing and Design	3 hours
N. A. 12, Experimental Tank Work	2 hours
N. A. 13, Ship and Engine Specifications	1 hour
Group Options	6 hours
Total	18 hours

B. MARINE ENGINEERING.

M. E. 5, Thermodynamics	3 hours
M. E. 13, Steam Turbines	3 hours
M. E. 15, Gas Engines	3 hours
Mar. Eng. 11, Marine Engine Design	3 hours
Group Options	6 hours
Total	18 hours

C. AERONAUTICS.

Aero. 1, General Aeronautics	2 hours
Aero. 2, Theory of Aviation	2 hours
Aero. 3, Theory and Design of Propellers	3 hours
Aero. 4, 4*a*, Aeroplane Design	4 hours
Aero. 5, Aeronautical Laboratory	1 hour
Aero. 6, Design of Aeronautical Motors	2 hours
Group Options	8 hours
Total	22 hours

146. COMBINED COURSE WITH ALBION COLLEGE

At the November meeting of the Board of Regents, 1914, a schedule was approved for a combined course between Albion College and the College of Engineering of the University.

In general, it is proposed that a student shall spend at least three years at Albion College and two succeeding years at the University. At the end of his first year's work at the University, provided the reports are satisfactory, he will receive the degree of Bachelor of Arts from Albion College; the latter institution being willing to accept the work done at the University as the equivalent for the fourth year.

Upon the completion of the requirements for graduation in the College of Engineering, the student will receive the degree of Bachelor of Science in Engineering.

The schedule of work for the first three years at Albion College is shown below.

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
German or French	4	German or French	4
English I	3	English I	3
College Algebra	4	Trigonometry	4
Mechanical Drawing	2	Descriptive Geometry	2
General Physics	3	General Physics	3

Second Year

	HOURS		HOURS
German or French	4	German or French	4
English II	2	English II	2
General Chemistry	4	Qualitative Analysis	4
Analytic Geometry	4	Calculus	4
Laboratory Electricity	2	Laboratory Electricity	2

Third Year

	HOURS		HOURS
Mechanics	2	Mechanics	2
Advanced Physics	3	Advanced Physics	3
Advanced Analytics and Calculus	4	Advanced Calculus	4
		Statics	2
Electives	6 or 7	Electives	4 or 5

Electives

In Civil Engineering:
Geology (3 hours each semester).
Cultural (5 or 6 hours).

In Mechanical and Marine Engineering:
Surveying (2 hours); Machine Drawing (2 hours); Metallurgy (2 hours); Cultural Electives (3 hours each semester).

In Electrical Engineering:
Surveying (2 hours); Machine Drawing (2 hours); Metallurgy (2 hours); Electrical Measurements (3 hours each semester).

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147. COMBINED COURSE WITH OLIVET COLLEGE

The following schedule has been approved for a combined course between Olivet College and the College of Engineering of the University. In general, it is proposed that a student shall spend at least three years at Olivet College and two succeeding years at the University. After one year of satisfactory work in the College of Engineering the degree of Bachelor of Arts will be conferred by Olivet College. Upon the completion of the requirements for graduation in the College of Engineering, the student will receive the degree of Bachelor of Science in Engineering.

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
College Algebra	3	Analytic Geometry	5
Plane Trigonometry	2	English	3
English	3	Religion	1
Applied Psychology	1	French or German	5
French or German	5	Gymnasium	½
Gymnasium	½	Elective	2
Elective	2		

Second Year

	HOURS		HOURS
Calculus	3	Calculus	3
Physics	5	Physics	5
Chemistry	5	Chemistry	5
French or German	3	French or German	3
Gymnasium	½	Gymnasium	½

Third Year

	HOURS		HOURS
Calculus	2	Calculus	2
Surveying	2	Descriptive Geometry	2
Descriptive Geometry	2	Mechanics	4
Mechanics	3	Elective	7
Elective	6	Gymnasium	½
Gymnasium	½		

Electives

Freehand and Mechanical Drawing (4 hours); Mineralogy (3 hours); Qualitative Analysis (3 or 5 hours); Quantitative Analysis (3 or 5 hours); Economics (6 hours); Psychology (6 hours); Philosophy (4 hours).

COLLEGE OF ARCHITECTURE*

GENERAL STATEMENT

148. The College of Architecture aims to give the student a thorough training in the fundamentals of modern architectural practice.

The following is an effort to reply in a general way to the questions which prospective students and their parents ask regarding the profession of architecture and the courses in architecture. Once the services rendered by the architect are understood, there is a ready appreciation of the significance and value of the courses and subjects which make up the programs of study.

THE NATURE OF ARCHITECTURE

149. Architecture, the oldest of the constructive sciences, and since ancient times also ranked as a fine art, deals principally with the design of buildings, their accessories and surroundings, their construction, decoration, and equipment.

Architecture is born of the necessity for buildings and the desire to have them appropriate and pleasing in plan and design, as well as sound in construction. By its very nature, therefore, architecture is much more circumscribed as a medium of expression by utilitarian and technical conditions than is any other of the fine arts; unlike its sister arts of painting and sculpture, it must function at once practically and artistically, and misses its aim in failing in either.

SERVICES RENDERED BY THE ARCHITECT

150. The duties of the architect consist for the most part in conferences with clients and builders, in the preparation of drawings

* For admission requirements, etc., see Sec. 5. For courses other than those in Architecture, see Secs. 186-212.

and documents required for the erection of buildings, and in the supervision of building operations. The drawings consist of several kinds: "Preliminary studies," in which the general arrangement and design of the building are fixed upon, many schemes often being made in order to reach the one most advantageous in point of arrangement, appearance, and economy.

"Working or scale drawings" are prepared after a scheme has been approved by the owner. These are larger drawings which accurately define the proportions of the design, the disposition and dimensions of all the parts, such as walls, openings, and heights of stories, and show the distribution of the structural, enclosing, and decorative materials. In connection with these drawings all calculations are made to determne the required strength of constructive parts, such as the foundations, columns, beams, and trusses, the capacity and character of the equipment for heating, ventilation, sanitation, and illumination. The working drawings are accompanied by "specifications," which define the kind and quality of materials to be used throughout the fabric; they describe the apparatus and fixtures to be installed, the grade of workmanship that is expected, and define just what is expected of all parties concerned.

After bids have been received and the builders selcted, contracts are drawn by the architect which define the obligations of the builders and owner. The larger "detail drawings" are then made for structural and decorative features, while the architect supervises the progress of the actual building operations to see that the terms of the contract are fairly carried out by the builder, his agents, and the owner.

OTHER ACTIVITIES OF ARCHITECTS

151. Architects also occasionally take part in competitions for which, ifproperly conducted, a carefully prepared program is given all competitors and an expert jury is retained to select the best solution presented. In such competitions the drawings are confined to the preliminary study stage. Owing to the delay, expense, and uncertainties of this method of selecting an architect, it is employed for but a small proportion of the building undertakings of this country, and then primarily for important public projects. Most architects gain their opportunities through demonstrated fitness and integrity. Architects also help determine and often design the decorative features of interiors, for larger work coöperating with decorators, painters, and sculptors; they often design the grounds and approaches of buildings, and have taken an active part in the planning of cities, independently and in association with landscape designers and engineers, for, after all, buildings must form the most permanent and salient decorative features of the city.

The architect, then, is expected to meet alone or with the aid of his assistants and experts the varied artistic and practical problems related to all classes of buildings. In doing the above he must deal with public and private interests, with an exceptionally wide range of activities and human endeavor, extending from those of the laborer and artisan to those of artists and technical specialists as well as with the products of numberless industries.

TRAINING OF THE ARCHITECT

152. Those who are to exercise in so nearly equal degree the functions of an executive, an artist, and a constructor must needs receive a comprehensive training, one which will develop the kind of mental and moral fibre required for doing effective artistic and technical work and for meeting and dealing with men and affairs.

The old apprenticeship system which preceded the organization of architectural schools is rapidly disappearing, and is being replaced by the modern apprenticeship, which consists in working in an architect's office during vacations and after graduation from college, since progress is thus far more rapid, sure, and remunerative. The technically trained architect having "made good," it is now expected, most fortunately, that in addition to professional training he, like other educated men, have an insight into the larger questions underlying the affairs of the world.

Success in the architectural field depends largely on the same general conditions and personal qualities as are demanded in other professions. Those who expect to follow architecture as a profession should be imbued with an interest in building, in beautiful things, and in drawing. To a certain extent skill in design, construction, and drawing may be attained by all those who persist and have a real interest in the work. Artistic or constructive talent is valuable only if developed by a serious work and supported by knowledge, while the mere assimilation of knowledge and acquirement of skilled draftsmanship are insufficient. Unremitting self-discipline and enthusiastic effort are required to attain the creative power and the ability to use knowledge effectively which mark the productive worker.

Until recently it was considered that graduation from a good high school, followed by four years in an architectural school and several years' experience in architects' offices should be the minimum preparation for independent practice, while a longer period of collegiate training, along with travel in this country and study and travel abroad, now actually forms the more extended preparation of many.

The American Institute of Architects and the Association of Collegiate Schools of Architecture now recommend that students devote at least five years to collegiate study as preparation for the

baccalaureate degree in Architecture, dividing the additional year between technical and non-technical subjects with a view to attaining greater breadth and thoroughness.

In the three four-year programs in Architecture now offered at this University fully one-third of the time, approximately three semesters, is given to non-technical subjects, such as English, foreign language, economics, physics, mathematics, geology or mineralogy, fine arts, and electives. By apportioning a fifth year between cultural and technical courses the student will spend approximately two full years on fundamental and general subjects and three full years on semi-professional and professional subjects. Since it is desirable to begin drawing and creative work immediately upon entering the Architectural School, the general and cultural courses should be distributed over the entire time the student is in residence rather than completing the cultural before the technical subjects.

The training requisite for the architect may be stated under three principal heads:

a. General education.
b. Technical or professional education.
c. Experience in actual architectural work and business affairs.

a. GENERAL EDUCATION

The purpose of the first of these is to provide the essentials of a liberal education, that which tends to make the educated man and citizen, and helps give an understanding of the larger questions of life and thought and of the interests of others. Undoubtedly, university life and associations stimulate interest in the above.

The student should therefore while in the university receive those fundamentals of a general education which cannot be studied systematically later when he is absorbed in the exacting routine of the practical field. These studies will help keep him from becoming merely a narrowly specialized tool to be used by men of broader caliber. Moreover, the economic and social forces which shape his very opportunities must be understood if he is to interpret them with sympathy, intelligence, and artistic judgment. To this end literature, science, business administration, economics, philosophy, and kindred subjects are invaluable and should receive attention throughout the collegiate period, since they require as great thoroughness of preparation and maturity of mind as the most advanced technical subjects.

b. PROFESSIONAL OR TECHNICAL EDUCATION

Technical education, the second division, provides the special knowledge expected of the architect, trains him in fundamental principles, and develops his taste and skill in solving the problems peculiar to the architectural field. A full statement regarding technical courses will be found under the "Work of the College" in this pamphlet.

c. EXPERIENCE

General and technical education prepare for the third division, in which the graduate, preliminary to independent practice, gains experience in an architect's office in the application of technical knowledge and in the conduct of an office and actual building operations. This period brings home a fuller realization of the need of thorough training and of personal force to carry to completion building projects, and to cope with all the attendant conditions. The time required for this practical experience will vary according to the ability and opportunity of the individual.

HIGHER DEMANDS ON PROFESSIONAL MEN

153. Higher demands than ever before are being made today upon professional men. Hence, professional education is characterized by a demand for at once higher specific training and additional general education. This is shown by the tendency to require more or less collegiate cultural preparation—indeed, in some cases the bachelor's degree—for admission to schools of medicine and law.

In some professional fields specialization may or should come on the basis of a groundwork of general collegiate training alone, but in architecture training in drawing and design should begin with the first year of college, since development of the power of expression and creative design is facilitated by being continued over a long period rather than concentrated in a short one. This is particularly true in a country where the lack of artistic environment and of adequate preliminary training in drawing seriously handicaps architectural education, making it necessary to give, for the majority of students, all or mort of the preliminary and subsequent technical training, as well as the elements of a general education, in four years.

SPECIALIZATION IN ARCHITECTURE

154. While ideally desirable that the architect be expert in all allied fields, it is manifest that such omniscience is denied to men at the end of a four-year course or an infinitely longer one. Indeed, the impossibility today of mastery in all fields of architecture by even the most accomplished practitioner has led to specialization within the architectural field. There are now, as a result, architects who specialize in the design and construction of single classes of buildings, such as hospitals, theatres, schools, churches, office buildings, residential work, or city planning, and who in doing this work employ a corps of trained assistants.

Parallel with the increased demands made on the profession,

education in architecture has developed to such an extent that four or more years may be devoted solely to technical subjects. If, however, students were permitted to pursue such an over-professionalized course without preliminary or parallel cultural training they would find, when too late, that they had lost one of the primary opportunities of their college course.

If specialization is desired within the field of architectural education it must be either in the direction of architectural design or construction. Hence, at the University of Michigan there exist three four-year programs, the first of which is a general professional course, while the second and third emphasize, respectively, design and construction, in all of them a frair allowance being made for cultural studies.

Those who desire more advanced training are urged to plan their work in such a manner that it will include not less than five years, spreading the technical and cultural requirements over the entire period.

OUTLOOK FOR THE ARCHITECT

155. At no time in the history of the United States has there been so much interest in good architecture. Never before has there been so excellent an outlook for the trained architect. Classes of buildings which formerly were hardly considered from an artistic point of view, such as factories, warehouses, and the like, are now designed by architects. Our great corporations have come to a realization of the value of buildings which are at once adequate, attractive, and interesting. Cities everywhere, by means of general improvement plans, are recognizing the need of good design in everything, and in this city planning development the architect is playing a most important part; even in primarily utilitarian projects our municipalities will no longer permit the erection of structures which are merely adequate, but are employing architects to assure the creation of something that will be permanently pleasing as well as useful.

The art development, of which architecture forms but a part, has barely begun in this country. So long as this country continues its marvelous growth highly trained men will be needed to give form to building projects of the most varied character. The prospect is therefore full of promise for the architect and hence for the architectural school.

FOUR-YEAR PROGRAMS OF STUDY

156. Three four-year programs are offered, Programs I and II in Architecture, and Program II, Architectural Engineering, each requiring four years of study. These should be supplemented by

office work during the vacation periods. In each program provision is made for the study of theory, history, and practice of architecture, for training in language, mathematics, science, construction, design, building equipment, drawing, and electives.

The first year being practically identical in these three programs, students can, if advisable, at the end of that period change from one program to another without loss of credit. The courses in drawing, most of those in architectural design, practical building construction, and working drawings, sanitation and architectural history are common to all three programs. General Physics is required in Architecture I and II; Engineering Physics in Program III.

Programs I and II aim to prepare the student for general architectural practice. They differ only in that solid analytic geometry and a course in calculus are required in Program I, in place of which six hours of design and a course in landscape design are required in Program II. The advanced construction is taught on the basis of two special courses in mechanics given by the College of Architecture.

Program III, Architectural Engineering, or Construction, meets the needs of those who in association with architects or others will specialize in building construction and equipment. Hence, in addition to architectural design and practical building construction, which together prepare for intelligent and sympathetic collaboration with architects and buildings, these students pursue engineering courses in structural design, heating and ventilation, heat engines and some work in testing materials, surveying, and the chemistry of engineering materials. In this program the architectural studies may be completed in two and one-half years. Hence, students who have completed the first year of an engineering course and wish to take up architectural engineering may yet graduate at the end of four years.

During the senior year architectural design forms the chief study in Programs I and II, while in Program III framed structures, structural design, and other engineering subjects take up most of the year.

The above programs may be completed in four years by well-prepared and conscientious students; those who have difficulty with a subject can either extend their period of study or make up deficiencies in the Summer Session.

DEGREE CONFERRED IN THE COLLEGE OF ARCHITECTURE

157. The degree conferred in Programs I, II, and III of the College is Bachelor of Science in Architecture, the diploma specifying the program which the student has completed.

GRADUATE STUDY AND DEGREE

158. Students who are able to attend an additional year for graduate work will find the time well spent. Graduate work may be done in design, construction, the history of architecture, and in general studies. Such work shall be of an advanced character, a thesis on the design and construction of a building being required in the second semester.

For graduate courses leading to the degree of Master of Science in Architecture, the student must register in the Graduate School, but will pursue his work under the supervision of the Faculty of the College of Architecture. For particulars, see the Annual Announcement of the Graduate School.

OTHER CLASSES OF STUDENTS

159. Candidates for both the Bachelor of Arts and Bachelor of Architecture degrees, in order to graduate in Architecture in two years after obtaining the Arts degree, should complete at least the first two years of the architectural course, while candidates for the first degree. Students wishing to carry on some general college work parallel with or before beginning the work in Architecture should consult as soon as possible with the Professor of Architecture in order to plan their work in the most advantageous manner. In general, work in drawing and design should be begun early and extend over a long period rather than be concentrated into one or two years.

Graduates of colleges with the Arts degree are able to earn the professional degree in from two to three years, according to the program pursued and the kind of preparation brought by them.

Those who expect to enter from other colleges or transfer from other departments of this University should aim to bring as much credit as possible in free-hand drawing, as well as credits in descriptive geometry (the equivalent of Drawing 4*a* and 5*a*) and the mathematics and physics of the program they intend to follow.

Students registered in other colleges may elect the courses in History of Architecture, Elements of Design, Allied Arts Design, and other courses for which they are qualified.

TWO-YEAR PROGRAM FOR SPECIAL STUDENTS

160. A two-year course is provided for special students in Architecture upon the completion of which there is awarded a certificate of proficiency.

Owing to the difference in the preparation of such students but

part of the work is prescribed, the remainder being elective, to be arranged in consultation with the head of the College.

Special students may specialize in either design or construction.

Design, history of architecture, and free-hand drawing are studied throughout the two-year program; one year is devoted to construction, another year to building equipment.

In design such students are placed in the class indicated by their preparation. Very often the preparation of such students is sufficient to enable them to enter as regular students. It is then to their advantage to elect as much as possible of one of the four-year programs, returning later to complete the requirements of a regular program.

Special students who enter with enough preparation in mathematics can go on with Mathematics 1, then Architectural Mechanics 19 and 20, finally structural design, Architecture 22 and 23, thus completing part of the advanced building construction within two years of residence.

THE WORK OF THE COLLEGE

161. Design.—While design, owing to its comprehensive character, is of the greatest importance to the architect, it should be, and is, carried on parallel with courses in construction, the history of architecture, science and general studies, which actually increase efficiency in design and make for breadth of view and greater ultimate success in the field of independent practice.

The aim throughout these courses is to develop the imagination, creative power, ability to work out the organism of a building, and skill in the clear and artistic presentation of the drawings.

The policy in teaching design, while insisting on fundamental principles, is to encourage freedom of expression, to make possible, where permitted by the character of the problem and the requirements of the program, a wide range of interpretation, thus to bring into relief the relative value of the various solutions of which each problem is capable. While the larger aspects of the composition are of chief importance, careful consideration is given to the character of the form as related to the constructive scheme and the material. Occasionally a special problem is assigned to emphasize this further. In allied arts design most of the problems deal with small objects in various materials, involving a consideration of good craftsmanship, which the architect must appreciate if he is to expect it from artisans.

The history of architecture is also of importance in this connection, for the architect must know the experience and inspiration of the past, its successes and failures, that he may the better live, think, and build in terms of the present.

Emphasis is placed on perspective as a corrective and supple-

ment of design in elevation, to develop appreciation of the third dimension and as a means of presentation in itself.

In design, as in all other drawing courses, the right is reserved to keep drawings that may be of help for purposes of illustration or instruction.

162. **Architectural Design.**—In the courses in architectural design the students work out, in the drafting room, designs for a great variety of buildings, ranging from a small structure to large public buildings and groups of buildings. Lectures are given from time to time bearing on the type of building then being designed.

The problems vary from year to year, with the various classes, in order to cover as many as possible of the types of structures which make up architectural practice. Among these are the school, railroad station, library, hospital, church, theatre and auditorium, and such other public structures as the postoffice, museum, the monument, and the bridge, as well as the various kinds of business, manufacturing and residential buildings. Under "Housing" the entire street plan of a city is worked out, the disposition of the various sections for commercial, industrial, residential, and recreational purposes, and the actual design of typical buildings of all the kinds needed in an entire city.

Problems are occasionally assigned in architectural design which must be completed the same day; usually, however, the problems require from three to five weeks for their completion. A preliminary sketch or study is made by the student without criticism from the instructor or reference to documents; from a general criticism of all these sketches is given before the class, after which the sketches are returned to the students to have the essential features developed in the drafting room under the direction and criticism of instructors. After the drawings have been completed they are hung up and a general criticism is given. Thus, while the character of the instruction is of necessity largely individual, each student may profit by the progress of the others.

The preliminary sketch, usually executed in three or four consecutive hours, compels concentration on essentials and promotes accuracy and facility. The necessity of retaining in the final design the principal characteristics of the first sketch develops a sense of responsibility and individuality, and through the different solutions by members of the class demonstrates the varied possibilities of a given problem. All the designs for a given problem must be handed in at a fixed time. They are then carefully examined by the instructors and graded according to degree of excellence.

Test or examination problems, some without criticism, form a part of the requirement in each course.

In the last design course required of students in Architectural Engineering problems of a special character for such students are given.

163. **Advancement in Design.**—Promotion in design is individual, and takes place at any time during the year whenever a student has earned the number of points required in a course. This enables students to progress in proportion to their ability, application, and actual attainment, puts a premium on good work, and stimulates helpful emulation.

While the average student is able to complete the requirements in design in the normal time allowed, students of unusual ability or those who can devote more time to the subject may complete the requirements earlier and then elect additional cultural or technical courses.

164. **Allied Arts of Design.**—The course in Allied Arts of Design consists of a study of the elements of decorative design; designs are made for a piece of furniture, decorative glass, metal, and mosaic, and of other decorative features commonly used in connection with buildings.

165. **Construction.**—The courses in mathematics and physics are preparatory to those in structural mechanics, the strength and resistance of materials, advanced construction, or structural design, the testing of materials, and the courses in heating and ventilation, and building sanitation. The study of construction continues through two or three years, according to the program of study pursued, and is conducted by means of lectures, text-books, conferences, visits to buildings, and the preparation of working drawings. The work is at once practical and scientific, analytical and graphical methods being employed, and most of it is completed before the advanced work in architectural design is begun. The character of building materials, their structural and artistic possibilities, and the methods of building practice are studied and problems assigned which train the student in the fundamentals of sound construction.

The drawing work of the course in construction begins with the making of working drawings of a small building. This includes the framing plans of the floors, walls, and roofs, and full-size details of some of the finished portions. This is followed by working drawings for a larger building of heavy construction, and involves soils, foundations, walls, piers, columns, floors, roofs, and details. Steel and reinforced concrete construction are next studied, in the course of which girders, columns, trusses, and other structural work of a fireproof building are designed. There is a course in the chemistry of engineering materials and one in the testing of materials for students in Program III. The subject of specifications is taken up in connection with the work of construction. A special course is given on the law of contracts, and one in building details.

In those courses, which may most conveniently be grouped under Building Equipment (Heating and Ventilation, Building Illumination and Sanitation), the principles and applications are studied

which govern the design of the apparatus, the installation of which forms a part of the architect's work.

166. **History of Architecture.**—Architecture, "the mother art," is an art of great and inspiring traditions, and these can be justly appreciated only through careful study of the monuments of the past, both remote and recent, in relation to the other arts and civilization of their time. Owing to the wealth of material and the possibility of illustration, the history of architecture is one of the richest and most valuable subjects in the architectural curriculum. It is at once cultural and technical in character; it helps inculcate an understanding of the true character of architecture, develops the critical power and taste of the student, and demonstrates how we may best profit by the experience and example of the past.

The development of the art of building is traced from the earliest times to the present day. The causes and influences which moulded the various modes of building or styles are analyzed and, where possible, demonstrated by means of the stereopticon. Many of the important buildings of the world are fully illustrated and critically studied, the student thus gaining a knowledge of the finest achievements of the art. Not only are the buildings studied in their larger aspects, but also in many of their details of plan, construction, and form. The principles of design, the effect of construction and material on form, the value of sculpture, painting, the crafts, and landscape design in relation to architecture are discussed. Decorative sculpture, color, and ornament are considered along with the particular architecture of which they form a part, thus preserving for the student the unity of each style.

In addition to the above, all Architectural students registered in Programs I and II elect one or more courses in the history of art, in order to acquaint themselves with the development and masterpieces of painting and sculpture, these courses being more intensive studies in the sculpture, painting, and decorative art of a period.

167. **Drawing.**—Thorough instruction is provided in descriptive geometry, shades and shadows, perspective and stereotomy. Special classes are provided for architectural students in these subjects. Here the student receives an exacting drill in projections and intersections, accurate and neat instrumental drawing, and learns those methods which are essential to skilled draftsmanship. Many of the problems assigned as illustrations are architectural in character, and thus the student, while learning principles, works out applications directly connected with his chosen field.

168. **Free-hand Drawing.**—Because of the need of facility in this field considerable attention is paid to free-hand drawing. The students begin drawing from simple geometrical solids involving the accurate representation of form in line and light and shade; simple decorative, natural, and architectural forms are next drawn, after

which proportions of the figure, the hand, foot, etc., are drawn from cast, after the satisfactory completion of which follows drawing from the living model. Outdoor sketching is also encouraged, and is especially recommended for the summer months, when such instruction is given in the Summer Session.

Throughout this discipline, in the observation and artistic representation of line, from, proportion, light and shade, the aim is to develop in the student the power of free artistic expression. The student is advanced as rapidly as his progress warrants. The pencil, charcoal, and monochrome wash are used.

169. **Water Color and Rendering.**—Instruction is given in painting from still life. Almost from the very beginning color is employed in rendering. The continued use of color in rendering is insisted on in order to cultivate as much as possible the ability to produce good color relations when dealing with the various materials used in exterior and interior design.

170. **Pen and Ink.**—Rendering in pen and ink is taught for advanced students.

171. **General Studies.**—A fair quota of general studies is provided in the four-year program, the following forming part of the regular work: English, German, or French, the history of art, business administration, and elective hours, which permit courses in economics and philosophy, or additional courses in language.

Mathematics, physics, and geology have considerable importance as liberal studies, as well as being necessary to an understanding of materials, structural mechanics, heating and ventilation, and other technical subjects. Moreover, the study of architecture has a high cultural value in addition to constituting an exacting intellectual discipline.

172. **Summer Work.**—In order to encourage practical experience in architects' offices during the summer vacations, four hours' credit is given towards graduation for four months of such work. To the majority of students who enter college without such experience this kind of summer employment, while at first but moderately remunerative, brings home a keen realization of some of the demands of the professional field and results in more serious and better college work. It also enables students upon graduation to adapt themselves more readily to the demands of architectural office routine.

Letters should be brought from Architects stating what kind of work was done by the student and how long he was employed.

173. **Summer Session.**—The courses offered for Architectural students during the summer of 1921 will include architectural design, free-hand drawing, descriptive geometry, shades and shadows, perspective and stereotomy. The Summer Session will begin July 6.

A Special Announcement of the Summer Session can be had by addressing the Secretary of the University.

174. **Facilities and Equipment.**—The College of Architecture is housed in large and commodious quarters on the main floor of the Engineering building, immediately adjoining the library. The three drafting rooms are well lighted, provided with drafting tables of special design, and hung with valuable original competition and measured drawings. The free-hand drawing room is situated on the top floor at the north of the Engineering building. It is about sixty feet square, is lighted by means of side and north skylights and is fully equipped for the instruction in free-hand drawing, pen and ink, water color, and drawing from life. There is a comprehensive collection of plaster casts, of sculpture, of decorative and architectural form, pottery and textiles for painting from still life, and a number of original drawings in pencil, color and pencil, pen and ink.

In addition to the above, there are in the Alumni Memorial building a number of casts from the antique, among which are the Victory of Samothrace, the Hermes of Praxiteles, and some of the remarkable decorative figure sculpture from the Arch of Trajan at Beneventum. Here are also a number of paintings and other objects of artistic and archæological value.

175. **Exhibitions and Special Lectures.**—Each year a number of art exhibitions are held in the main gallery of the above building. During the past year these exhibitions consisted of a collection of oil paintings by American painters, brought together by the American Federation of Arts; the work of Charles Herbert Woodbury in oil and water-color painting, pencil drawing, and etching; a collection of textiles presenting the history of the development of textile design, by Cheney Brothers of New York City, and work from four leading art and design schools.

Exhibitions of current student work are held from month to month, a larger one, serving as a review of the work of the year, being held during Commencement week.

Many lectures are given each year under the auspices of the University, its colleges and schools, and local organizations. Among the lectures given at the University during the past year of special interest to Architectural students are the following: "The Economic Situation and Building," by Frederick L. Ackerman, architect, New York City; "Greek and Roman Sculpture in American Collections," "The Excavations of the American Expedition at Sardis," "Recent Work on the Acropolis," by Professor George H. Chase, Harvard University; and "Dynamic Symmetry," by Miss Rose Netzorg.

176. **The Library.**—No private and few public collections can be as complete as the library of a well-equipped architectural school. These books record the world's experience and achievements in archi-

tectural and allied fields and give an opportunity to study critically the finest work of all periods. The architect must have a fair knowledge of the literature bearing on his art, and since he may never possess many of these valuable works, and perhaps rarely again see them, the library forms a valued privilege during the student period.

The Architectural library is house with the Engineering library. It comprises about 1,800 bound volumes and folios of plates, including, besides the standard books of reference, many important early works and an unusual number of recent publications, many photographs, and about 11,000 lantern slides. With the works available in the Engineering library on engineering, heating, ventilation, and illumination, and those in the General library, it constitutes an exceptional collection for the study of construction, architectural design, and architectural history. It is especially strong in works on modern architecture and on the allied arts of ceramics, glass, metal work, textiles, and furniture. The leading architectural journals are received and bound volumes are kept on file.

Among the notable works available a few items which call for special mention are, in ancient literature, the Newton and Marino editions of Vitruvius, Palladio's Fabbriche Antiche, the works of Stuart and Revett, Desgodetz, Cresy and Tyler, Koldewey and Puchstein, the Restaurations des Monuments Antiques, D'Espouy's monuments, Antiques and Fragments d'Architecture Antique, and monographs on a number of Greek and Roman sites and buildings; in mediæval architecture, the works of Dehio and von Bezold, Britton, Pugin, Viollet-le-Duc, the Archieves de la Commission des Monuments Historiques; in renaissance architecture, the works of Geymüller, Raschdorff, Cicognara, Blondel, Gotch, Belcher and McCartney, and a very full collection of special works on the buildings of the Renaissance in France.

Every reasonable facility is accorded the student. A librarian is always in attendance, the library being open until ten o'clock at night.

The General library also contains an excellent collection of reference material on painting, sculpture, and archæology, a large number of photographs of Greek and Roman sculpture, and a collection of nearly five thousand prints, mostly of art subject materials.

177. **Materials.**—The College supplies drawing tables and lockers. The student provides himself with all other materials. Large drawing boards may be secured by making a deposit and the payment of a small fee. A good set of instruments and small drawing boards must be purchased. Water colors should not be purchased until after arrival here, when a list of the required colors may be had.

SCHOLARSHIPS

178. There are two scholarships for students of Architecture. Preference will be given to experienced architectural draftsmen and to those who show decided artistic ability. Application should be made to the Professor of Architecture. The scholarships are as follows:

The Smith, Hinchman and Grylls Scholarship for $100.00.

The Scholarship of the Michigan Chapter of the American Institute of Architects for $55.00.

Architects' Juries.—During the past few years visiting architects have been invited to assist in grading the design problems. During the present year Messrs. Ernest Wilby, H. J. Maxwell Grylls, William B. Stratton, and Alvin E. Harley, of Detroit, have served as jurors.

State Examinations for Admission to Architectural Practice.—Students who are planning to enter the architectural profession should bear in mind that twenty states of the Union now have laws prescribing qualifications for architectural practice and require the passing of examinations given by a state board. In a very few years the remaining states will probably have such laws, a number of laws now being under consideration. These examinations comprise tests in the planning, design, construction, and equipment of buildings. Three or four days are usually required for such examinations, distributed about as follows: Planning and design, one day; reinforced concrete and steel construction, one day; building equipment and specifications, one-half day; architectural history and truss design, one-half day. Candidates may, by passing a somewhat more difficult examination, given under the auspices of the National Council of Architectural Registration Boards, qualify for interstate practice.

American Academy in Rome.—Graduates in Architecture are admitted to the annual competition for the fellowship in Architecture of the American Academy in Rome. This fellowship entitles the successful candidate to three years' study abroad with a stipend of $1,000 per annum.

American Institute of Architects.—Graduates in Architecture of the University of Michigan are received as candidates by the American Institute of Architects without examination, after they have had a certain amount of office training.

Medal of the American Institute of Architects.—The Institute annually awards a medal to that member of the graduating class having the highest standing during the four-year period of study in Architecture.

Association of Collegiate Schools of Architecture.—The College is a charter member of this organization.

179. CREDIT HOURS REQUIRED IN THE THREE FOUR-YEAR PROGRAMS AND IN THE TWO-YEAR PROGRAM FOR SPECIAL STUDENTS

One hour of credit represents ordinarily about three hours of actual work during each week of one semester.

	I	II	III	Spl.
ARCHITECTURE:				
Elements of design	3	3	3	..
Architectural design	31	37	17	23
Allied arts design	3	3	..	..
History of architecture	8	8	6	8
Office work	4	4	4	..
CONSTRUCTION:				
Structural mechanics	6	6	7	..
Roofs and bridges, and framed structures	..	..	5	..
Construction (elementary)	2	2	2	2
Structural design (steel)	5	5	2	..
Masonry and reinforced concrete	4	4	5	..
Testing materials	..	..	2	..
Chemistry of materials	..	..	3	..
Surveying	..	..	2	..
BUILDING EQUIPMENT:				
Building sanitation	1	1	1	1
Heating and ventilation	2	2	2	2
Heat engines	..	..	4	..
DRAWING:				
Free-hand drawing	10	10	6	6
Water-color painting	2	2	..	2
Descriptive geometry and shades and shadows	3	3	3	1
Perspective and stereotomy	2	2	2	2
SCIENCE:				
Mathematics	13	4	18	..
Physics	4	4	10	..
Acoustics	2	2	..	..
Chemistry	..	..	5	..
Geology or Mineralogy	3	3	3	..
LANGUAGE:				
English	6	6	6	..
French or German	12	12	12	..
GENERAL:				
Business Administration	3	3	..	..
History of art	3	3	..	3
Landscape Design or City Planning	..	3	..	..
Cultural and free electives	8	8	10	16
	140	140	140	66

180. PROGRAM I. ARCHITECTURE

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 1	4	*Modern Language	4
Alg., Anal. Geom. (Math. 1E)	4	Analytic Geom. (Math. 2E)	4
Desc. Geom. (Dr. 4a)	3	Free-hand Drawing (Dr. 22)	2
Free-hand Drawing (Dr. 21)	2	Arch. Design (A. 4)	3
Elements of Design (A. 1)	3	Bldg. Construction (A. 21)	2
		Ancient, Med. Arch. (A. 12)	3
	16		18

Second Year

Calculus (Math. 3E)	5	English	2
Mechanics, Sound and Heat (Phys. 1)	4	Perspective, Stereotomy Dr. 5a)	2
Free-hand Drawing (Dr. 23)	2	Mechanics (A. 19)	3
Arch. Design (A. 5)	4	Arch. Design (A. 6)	4
Gothic, Ren., Modern Arch. (A. 13)	3	Allied Arts (A. 17)	3
		Geol. 1 or Min. 16	3
	18		17

Third Year

*Language	4	*Language	4
Mechanics (A. 20)	3	Free-hand Drawing (Dr. 25)	2
Arch. Design (A. 7)	6	Steel Construction (A. 22)	3
Arch. Hist. Research (A. 14)	3	Structural Design (A. 23)	2
Water Color (Dr. 24)	2	Arch. Design (A. 8)	6
Bldg. Sanitation (A. 24)	1		
	18		17

Fourth Year

Reinforced Concrete (A. 26)	2	Hist. of Painting, Sculpture	3
Structural Design (A. 27)	2	Arch. Design (A. 10)	8
Heating and Ventilation (M.E. 18)	2	Business Admin. (Ec. 32)	3
Life Drawing (Dr. 27)	2	Acoustics (Phys. 20)	2
Electives	7	Elective	1
	15		17

* See Sec. 132.

181. PROGRAM II. ARCHITECTURAL DESIGN

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
*Modern Language	4	*Language	4
English 1	4	Alg., Anal. Geom. (Math. 1E)	4
Descriptive Geometry (Dr. 4a)	3	Free-hand Drawing (Dr. 22)	2
Free-hand Drawing (Dr. 21)	2	Arch. Design (A. 4)	3
Elements of Design (A. 1)	3	Bldg. Construction (A. 21)	2
		Ancient, Med. Arch. (A. 12)	3
	16		18

Second Year

*Language	4	English	2
Mechanics, Sound and Heat, (Phys. 1)	4	Perspective, Stereotomy (Dr. 5a)	2
Free-hand Drawing (Dr. 23)	2	Mechanics (A. 19)	3
Arch. Design (A. 5)	4	Arch. Design (A. 6)	4
Gothic, Ren., Modern Arch. (A. 13)	3	Allied Arts (A. 17)	3
		Geol. 1 or Min. 16	3
	17		17

Third Year

Mechanics (A. 20)	3	Hist. of Painting, Sculpture	3
Water Color (Dr. 24)	2	Free-hand Drawing (Dr. 25)	2
Arch. Design (A. 7)	6	Arch. Design (A. 8)	6
Arch. Hist. Research (A. 14)	2	Steel Construction (A. 22)	3
Bldg. Sanitation (A. 24)	1	Structural Design (A. 23)	2
Elective	3	Elective	2
	17		18

Fourth Year

Heat., Vent. (M.E. 18)	2	Life Drawing (Dr. 27)	2
Arch. Design (A. 9)	6	Arch. Design (A. 10)	8
Reinforced Concrete (A. 26)	2	Business Admin. (Ec. 32)	3
Structural Design (A. 27)	2	Acoustics (Phys. 20)	2
Landscape Design I or City Planning	3	Elective	3
	15		18

* See Sec. 132.

182. PROGRAM III. ARCHITECTURAL ENGINEERING

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
English 1	4	*Modern Language	4
Alg., Anal. Geom. (Math. 1E)	4	Analytic Geom. (Math. 2E)	4
Descriptive Geom. (Dr. 4a)	3	Free-hand Drawing (Dr. 22)	2
Free-hand Drawing (Dr. 21)	2	Arch. Design (A. 4)	3
Elements of Design (A. 1)	3	Bldg. Construction (A. 21)	2
		Ancient, Med. Arch. (A. 12)	3
	16		18

Second Year

Calculus (Math. 3E)	5	Perspective, Stereotomy (Dr. 5a)	2
Physics (1E)	5	Calculus (Math. 4a)	3
Free-hand Drawing (Dr. 23)	2	Physics (2E)	5
Arch. Design (A. 5)	4	Eng. Mechanics I	4
Gothic, Ren., Modern Arch. (A. 13)	3	Arch. Design (A. 6)	4
	19		18

Third Year

*Language	4	*Language	4
Calculus (Math. 4b)	2	Steel Construction (A. 22a)	3
Eng. Mechanics (2)	3	Structural Des. (A. 23a)	2
Chemistry (2E)	5	Geol. 1 or Min. 16	3
Arch. Design (A. 7a)	4	Chem. Eng. 1	2
		English	2
	18		17

Fourth Year

Masonry (A. 36 or C.E. 3)	3	Building Details (A. 25)	2
Surveying 4	2	Testing Materials (E.M. 5)	2
Heat Engines (M.E. 3)	4	Adv. Struct. Design (A. 35)	4
Bldg. Sanitation (A. 24)	1	Heat. and Vent. (M. E. 18)	2
Elective	5	Elective	5
	15		15

* See Sec. 132.

183. TWO-YEAR PROGRAM FOR SPECIAL STUDENTS IN ARCHITECTURE

Special students have such varied preparation that a program of courses must practically be planned to meet the needs of each student.

Experienced draftsmen can, in two years, accomplish much in design; they cannot, however, advance far in construction without Mechanics,—Graphic Statics (A. 19) and Strength of Materials (A. 20). They are, therefore, advised to bring preparation in high school algebra and trigonometry, taking Mathematics 1E at the University, then going on with Mechanics,—Architecture 19 and 20. With this training they can elect steel and reinforced concrete construction. Those who desire to specialize in design can substitute other courses for those in mathematics, mechanics, and structural design.

The following is suggested as an outline for special students desiring a well-balanced training when but two years are available:

First Year

FIRST SEMESTER	HOURS	SECOND SEMESTER	HOURS
Shades and Shadows (Dr. 4a)	1	Perspective and Stereotomy (Dr. 5a)	2
Free-hand Draw. (Dr. 22 or 23)	2	Arch. Design (A. 6)	4
Arch. Design (A. 4)	3	Water Color (Dr. 24)	2
Arch. Design (A. 5)	4	Ancient, Med. Arch. (A. 12)	3
Alg., Anal. Geom. (Math. 1E) or Elective	4	Mechanics (A. 19) or Elective	3
Elective	1	Bldg. Construction (A. 21)	2
	15		16

Second Year

Arch. Design (A. 7)	6	Arch. Design (A. 8)	6
Gothic, Ren., Modern Arch. (A. 13)	3	Arch. Hist. Research (A. 14)	2
Mechanics (A. 20) or Elective	3	Steel Construction (A. 22) or	3
Bldg. Sanitation (A. 24)	1	Structural Design (A. 23) or Elective	2
Heat. and Vent. (M.E. 18)	2	Water Color or Pen and Ink	2
Free-hand Drawing (Dr. 25)	2	Hist. of Painting, Sculpture	3
	17		18

184. Decorative Design and Interior Decoration.

Instruction is given in these subjects. Those who desire a systematic program of study, as special students or parallel with their general courses, should consult with the Professor of Architecture. They should, in general, elect courses in free-hand and instrumental drawing, and in water color, in order to acquire skill in expressing their ideas; Elements of Design (A. 1) and Allied Arts Design (A. 17), for specific training in fundamental principles of composition and their application; Architectural History (A. 12 and A. 13) and some architectural design to get some grasp of architectural form and the larger aspects of decorative form, as well as to familiarize themselves with the finest existing examples of decoration.

The College of Architecture has a splendid collection of illustrated works, many in color, on decoration in all its aspects, many lantern slides and a number of original designs for interiors by professional decorators.

COLLEGES OF ENGINEERING AND ARCHITECTURE

COURSES OF INSTRUCTION

185. The courses of instruction are subject to change from time to time; those proposed for the year 1921-1922, and required for graduation, are described below, together with some advanced elective and technical courses, which are designated accordingly. The amount of credit toward graduation assigned to each course is indicated by the expression of one hour, two hours, etc., an hour of credit being given for the satisfactory completion of work equivalent to one exercise a week during one semester. Lectures and recitations are usually one hour in length, but in laboratory work, drawing, surveying, and other practice work a longer attendance is required in order to secure an hour of credit. An hour of credit represents ordinarily about three hours of actual work, including preparation.

Courses given in the College of Literature, Science, and the Arts are (with the exception of the courses in German and in French, for which special permission is required) open as electives to Engineering students who can spare the time and are qualified to pursue them with advantage.

No credit is given for work done outside of the University during the student's connection with the Colleges, unless such work is substantially equivalent to some course offered in these Colleges and has been done under approved supervision.

186. AERONAUTICS

Professors SADLER, PAWLOWSKI

1. GENERAL AERONAUTICS. Lectures and recitations. *Two hours.* First semester.

An introductory course giving the essential principles of aeronautics (balloons, dirigibles, ornithopters, helicopthers, aeroplanes, helicoplanes, and kites), history of flight and description of modern aircraft.

Open to all students.

2. THEORY OF AVIATION. Lectures and recitations. *Two hours.* Second semester.

The course deals with the following questions: properties of the air, general discussion of aerodynamics, aerodynamical properties of planes and various constructive elements of an aeroplane, analysis of performance, equilibrium, and stability of aeroplanes, air currents. In this course each student makes a complete analysis of performance of a given aeroplane, as well as a determination of its stability.

Must be preceded by Courses 1, E. M. 2 and E. M. 3.

3. THEORY AND DESIGN OF PROPELLERS. Lectures, recitations, and drawing. *Three hours.* First semester.

Theory of propellers and analysis of propeller performance on the Drzewiecki system; Eiffel's method of propeller analysis and graphical method of determining propellers for specified conditions; analytical and graphical methods of investigating the strength of propellers and influence of gyrostatic moments in quick turns. The student will design a propeller and analyze the distribution of stresses in the blades

Must be preceded or accompanied by Course 2.

4. AEROPLANE DESIGN. Lectures and recitations. *Two hours.* First semester.

This course includes the investigation of the design of the aeroplane from the aeronautical and strength standpoints. The strength and design of all the details are discussed and a completed design prepared.

Must be preceded or accompanied by Course 3, and preceded M. E. 6 and C. E. 2.

4*a*. AEROPLANE DESIGN. Continuation of preceding course. Drawing only. *Two hours.*

5. AERODYNAMIC LABORATORY. *One hour.* Second semester.

An elementary course covering use of instruments, investigation of aerodynamical properties of the various combinations of

bodies and aerofoils used in aeroplanes and airships, test of propellers.

Must be preceded or accompanied by Courses 2 and 3, and preceded by M. E. 7.

6. DESIGN OF AERONAUTICAL MOTORS. Lectures and drawing. *Two hours.* Second semester.

Complementary course to M. E. 15 or M. E. 30, dealing with special features of the aeronautical motors, a more refined method of cam design, analysis of vibrations and balancing of motors, critical study of various types of motors, and complete general plans of a motor of certain type are prepared.

Must be preceded by M. E. 15 or M. E. 30.

7. THEORY OF BALLOONS AND DIRIGIBLES. Lectures and recitations. *Two hours.*

Study of equilibrium and stability of spherical balloons and dirigibles; description of French, German, Italian, British, and American types; resistance and propulsion, stability of dirigibles; operation and maintenance of balloons and dirigibles.

Must be preceded by Courses 1, 2, and 3.

8. DESIGN OF BALLOONS AND DIRIGIBLES. Lectures and drawing. *Four hours.*

Investigation of the design of a balloon and a dirigible from the aeronautical and strength standpoints. Questions of strength and design of all the details of the non-rigid, semi-rigid, and rigid types are discussed and complete general plans of one type prepared.

Must be preceded by Course 7.

9. THEORY AND DESIGN OF KITES. Lectures, recitations, and drawing. *Two hours.*

Critical study of various types of man-carrying kites and the launching devices. Investigation of the design from the aeronautical and strength standpoints. Completed design of a kite train of one type is prepared.

Must be preceded by Course 7.

10. DESIGN OF AERODROMES AND HANGARS. Lectures, recitations, and drawing. *Two hours.*

Planning and equipment of aerodromes and aero-ports; construction of transportable, stationary, revolving, and floating hangars. Complete general plans of one type is prepared.

Must be preceded by Courses 2 and 7.

11. ADVANCED STABILITY. Lectures and recitations. Advanced study of more complicated phenomena of stability according to

Bryan, with Bairstow's applications of experimentally determined resistance derivatives and rotary coefficients.
Must be preceded by Course 2 and Math. 4*b* (Differential Equations).

12. SEMINARY. Reading and reports on selected aerodynamical and aeronautical problems. Credit to be arranged. Open only to graduates and seniors who receive special permission. A reading knowledge of French and German is most desirable.

13. ADVANCED DESIGN. Continuation of Course 4*a*, taking up some of the more complex or special problems. Credit to be arranged.
Open primarily to graduates.

14. RESEARCH. Continuation of Course 5, offering an opportunity for students to pursue advanced experimental and analytical investigations of any problems in connection with aeronautics. The work of course consists of investigations for securing data on the more difficult problems of aeronautics and of mathematical interpretation of the results. Credit to be arranged.
Must be preceded by Math. 57 and 58. Open primarily to graduates. A reading knowledge of French and German is desirable.

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187. ARCHITECTURE

Professors LORCH, BOYNTON, ROUSSEAU, Associate Professor MCCONKEY, Assistant Professors BENNETT, LOOMIS, NEWMAN, Mr. MAKIELSKI, Mr. BARNES, Mr. O'DELL

1. ELEMENTS OF DESIGN. *Three hours.* Both semesters.
An introductory course to the field of artistic design, decorative and architectural. Principles of design and the possibilities in design of line, color, and form. Architectural elements, their function and form; the influence of material. The pier, lintel, arch, wall, openings; the plan and roof.
Methods of indication; rendering, lettering. Drawing exercises and lectures. This course or its equivalent must precede all architectural design courses. It should be accompanied or preceded by Drawing 4*a* and 21.

Architectural Design

In the following courses in Architectural Design problems are assigned to be worked out in the drafting room. Lectures are given from time to time bearing on the type of building then being designed.

Study of the requirements of various classes of buildings and of the artistic possibilities of building materials, training of the student in composition in plan, section, elevation, and perspective, in accurate draftsmanship and rendering in line, black-and-white and color.

Courses 4 to 10, inclusive, constitute a progressive series of problems in architectural planning and design, advancing from the small building to the more important classes of buildings and to the group problems. The courses must be taken in the order given.

4. ARCHITECTURAL DESIGN. *Three hours.* Second semester.
A continuation of Course 1; the orders and simple problems in design. Illustrated lectures and drawing exercises.
Course 4 must be preceded by Course 1, Drawing 4*a* and 21.

5. ARCHITECTURAL DESIGN. *Four hours.* Both semesters.
The small ensemble. Course 5 should be preceded by Drawing 5*a* and 22 and by Courses 4 and 21 in Architecture.

5. ARCHITECTURAL DESIGN. *Four hours.* Both semesters.
This course, a continuation of Course 5, should be preceded by Architecture 5 and 22.

7. ARCHITECTURAL DESIGN. *Six hours.* Both semesters.
Plan problems. This course must be preceded by Architecture 6.

7*a*. ARCHITECTURAL DESIGN. *Four hours.* Both semesters.
For students in Program III.

8. ARCHITECTURAL DESIGN. *Six hours.* Both semesters.
Plan problems. This course must be preceded by Architecture 7.

9. ARCHITECTURAL DESIGN. *Six hours.* Both semesters.
Advanced plan problems. This course must be preceded by Architecture 8.

10. ARCHITECTURAL DESIGN. *Eight hours.* Both semesters.
Advanced plan problems. This course must be preceded by Architecture 8 or 9.

11. ARCHITECTURAL DESIGN. *Credit to be arranged.*
Housing problems. The design of various types of residential units, single and multiple, and their relation to the city plan and public health. Lectures, reading, and drawing.
Must be preceded by Architecture 6.

Technical and Historical Development of Architecture and Design

For students in Architecture, Courses 12, 13, and 14 assume some knowledge of history, drawing, and design; they should be elected in the order given. The purpose of these courses is to study the

historical conditions, building materials and methods, planning and design, as well as the sculptured and painted decoration and ornament of the more important and significant works of architecture. The courses are carried on by means of illustrated lectures, conferences, drawing exercises, research, and required visits to buildings in neighboring cities.

12. ANCIENT AND MEDIÆVAL ARCHITECTURE. Three hours. Second semester.
Should be preceded by Drawing 21 and accompanied by Architecture 4.
The architecture of Egypt, Assyria, Persia, Greece, and Rome, and a survey of the subsequent architectural development to Gothic architecture.

13. GOTHIC, RENAISSANCE, AND MODERN ARCHITECTURE. *Three hours.* First semester.
Should be preceded by Architecture 12.
The Gothic, Renaissance, and Modern Architecture of European countries, and Architecture in the United States.

14. ARCHITECTURAL HISTORY RESEARCH. *Two hours. First semester.*
Must be preceded by Courses 12 and 13 and one year of architural design.
An intensive study of the architecture of a specific period or country, and the making of one or more designs embodying the results of this study.

15. GENERAL COURSE IN THE HISTORY OF ARCHITECTURE. *Two hours.*
The aim of this course is to give students seeking a liberal culture a survey of the development of the art of building. The temples, cathedrals, palaces, and other characteristic monuments of the ancient, mediæval, renaissance, and modern styles, their design, sculpture, and painted decorations will be studied by means of lectures illustrated by the stereopticon, and collateral reading. This course is open to all students in the University. but cannot be counted towards graduation in Architecture.
For students of art and archæology desiring a more intensive study of the technical and historical development of architecture, Courses 11, 12, 13, and 14 are recommended.

17. THE ALLIED ARTS OF DESIGN. *Three hours.* Second semester.
A study of the elements of decorative design and ornament, and a survey of the decorative equipment of buildings, such as furniture, metal work, glass, ceramics, textiles, mural painting and decorative sculpture.
Short problems in design, research work, illustrated lectures.
Prerequisites: Drawing 21 and 22; Architecture 5 and 11.

18. ARCHITECTURAL COMPOSITION. *One hour.*
This course supplements the courses in architectural design by a series of illustrated lectures.

Building Construction and Equipment

19. ARCHITECTURAL MECHANICS. Statics. Stresses in Simple Frames. *Three hours.* Both semesters.
The principle of equilibrium. Analysis of stresses in simple frames by graphic and algebraic methods. Must be preceded by Mathematics 1E and Physics 1.

20. ARCHITECTURAL MECHANICS. Advanced Problems in Statics. Strength of Materials. *Three hours.* Both semesters.
Must be preceded by Architecture 19.

21. WOOD CONSTRUCTION. Lectures, conferences, drawing, and visits to buildings. *Two hours.*
Building materials and processes; working drawings; specifications and estimates of cost.
This course must be preceded by Drawing 4*a* and Architecture 1.

22. STEEL AND FIREPROOF CONSTRUCTION. *Three hours.* Second semester. Must be preceded by Architecture 19 and 20.
Lectures, problems, notes, and assigned reading on building materials and methods of construction, with particular reference to steel and enclosing and protection materials against fire and other destructive elements. Design of columns, beams, plate girders, and trusses; specifications and estimates.

22*a*. STRUCTURAL THEORY. *Three hours.* Both semesters.
Must be preceded by E. M. 1 and E. M. 2.
Recitations, problems, text, and occasional lectures. This course is devoted to a study of the laws of statics, moving and stationary loads, influence lines, reactions, shears, and moments in their relation to structures of various kinds. The practical design of beams and girders is given considerable attention.

23. STRUCTURAL DESIGN: STEEL. *Two hours.* Second semester.
Must be preceded or accompanied by Architecture 22.
Working drawings and details of a steel-frame building.

23*a*. STRUCTURAL DESIGN. *Two hours.* Both semesters.
Must be preceded or accompanied by Architecture 22*a*.
Lectures and drafting accompanying Architecture 22*a*. A course in which are considered fundamental principles underlying structural design and their relationship to structural theory. Its main object is to give the student the power to

analyze such problems as arise in practice. Elementary forms in wood, cast iron, and steel are considered through the preparation of designs and working drawings. Emphasis is laid on the cultivation of careful, systematic, and practical habit of computation.

24. BUILDING SANITATION. *One hour.* First semester.
Plumbing and drainage. A study of materials, fixtures, bethods of assembling, and modes of arrangement. Lectures and drawings.
Prerequisites: Architecture 4 and 21.

25. BUILDING DETAILS. *Two hours.* Second semester.
Must be preceded by Architecture 6 and 21.
The purpose of this course is to give some specific training in detailing portions of buildings. Scale and full-size details.

26. MASONRY AND REINFORCED CONCRETE. *Two hours.* First semester. Must be preceded by Architecture 19 and 20.
Lectures, problems, text, and assigned reading on building materials and methods of construction, with particular reference to reinforced concrete. Brick, stone, terra cotta, cements, and waterproofing are also considered; specifications and estimates.

27. STRUCTURAL DESIGN: MASONRY. *Two hours.* First semester.
Must be accompanied by Architecture 26.
The design of foundations, columns, slabs, beams, and girders of various types, as used in buildings.

35*a*. STRUCTURAL THEORY (ADVANCED). *Four hours.*
Must be preceded by Architecture 22*a* and a course in reinforced concrete.
Recitations, problems, text, and lectures. This is an extended course in continuation of Architecture 22*a*. Part I, nine weeks, treats of the computation and design of structures of wood, metal, and masonry by algebraic and graphical methods. Subjects considered are the theory of columns, trusses of various kinds, mill building bents, and portals, earth pressure, buttresses and retaining walls.
Part II, six weeks, treats of the theory of least work, the slope deflection method, and higher framed structures. Study is devoted to the analysis of wind stresses in buildings and brief study is devoted to the elastic theory of metal, stone, and concrete arches, the cantilever, and suspension bridges.
The object is to further train the student in the application of the principles of mechanics to the design of structures with special reference to building work.

35*b*. STRUCTURAL DESIGN (ADVANCED). *Three hours.*
Must be preceded by Architecture 22*a*, 23*a*, and preceded or accompanied by Architecture 35*a*.
Lectures, occasional problems, and drafting. A course in which are prepared complete designs and working drawings of a structural frame building of steel and concrete. Great importance is placed upon the study of the details of the design. Special attention is devoted to types and methods of constructing foundations for buildings, materials of construction, and protection materials against fire and other destructive agencies. Various handbooks are used, and *Hool and Johnson's Handbook of Building Construction* is required.

36. CONCRETE THEORY. *Three hours.* Recitations, problems, text, and lectures covering theory and design of masonry structures, with particular reference to reinforced concrete. Foundations and flat slab construction are studied.

Drawing and Painting

The following courses are open to others as well as Architectural students. The courses are to be elected as Drawing 21, 22, etc., and in the order given.

All of the courses are offered both semesters and instruction is given in Courses 21 to 26, inclusive, every morning and every afternoon with the exception of Saturday afternoon only.

Drawing in charcoal, pencil, and wash, largely from casts and from the living model. This work may be varied somewhat to permit some sketching out of doors. Pen and ink should not be elected until after the student has mastered the fundamentals of representation.

For the general student Courses 21, 22, and 24 will give an elementary training in drawing and painting. Course 30 provides more advanced work in painting; Courses 25, 26, and 27 more advanced training in drawing. Course 23 is a special course in the drawing of ornament for students of architecture and decoration, while Course 35 is primarily for Architectural students, although open to others. Outdoor sketching and painting can best be studied during the Summer Session.

At present there are no classes in portrait painting nor painting from the costume model, but such instruction can, under certain conditions, be arranged for groups of students who have advanced preparation. Still-life painting in water color or oil cannot be studied profitably without some preliminary training in free-hand drawing (Drawing 21 and 22). For drawing from the living model some preliminary training is required from the antique (Drawing 25 and 26).

Advancement in all these courses is individual, depending on the progress made by the student and determined largely by work done

without criticism. Advanced standing may be had as in other subjects on the basis of satisfactory work done elsewhere. Drawings should be brought to help determine the student's standing, also letters or certificates from the institution attended.

21. FREE-HAND DRAWING. A general introductory course. *Two hours.*
Drawing from simple forms in line and light and shade.

22. FREE-HAND DRAWING. *Two hours.*
Drawing from simple decorative forms, natural and architectural.

23. FREE-HAND DRAWING. *Two hours.*
Drawing from decorative forms and portions of the figure.

24. WATER COLOR PAINTING. *Two hours.*
Painting from still life. Must be preceded by Drawing 21 and 22 or their equivalent.

25 and 26. FREE-HAND DRAWING. *Two hours each.*
Drawing from the full figure.

27 and 28. FREE-HAND DRAWING. *Two hours each.*
Drawing from life.
Admission to these courses is limited to those who have satisfactorily completed the preceding courses or their equivalent.

30. WATER COLOR PAINTING. *Two hours.*
Painting in water color from still life. This course must be preceded by Drawing 24.

33. CLAY MODELING. *Two hours.*

35. PEN AND INK DRAWING. *One or two hours.* Elective.
For regular students of Architecture this course must be preceded by Courses 4*a*, 21, 22, and 23 in Drawing, and Architecture 5. Students not registered in Architecture should have the equivalent of six credit hours in free-hand drawing before electing this course.

PRIMARILY FOR GRADUATES

30. ARCHITECTURAL DESIGN. Special problems in planning and design. Must be preceded by the equivalent of Architecture 10.

33. ARCHITECTURAL HISTORY. A thesis on the architectural work of a period or on a particular monument. Must be preceded by the equivalent of Architecture 12, 13, and 14.

38. STRUCTURAL DESIGN. Special problems in building construction. Must be preceded by equivalent of Architecture 22*a*, 23*a*, 35, and A. 36 or C. E. 3. *Hours to be arranged.*

SUMMER SESSION

ARCHITECTURAL DESIGN.

Problems to be worked out in the drafting room. Study of the requirements of various classes of buildings and of the artistic possibilities of building materials; training of the student in composition in plan, section, elevation, and perspective, in accurate draftsmanship and rendering in line, black-and-white, and color.

The following courses in Architectural Design will be offered:

5. *Elementary Architectural Design. Three hours.* Architectural form, drawing, and rendering; introductory problems in architectural design.

7. *Intermediate Architectural Design. Credit to be arranged.*

9. *Advanced Architectural Design.* Plan problems. *Credit to be arranged.*

FREE-HAND DRAWING.

A. *Free-Hand Drawing in Charcoal and Pencil.* Elementary. The aim of this course is to cultivate the eye and train the hand in order to develop the ability to represent correctly and interestingly simple decorative forms. The work assigned to each student will depend upon the previous preparation of the student and is planned to meet the needs of students of Architecture and Architectural Engineering, teachers, and others. For the students of Architecture and Architectural Engineering the work of the course will conform to that of Courses 21, 22, and 23 as given in the regular session. *Two hours' credit.*

B. *Free-Hand Drawing.* Advanced. The work of the course, if elected by students of Architecture or Architectural Engineering will conform to that of Courses 24, 25, 26, 27, and 28, as given in the regular session. For teachers and others the instruction will consist in drawing from casts and still life, and some outdoor sketching and painting. The work will be arranged to meet the needs of the student. *Two hours' credit.*

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188. ASTRONOMY

Professors HUSSEY, CURTISS, Dr. RUFUS, Mr. ROSSITER

Courses 1, 2, and *2a* are recommended to those who wish to obtain a general knowledge of Modern Astronomy without entering far into its mathematical details.

Courses in addition to those mentioned below are listed in the College of Literature, Science, and the Arts. These include advanced work in Theoretical Astronomy, Practical Astronomy, and Astrophysics. The instruments of the Observatory, when not otherwise employed, will be available to advanced students who have the technical ability to use them to advantage.

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1. GENERAL ASTRONOMY. The Solar System. *Three hours.* First semester only.
   A descriptive course, including the fundamental principles of Astronomy, and a presentation of the leading facts respecting the sun, moon, planets, and comets. Occasional lantern illustrations.

2. GENERAL ASTRONOMY. Stars and Nebulæ. *Two hours.* Second semester only.
   A general descriptive course in stellar and nebular astronomy. Occasional lantern illustrations. May be taken in continuation of Course 1, or independently, as desired.

2*a*. ELEMENTARY OBSERVATIONAL ASTRONOMY. *One hour.* Second semester only.
   Constellation studies and telescopic examinations of the heavenly bodies. Selected problems with the celestial globe and the equatorial telescope. Observational work and lectures at the Observatory.

3. PRACTICAL ASTRONOMY. *Two hours.* Second semester only.
   The elements of Spherical Astronomy. Theory of the sextant and transit and their use in the solution of practical problems, including determinations of time, latitude, azimuth, and longitude. The observational work at the Observatory in connection with this course will be varied to suit the needs of students from the different departments. See Course 3E.

3E. GEODETIC ASTRONOMY. *Two hours.* Both semesters.
   Covers ground of Course 3, with less Observatory practice and more classroom work, including a short course in Descriptive Astronomy.

6. LEAST SQUARES AND EMPIRICAL CURVES. *Two hours.* Second semester only.
   Theory of the error curve and the treatment of observational data according to the Method of Least Squares.

22. NAVIGATION. Lectures. *Three hours.* Second semester only.
   The principles of piloting, dead reckoning, and Nautical Astronomy, including practice with sextant.

SUMMER SESSION

Courses 1s, 2s, and 3 or 3E will be given during the Summer Session of 1921. Provision will also be made for graduate students who are specializing in Astronomy.

189. BACTERIOLOGY, AND WATER ANALYSIS

Professors VAUGHAN, NOVY, Mr. EMERSON

3E. PRACTICAL BACTERIOLOGY.
This course is open only to students of Sanitary Engineering. Three afternoons each week during the second half of the first semester, beginning December 1.

5E. WATER ANALYSIS.
Two afternoons weekly, from October 1 to December 1.
This course is open only to students of Sanitary Engineering.

190. CHEMICAL ENGINEERING

Professors A. H. WHITE, HOLLEY, A. E. WHITE, BADGER, BRIER, LESLIE, Assistant Professors WOOD, UPTHEGROVE, BAKER, CAMPBELL, Mr. BROWN, Mr. GENIESSE, Mr. CARR

Students intending to specialize in Chemical Engineering are advised to obtain a reading knowledge of both French and German. If only one language can be studied, it should be German, which, on account of the importance of its scientific literature, will be found to be almost indispensable to the advanced student.

1. ENGINEERING MATERIALS. Lectures and recitations. *Three hours.* Both semesters.
An elementary study of the manufacture and properties of the ferous and non-ferrous alloys, cements, clay products, and protective coatings.
Prerequisite: Chem. 2E.

2. FUELS AND THEIR UTILIZATION. Lectures and recitations. *One hour.* Both semesters.
A descriptive study of fuels and their combustion, either directly or after conversion into gas or coke; and of regenerative furnaces and the means of obtaining high temperatures.
Prerequisite: Preceded or accompanied by Course 1 in Chemical Engineering and 2E in Physics.

4. SALTS, ACIDS, AND ALKALIES. Lectures and recitations. *Two hours.* Both semesters.
A descriptive study of the evaporation of salts and their separation from one another by fractional crystallization; of the manufacture of sulphuric, nitric, and hydrochloric acids; of the manufacture of alkali and chlorine by the older chemical processes and by electrolytic processes, together with a consideration of some other electrolytic and electrothermal processes.
Prerequisite: Course 2 in Chemical Engineering, Course 8 or 8E in Chemistry and 2E in Physics.

5. CHEMICAL TECHNOLOGY OF CARBON COMPOUNDS. Lectures and recitations. *Four hours.* Both semesters.
A study of the industrial chemistry of organic compounds including the following manufacturing processes: Destructive distillation of coal and wood with recovery of by-products; illuminating gas; starch, glucose, and sugar; fermentation and distillation; fats, oils, and soaps; bleaching and dying; tanning; paper manufacture; dyes and intermediates.
Prerequisites: Courses 2 and 4 in Chemical Engineering, and Courses 7 and 7*a* in Chemistry.

6. METALLURGY OF IRON AND STEEL. Lectures and recitations. *Two hours.* Both semesters.
A general course in the metallurgy of iron and steel covering the different manufacturing processes, calculations for furnace charges and efficiencies, and a study of the influence of chemical composition, mechanical work, and heat treatment on the properties of cast iron and steel.
Prerequisite: Courses 1 and 2 in Chemical Engineering, or Course 1 in Chemical Engineering and Course 3 in Mechanical Engineering.

7. NON-FERROUS METALS. Lectures and recitations. *Two hours.* First semester only.
A study of the metallurgy of copper, lead, and zinc.
Prerequisite: Courses 1 and 2 in Chemical Engineering, or Course 1 in Chemical Engineering and Course 3 in Mechanical Engineering.

8. METALLOGRAPHY OF IRON AND STEEL. Lectures and laboratory work. *Two hours.* Both semesters.
Especial study is made of the microscopic structure of iron, steel, and other alloys, and of the effects upon these structures caused by heat treatment, mechanical work, and composition.
Prerequisite: This course must be preceded or accompanied by Course 6 in Chemical Engineering and preceded by Course 5 in Chemistry or Course 2 or 6 in Engineering Mechanics.

9. TECHNICAL EXAMINATION OF GAS AND FUEL. *Two hours.* Both semesters.
Mainly laboratory work. The analysis of commercial gases, the determination of the heating value of fuels and the photometry of gas flames are studied.
Prerequisite: Must be preceded or accompanied by Course 2.

10. TECHNICAL EXAMINATION OF GAS AND FUEL. *One hour.* Both semesters.
Similar to Course 9, but briefer and designed especially for mechanical Engineering students. Not open to students in Chemical Engineering.
Prerequisite: Must be preceded by Course 1 in Chemical Engineering, Course 2E in Chemistry, and Course 1E in Physics, and accompanied by Course 7 in Mechanical Engineering.

12. SPECIAL PROBLEMS. *Three to eight hours.* Both semesters.
The purpose of this course is to train the student in methods of independent study. Each student is, after consultation, assigned a subject connected with some manufacturing process which he is to study intensively both in the library and laboratory. Wide latitude is allowed in the choice of a subject and the student is, as far as possible, urged to select that which interests him most.
Prerequisite: Courses 1, 2, and 4 in Chemical Engineering, and Chemistry 28, with Course 5 in Chemical Engineering, and Chemistry 7 and 7*a* in addition if the subject involves organic chemistry. A reading knowledge of French or German (preferably German) is also required.

13. EVAPORATION, FILTRATION, AND TRANSPORTATION OF LIQUIDS ON THE MANUFACTURING SCALE. *Two hours.* First semester only.
A study largely from blue prints and trade bulletins of apparatus required in many chemical manufacturing operations.
Prerequisite: Courses 1, 2, and 4 in Chemical Engineering.

14. MACHINERY AND PROCESSES FOR CONVEYING, GRINDING, AND MIXING. *Two hours.* Second semester only.
A descriptive study of the treatment of materials on the manufacturing scale.
Prerequisite: Courses 1 and 2 in Chemical Engineering.

15. SEMINARY. Reading and reports on selected subjects. *Two hours.* Both semesters.
Open only to graduates and seniors who receive special permission. A reading knowledge of German and French is required.

16. THE MANUFACTURE OF ILLUMINATING AND FUEL GASES AND MOTOR FUELS. Lectures and recitations. *Two hours.* Second semester only.
The larger part of the time will be devoted to a consideration of the problems involved in the manufacture and purification of coal gas and to the manufacture of water gas.
Prerequisite: Course 5 in Chemical Engineering, and Course 3 in Mechanical Engineering.

18. METALLOGRAPHY OF THE NON-FERROUS METALS. *Two hours.* First semester only.
A study of the microscopic structure of the common non-furrous metals and alloys, and of the effect on their structure and properties of heat treatment, mechanical work, and composition.
Prerequisite: Course 5 in Chemistry and Course 6 in Chemical Engineering; must be preceded or accompanied by Course 7 in Chemical Engineering and Course 2 or 6 in Engineering Mechanics.

21. SPECIAL LABORATORY WORK. *Three to eight hours.* Both semesters.
This is research work along special lines. These courses are open only to graduates and seniors who receive special permission.

a. THE CONSTITUTION OF STEEL.
Research work on the constitution of steel as influenced by chemical composition, and heat and mechanical treatment.

b. HYDRAULIC CEMENTS.
Research work on the properties of hydraulic cements as influenced by chemical composition, temperature of burning and heat treatment.

d. PAINTS AND VARNISHES.
Research on the manufacture and properties of protective coatings.

h. EVAPORATION.
Work in the Evaporator Laboratory on the design of evaporators and on problems connected with handling liquids on the commercial scale.
Should be preceded or accompanied by Course 13.

i. ADVANCED METALLURGY (FERROUS).

j. ADVANCED METALLURGY (NON-FERROUS).

k. FUEL OILS AND MOTOR FUELS.

l. DYES AND INTERMEDIATES.

23. DESIGN OF CHEMICAL PLANTS. *Two hours.* Both semesters.
A simple chemical process is selected, and the student proceeds to plan the steps in the process and select the type of apparatus for each.
Must be preceded by Course 13, and preceded or accompanied by Course 14 in Chemical Engineering and Course 2 in Mechanical Engineering.

24. PYROMETERY AND FURNACE DESIGN. *Two hours.* Both semesters.
A study of commercial pyrometers, their construction, use, and calibration; and of the principles of design of metallurgical and industrial furnaces.
Must be preceded by Courses 2 and 6.

26. ADVANCED FERROUS METALLURGY. Lectures and recitations. *Two hours.* Second semester.
A study of the constitution of irons and steels and the effect on their properties of composition, heat treatment, and mechanical work.
Prerequisites: Courses 6 and 8 in Chemical Engineering.

27. DESIGN OF CHEMICAL MACHINERY. Conferences and drafting. *Two hours.* Both semesters.
The student selects some piece of chemical machinery and makes a complete set of drawings as would be required for its actual construction.
Prerequisites: Course 13 in Chemical Engineering and Course 2 in Mechanical Engineering.

28. MACHINERY AND PROCESSES FOR EXTRACTION, DRYING, AND DISTILLATION. *Two hours.* Second semester only.
A study from trade bulletins of the design of equipment for counter-current extraction, sprays for cooling and scrubbing gases, drying, leaching, and distilling.
Prerequisites: Must be preceded or accompanied by Courses 4 and 5 in Chemical Engineering; and should be preceded by Course 13 in Chemical Engineering.
Summer Session Courses, 1, 2, 6, 8, 9, and 12, as described in the regular sessions, will be given in the Summer Session of 1921. In addition Courses 4 and 5 may be given if there is sufficient demand.

30. SEMINARY IN METALLURGY. Reading and reports on metallurgical subjects. *Two hours.* Both semesters. Only open to graduates and seniors who receive special permission.

31. ADVANCED ORGANIC TECHNOLOGY. *Two hours.* First semester.
A study of manufacturing processes, particularly those pertaining to the dye, intermediate and textile industries.

Must be preceded by Chemical Engineering 5 and preceded or accompanied by Course 45 in Chemistry.

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191. CHEMISTRY

Professors CAMPBELL, GOMBERG, BIGELOW, LICHTY, SMEATON, WILLARD, BARTELL, Assistant Professors CARNEY, SCHOEPFLE, MELOCHE, Mr. COLE, Mr. MCALPINE, Dr. FERGUSON, Dr. HODGES.

Students admitted with a deficiency in entrance chemistry may remove it by completing Course 1 or 1*b*, but the credit thus obtained is entered on the admission, not the graduation, requirements. Students who have thus completed Course 1 or 1*b* will proceed with Course 2 instead of 2E.

Other courses in chemistry are given in the College of Literature, Science, and the Arts, and in the Graduate School, and may be elected by students of the College of Engineering who have had the requisite preparation.

Students intending to specialize in chemistry are advised to obtain a reading knowledge of both French and German.

Fees for laboratory courses in chemistry may be increased owing to the uncertainty of obtaining supplies.

1. GENERAL AND INORGANIC CHEMISTRY. *Four hours.* Two lectures, two recitations, two laboratory periods. First semester only.

This course embraces a study of non-metallic elements and their compounds, with special emphasis upon the interpretation of chemical phenomena from the viewpoint of recent theory and investigation, accompanied by a systematically arranged course of laboratory experiments designed to illustrate the fundamental principles underlying the science.

1*b*. GENERAL AND INORGANIC CHEMISTRY. *Four hours.* Two lectures, two recitations, two laboratory periods weekly.

This course offers an opportunity for those entering the University at the opening of the second semester to commence the study of chemistry, but no student will be admitted who might have elected 1. Special permission must be obtained from the instructor in order to elect this course.

2E. GENERAL AND INORGANIC CHEMISTRY. Two lectures, two recitations, and two laboratory periods weekly. *Five hours.* Both semesters.

The descriptive chemistry of the non-metals and metals is cov-

ered, with special reference to engineering problems. The course is based upon modern theoretical principles, including the development of the stöchiometrical laws, the law of mass action, chemical equilibria, the kinetic theory of gases, theory of solution, theory of electrolytic dissociation, atomic and molecular hypotheses, and the periodic classification.

This course is for students who have presented a unit of chemistry for entrance. An examination will be held within the first four weeks and those considered inadequately prepared will be transferred to Course 1, to be elected without credit.

2. GENERAL AND INORGANIC CHEMISTRY. Continuation of Course 1. *Four hours.* Second semester only.

3. QUALITATIVE ANALYSIS. Recitations and laboratory work. *Five hours.* Both semesters.

In this course the distinctive properties of some of the more common chemical compounds are studied, with special reference to their use in analysis. In addition to practice with known materials, the correct analysis of a considerable number of unknowns is required.

Open to those who have completed Course 2 or 2E.

3*a*. QUALITATIVE ANALYSIS. Recitations and laboratory work. *Four hours.* Both semesters.

A study of the distinctive properties of some common substances in water solution and the reactions used in identification of such substances. Attention is directed to reactions which bear on problems met in engineering practice.

Open to those who have completed Course 2 or 2E.

3*b*. QUALITATIVE ANALYSIS. Continuation of Course 3*a*. *Four hours.* Both semesters.

This course involves the identification of a wider range of substances and the analysis of more difficult mixtures, including some alloys, slags, and phosphates.

5. QUANTITATIVE ANALYSIS. Recitations and laboratory work. *Five hours.* Both semesters.

General methods of determining not only the identity but also the amounts of constituents present in a given mixture are studied in classroom and laboratory.

Open to those who have completed Course 3 or 3*b*.

7. ORGANIC CHEMISTRY. Lectures, recitations, and laboratory work on the properties and classification of carbon compounds. *Five hours.* Both semesters.

7*a*. ORGANIC CHEMISTRY. Lectures, recitations, and laboratory work. *Five hours*. Continuation of Course 7. Both semesters.

8. ELEMENTARY THEORETICAL AND PHYSICAL CHEMISTRY. Lectures and recitations. *Four hours*. Second semester only.

8E. ELEMENTARY THEORETICAL AND PHYSICAL CHEMISTRY. Lectures and recitations. *Three hours*. First semester only.
Special attention will be paid to the study of chemical equilibrium, velocity of chemical reactions, and applications of physico-chemical theory. Open to those who have completed Chemistry 3 or 3*b* and Physics 2. A knowledge of calculus is also required.

15. HISTORY OF CHEMISTRY AND DEVELOPMENT OF CHEMICAL THEORY. *Three to five hours*. Both semesters.

28. ADVANCED QUANTITATIVE ANALYSIS. Lectures and laboratory work. *Three to five hours*. Both semesters.
Application is made of the principles laid down in Course 5 to the analysis of some technical products, including coal, iron ore, a silicate rock, and alloy steels.
Open to those who have completed Course 5.

31. INDEPENDENT WORK IN MINERAL ANALYSIS. *Five hours*. Both semesters.
A study of some of the more difficult and uncommon problems of quantitative analysis. The student is left largely to his own resources.
Open to those who have completed Course 28.

36. RESEARCH IN INORGANIC CHEMISTRY. Special attention will be given to the chemical constitution of metals, silicates, or other substances of importance. *Credit to be arranged.*
Course 36 requires special permission.

37. ORIGINAL INVESTIGATION IN ANALYTICAL CHEMISTRY. Laboratory work. *Credit to be arranged.*
Course 37 is open only to those who have special permission.

40. ADVANCED METALLURGICAL CHEMISTRY. *One hour*. First semester only.
Seminary on the theory of steel and properties of metallic solutions.

40*a*. Continuation of Course 40. Second semester.

43. ADVANCED ORGANIC CHEMISTRY AND ULTIMATE ANALYSIS. Laboratory work and reading. Continuation of Courses 42 and 7*a*. *Three, four, or five hours.*

SUMMER SESSION

Courses 1, 2, 3, 3*a*, 36, 5, 8E, 15, 28, and 42, as described for the regular session, will be given in the Summer Session of 1921.

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192. CIVIL ENGINEERING

Professors RIGGS, JOHNSTON, KING, HOAD, GRAM, DECKER, BIANCHARD, CISSELL, BATEMAN, WISLER, ERIKSEN, Mr. ALT, Mr. ELLIOTT, Mr. POPE.

Structural Group C. E. 1 to C. E. 9, inclusive.
Hydraulic Group C. E. 10 to C. E. 19, inclusive.
Railroad Transportation Group C. E. 20 to C. E. 29, inclusive.
Sanitary and Municipal Group C. E. 30 to C. E. 39, inclusive.
Highway and Highway Transport Group C. E. 40 to C. E. 49, inclusive.
Graduate Group C. E. 60 to C. E. 83, inclusive.
Graduate Short Period Courses in Highway Engineering and Highway Transport C. E. 67 to C. E. 83, inclusive.

1. DRAFTING ROOM PRACTICE. *Two hours.* Both semesters.
Drawing room exercises covering practice in lettering, tracing, office reproduction of field sketches of engineering structures, all with a view of preparing the student for later design courses.
Course 1 must be preceded by Courses 4 and 5 in Drawing.
Required of all Civil Engineering students.

2. THEORY OF STRUCTURES. *Three hours.* Both semesters.
Lectures, text and problems covering analysis of stresses in simple structures under various conditions of loading. Both graphical and analytical methods are discussed and applied to practice problems.
Course 2 must be preceded by Course 2 in Engineering Mechanics. Required of all Civil Engineering students.

2*a*. ELEMENTARY DESIGN OF STRUCTURES. *Two hours.* Both semesters.
Lectures and drawing work to accompany Course 2, covering theory of beams and plate girders, mill buildings, and elements of design of simple structures. Two afternoons a week.
Course 2*a* must be accompanied or preceded by Course 2.
Required of all Civil Engineering students.

3. MASONRY. *Three hours.* Both semesters.
Lectures, text, and problems covering study of materials, analysis of stresses, and elements of design of reinforced concrete structures; earth pressures; and general design of simple types of retaining walls and dams.
Course 3 should be preceded by Course 2.
Required of all Civil Engineering students.

4. ADVANCED THEORY OF STRUCTURES. *Two hours.* Second semester only.
Lectures, problems, and assigned reading covering analysis of stresses in special types of structures, cantilevers, draw spans, and arches.
This course is a continuation of Course 2 for students especially interested in structural engineering, and must be preceded by it.

5. DESIGN OF STRUCTURES. *Three hours.* Both semesters.
Lectures, text, and drawing covering the general design of reinforced concrete, steel, and timber structures. Two afternoons a week.
Course 5 must be preceded by Courses 2*a* and 3.
Course 5 required of all Civil Engineering students electing Group A, Structural Engineering.

6. ADVANCED MASONRY AND FOUNDATIONS. *Two hours.* Both semesters.
Lectures, text, and problems covering theory of ordinary foundations; footings; piling; advanced study of reinforced concrete and its application in practical problems; analysis of stresses and elements of design of higher forms of masonry structures, pipe rings, culverts, portals, and arches.
Course 6 must be preceded by Course 3.
Required of all Civil Engineering students.

7. ADVANCED DESIGN OF STRUCTURES. *Three hours.* Second semester only.
A drawing room course for advanced work in the design of various types of structures. Two afternoons a week.
Course 7 must be preceded by Course 5.
Course 7 open only to fourth and fifth-year students.

7*a*. CONCRETE AND STEEL HIGHWAY BRIDGE DESIGN. *Three hours.* Second semester only.
A drawing room course in the design of reinforced concrete and structural steel. This is a modification of Course 7 specially designed to meet the requirements of students electing the Highway Engineering Group, and must be accompanied by Course 43, the two courses constituting the required group design.

8. ANALYSIS AND DESIGN OF ARCHES. *Two hours.* Second semester only.

A course of lectures, recitations, and drawing covering the analysis of stresses and design of arches, with particular reference to reinforced concrete.

Must be preceded by C. E. 3.

10. HYDROLOGY. *Three hours.* Both semesters.

Lectures, reference texts, problems, and field work. Stream gauging; study of drainage basins; relation between precipitation and run-off; effect of seepage, evaporation, and temperature on run-off; estimates of discharge from existing data; fluctuations in discharge of streams—daily, monthly, and yearly; the storage of water; study of floods.

Course 10 must be preceded by Course 4 in Engineering Mechanics. Required of all Civil Engineering students.

11. HYDRAULICS. *Two hours.* First semester only.

Lectures, reference texts, and problems. Flow of water in open channels; flow of water in pipes; the use of weirs; determination of hydraulic coefficients; transportation of sediment in streams and canals.

Course 11 must be preceded by Course 4 in Engineering Mechanics.

12. DEVELOPMENT OF WATER POWER. *Three hours. Second semester.*

Hydraulic problems in connection with water power development; hydraulics of turbines; market conditions; estimates of cost of construction and operation; economic considerations; reports; dams and power houses.

Course 12 must be preceded by Course 4 in Engineering Mechanics and preceded by Course 10.

13. ADMINISTRATION OF WATER RESOURCES. *Two hours.* Second semester only.

The administration of streams of foreign countries: (a) Under the common law. (b) Modern administration under the direction of engineers. The development of the common law doctrine and its introduction into the United States. The expansion of the doctrine by court decision and present-day status of stream administration in the United States. The necessity for an engineering administration. Study of stream administration in Western States where the courts are resorted to, only upon appeal, and where litigation is not common. Specific problems relating to the organization of an administration for any particular state.

Open to fourth and fifth-year students.

14. IRRIGATION AND DRAINAGE. *Two hours.* Second semester only. Lectures, reference texts, and problems.
History of the development of both sciences; demand for them in the United States and throughout the world; principles underlying the use of water from streams; laws relating to irrigation and drainage; laying out irrigation and drainage systems—structures, designs, construction; maintenance of irrigation and drainage systems; use of water; economic considerations.
Course 14 must be preceded by Course 10.

16. DESIGN OF HYDRAULIC STRUCTURES. *Three hours.* Second semester only. Lectures and design.
Dams; power houses; tunnels; penstocks; pressure pipes; headgates, spillways, other structures.
Open only to fourth and fifth-year students.
Course 16 must be preceded by Courses 3 and 10 and accompanied by Course 12.
Required of students electing Group B, Hydraulic Engineering.

18. RIVERS AND HARBORS. *One hour.* Second semester only. Lectures and assigned reading.
Breakwaters; dredging, wharves, sea-walls, and river regulation.

20. RAILROAD LOCATION. *Two hours.* First semester only.
Field and office methods of railroad location; train resistance; curve resistance; the vertical profile.
Organization and capitalization of railroads; estimation of volume of traffic; the locomotive; locomotive types; engine rating; assistant engineers; resistance to traction; the influence of location in earning power.
Open only to students in Engineering.

21. RAILROAD ENGINEERING. *Two hours.* Both semesters.
Grading, track, railway structures, water, fuel, and icing stations; signalling; types of construction; methods and costs of construction, maintenance, and location.
Open to students in Engineering and Railroad Administration Course.

22. TRANSPORTATION. *Two hours.* Second semester only.
History of transportation; the relationship of waterway and railway transportation; the highways and highway transport as auxiliaries of transportation; the relation of transportation to the political and economic development of the nation.
This course is for students of the Economics department who desire a general knowledge of transportation, and for students of Engineering.

23. RAILROAD DESIGN. *Three hours.* Second semester only.
Yard and station ground maps; turnouts and track special work; yard design; railway structures; study of standard plans of railroads; problems in special railway structures.
This course is designed to offer a series of problems such as are regularly met in railway practice Occasional field work and inspection trips take the place of some of the design periods.
Required design course for students electing Group C, Transportation Group.
Must be accompanied by Courses 20 and 21.
Open only to fourth and fifth-year Engineering students.

26. SPECIFICATIONS AND CONTRACTS. *Two hours.* Both semesters.
Lectures and assigned reading or discussion.
The essential elements of a contract; bids and bidders on public work; the conduct of public lettings; clauses which should be included in properly drawn contracts covering time, liquidated damages, manner of payment, extra work, defective materials or work; custom and usage as affecting engineering contracts; the duties and powers of the engineer; limitation of engineer's powers; breach of contract; specifications; matter to be included; proper methods of preparing the engineer as a professional man; contracts for professional services; the engineer in court; witness as to facts; expert witness.
Open to fourth and fifth-year students in Engineering and Architecture.

27. PUBLIC UTILITY PROBLEMS. *One hour.* Second semester only.
Lectures and outside reading.
The Relations of Public Utility Corporations to the public served by them. Modern problems which have grown out of the failure to understand these relations.
The reasons for making valuations; theories of value; original cost; cost of reproduction; depreciation; going value and other intangible values. Estimating methods to be adopted under differing conditions. The analysis of estimates; Reasons for variation of estimates in different localities. Overhead items of expense engineering, legal expense and interest. Part of the work of this course will be in the analysis of unit prices to give the student a clear conception of the items that must be taken into account in estimating for various purposes.
Open to fourth and fifth year students.

30. WATER WORKS. *Three hours.* Both semesters.
Lectures and recitations, with assigned reading and problems.
A general study of the municipal water supply problem. In-

cludes a consideration of the sources and character of water supplies, and of the quality required for various municipal purposes; development of supply by means of impounding reservoirs, wells, infiltration galleries, and intakes; design and construction of aqueducts and pipe lines; purification by settling basins and filters; distribution; storage reservoirs, standpipes and elevated tanks, cast iron pipe; the use of meters: fire protection.

Course 30 must be preceded by Course 4 in Engineering Mechanics. Required of all Civil Engineering students.

31. WATER PURIFICATION. *Two hours.* Second semester only.

Lectures and recitations, largely supplemented by library reading and the study of plans.

This course relates chiefly to engineering methods and devices for improving the sanitary quality and enhancing the economic value of municipal water supplies. It involves studies of the relation of water supply to public health, the sources of impurities in water supplies, the effect of storage, the control of water sheds. Sedimentation, the action of coagulants, filtration, sterilization, iron removal, water softening, and other processes are studied in detail, both in the class room and by trips to nearby municipal purification plants.

Course 31 must be preceded by Course 30.

Open only to fourth-year and fifth-year students.

32. SEWERAGE. *Two hours.* Both semesters.

Lectures and recitations, with assigned problems.

A general course in municipal sewerage and drainage, comprising a study of the systems of sewerage, the design of storm water, sanitary and combined sewers; trunk and intercepting sewers and inverted siphons; ground water infiltration and its effects; sewer assessments; and a brief survey of the disposal of sewage.

Course 32 must be preceded by Course 4 in Engineering Mechanics. Required of all Civil Engineering students.

33. SEWAGE DISPOSAL. *Two hours.* Second semester only.

Lectures, recitations and library reading, supplemented by visits to sewage disposal plants.

This is a comprehensive survey of the sanitary, legal and economic problems involved in the disposal of city sewage and industrial wastes, and a detailed study of the various processes and engineering structures employed in sewage treatment. It includes a study of the subject of stream pollution and of the self-purification of streams and other bodies of water.

Course 33 must be preceded by Course 32.

Open only to fourth-year and fifth-year students.

34. MUNICIPAL AND INDUSTRIAL SANITATION. *Two hours.* First semester only.
Lectures and library reading. A general study of the foundations upon which the practice of public sanitation rests. The prevention of certain diseases, such as typhoid fever, malaria and yellow fever, through control of the physical environment. Effect upon public health of water purification, sewage treatment, good drainage, and other sanitary improvements. Industrial sanitation and health conservation.
Open to fourth-year and fifth-year students.

35. SANITARY ENGINEERING DESIGN. *Three hours.* Second semester only. Lectures and drawing room work.
A drawing room course in the design of typical structures related to water supply, water purification, sewerage and sewage disposal.
Course 35 must be preceded by Course 3; and accompanied by either Course 32. Course 33, or Course 34.
Open only to fourth-year and fifth-year students.
Required of students electing Group D, Sanitary and Municipal Engineering.

36. MUNICIPAL ENGINEERING. *Two hours.* Second semester only. Lectures and library reading.
This subject covers the subjects of street cleaning—organization, methods, cost;—the collection and disposal of garbage and other city wastes; and certain other administrative problems with which the city engineering office has to deal.
Open only to fourth-year and fifth-year students.

40. HIGHWAY ENGINEERING. *Two hours.* Both semesters.
Lectures and recitations, with assigned reading.
The course will treat of the fundamentals of highway engineering, including a study of the historical development of highways and highway transport; economics, administraton and legislation; preliminary investigations and transportation surveys; surveying and mapping peculiar to highway engineering; essential factors in the economic design of highways, including road and street systems, location, drainage, foundations, widths, curves, grades, and selection of type of surfacing; essential features of the construction and maintenance of the different types of roads and pavements and the materials used therein; street cleaning and snow removal; and highway structures.

41. HIGHWAY TRANSPORT SURVEYS AND THE THEORY AND ECONOMICS OF HIGHWAY IMPROVEMENTS. *Two hours.* Second semester only.

Lectures and recitations, with assigned library reading and problems, supplemented by inspection trips.

Highway transport surveys will cover the subjects of traffic classification and census; methods of estimating future highway transport; highway factors affecting economic highway transport; investigations of highway routes, transport legislation and regulations, rural and urban transportation opportunities and competing carriers including railway and waterway transport facilities. Under theory and economics of highway improvements will be considered the following subjects: road and street systems, the individual highway, drainage systems, foundations, locations, intersections, widths, cross-sections, curves, grades, selection of type of wearing course, and comparison of roads and pavements.

Open to fourth-year, fifth-year and graduate students in engineering. Fourth-year and graduate students in the College of Literature, Science and the Arts having the written approval of the Committee on Business Administration may elect this course for credit.

42. HIGHWAY ENGINEERING LABORATORY. *Two hours.* Both semesters.

Lectures, assigned reading and laboratory work.

This course includes the testing of cements and aggregates used in cement-concrete construction, the testing of broken stone and slag for hardness, toughness, abrasion, cementation, absorption and specific gravity; tests of the physical properties of sand and clay mixtures, sand, gravel, brick, wood blocks and stone blocks; tests of bituminous materials. Special emphasis is laid upon proper methods of making, reporting and interpreting tests of construction materials.

Course 42 must be preceded or accompanied by Course 40.

Open to fourth-year, fifth-year and graduate students.

43. HIGHWAY ENGINEERING DESIGN. *Three hours.* Second semesters only.

Lectures and recitations, with assigned reading and design problems, supplemented by inspection trips.

This course covers the design of highways and highway systems, drainage systems, culverts and small highway bridges, foundations, curves, grades, right-of-way and street intersections, widths of right-of-way and roadways, and cross-sections, and discussions of field methods of reconnoisance and surveying, and office methods used in mapping, estimating and recording.

This course must be preceded or accompanied by Course 41, or with written approval, by Course 44.

Open to fourth-year, fifth-year and graduate students.

44. HIGHWAY TRANSPORT ECONOMICS, METHODS, LEGISLATION, AND MANAGEMENT. *Two hours.* Second semester only.

Lectures and recitations, with assigned library reading.

History of American and foreign highway transport methods. Economic comparison of methods of transport of passengers and commodities by highway, railway, and waterway. Municipal haulage; municipal delivery systems; store door delivery; intercity haulage; intercity express; long and short rural haulage; rural motor express; plant and factory haulage; horse transportation methods; terminal clearing houses. Legislation pertaining to weights, dimensions, speeds and operation of motor trucks, tractors, trailers, and motor buses. Franchises for highway transport routes; rate legislation; traffic regulations. Fundamentals of efficient management and the different highway transport methods; administration and organization of transportation companies. Cost and record systems; elements of cost of operation of motor vehicles.

Open to fourth-year, fifth-year and graduate students in engineering. Fourth-year and graduate students in the College of Literature, Science, and the Arts having the written approval of the Committee on Business Administration may elect this course for credit.

60. SANITARY ENGINEERING RESEARCH. Credit to be arranged.

Assigned work upon some definite problem related to public sanitation. A wide range in both subject matter and method is available, covering field investigations, experimentation in the laboratory, searches in the library and among public records, and drafting board designing. Open to graduate students only. By appointment.

61. IRRIGATION AND DRAINAGE. *Two hours.* Continuation of Course 14. Open only to seniors and fifth-year students as an advanced course.

62. ADVANCED HYDRAULIC DESIGN. *Two hours.*

Continuation of Course 16 for fifth-year students.

64. HYDRAULIC ENGINEERING RESEARCH. Credit to be arranged.

Assigned work on some definite problem of Hydraulics. A wide range in matter and method is available, covering field experiments, laboratory experiments and designing. Open only to graduate students and fifth-year students who have completed courses in the Hydraulic Group.

65. STRUCTURAL ENGINEERING RESEARCH. Credit to be arranged.

Assigned work on some approved problem in Structural Engineering, preferably experimental work with discussion of de-

rived data. Open only to graduate students and fifth-year students who have taken prescribed courses in the Structural Group.

66. HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT RESEARCH. Credit to be arranged.
Assigned work on approved problems relating to administration, organization, economics, design, materials, construction and maintenance in the field of highway engineering research, or on approved problems relating to highway transport surveys, economics, methods, legislation and management. Open only to seniors, having the written approval of the Professor of Highway Engineering and Highway Transport, and to graduate students who have completed or are taking courses in the Highway Engineering and Highway Transport Group.

GRADUATE SHORT PERIOD COURSES

Graduate courses in highway engineering and highway transport leading to the degree of Master of Science or Master of Science in Engineering have been arranged especially for men engaged in the practice of highway engineering and highway transport. These courses will be given during the months of December to March, inclusive. Each course will consist of thirty lectures and will be given in a period of two weeks. Each course will count as two hours credit towards the total of twenty-four hours required for the Master's degree. This plan will afford highway engineers, chemists, contractors, engineer-salesmen, highway transport engineers and managers, motor truck salesmen and others interested in highway engineering and highway transport an opportunity to obtain advanced knowledge during the season of the year when a leave of absence may be easily obtained. These courses are open to graduate students and qualified special students.

67. HIGHWAY TRANSPORT SURVEYS. *Two hours.*
Lectures and library reading.
This course covers the subjects of traffic classification and census, weighs, speeds, and dimensions of vehicles, highway factors affecting economic highway transport, investigations of highway routes, transport legislation and regulations, rural and urban transportation opportunities and competing carriers including railway and waterway transport facilities.

68. BITUMINOUS SURFACES AND BITUMINOUS PAVEMENTS. *Two hours.*
Lectures and library reading.
This course will cover bituminous surfaces, bituminous mac-

adam pavements, bituminous concrete pavements, asphalt block pavements and sheet asphalt pavements. Each type of construction will be considered from the following standpoints: Description and historical development; economic value, conditions under which it may be used, and foundations; theory and design, external forces, stresses and strains; kinds of bituminous and non-bituminous materials used and desirable qualities thereof; methods of construction; types of machinery used, important features and manipulation thereof; inspection methods; nature of wear and deterioration, and causes of premature failues; methods of maintenance; guarantees, essential features, and economics.

69. HIGHWAY LABORATORY RESEARCH. *Two hours.*
Lectures, library reading, and laboratory investigations.
This course will include advanced problems pertaining to the physical properties of earth, sand and clay mixtures, sand, gravel, broken stone, broken slag, paving brick, cement-concrete, wood blocks and stone blocks; highway laboratory administration, organization, and equipment; sampling and inspection methods; reports and records; field surveys and investigations.

70. HIGHWAY STRUCTURES. *Two hours.*
Lectures and library reading.
Advanced course in the study of the economics and maintenance of all types of highway bridges and culverts, including preliminary investigations; determination of waterways; standard types of highway bridges of wood, steel, cement-concrete, and reinforced concrete; highway bridge foundations and floors; various classes of loads; retaining walls; design of foundations and pavements as structures.
Prerequisite: Theory and design of structures.

71. HIGHWAY SPECIFICATIONS, CONTRACTS, AND JURISPRUDENCE. *Two hours.*
Lectures and library reading.
The essential elements of a contract; bids and bidders on public work; the conduct of public lettings; clauses which should be included in properly drawn contracts covering time, liquidated damages, manner of payment, extra work, defective materials or work; custom and usage as affecting engineering contracts; the duties and powers of the engineer; limitation of engineer's powers; breach of contact; specifications; matter to be included; proper methods of preparing; the engineer as a professional man; contracts for professional services; the engineer in court; witness as to facts; expert witness; jurisprudence relating to surface waters and boundaries of highways.

72. EARTH, SAND-CLAY, GRAVEL, AND BROKEN STONE ROADS. *Two hours.*
Lectures and library reading.
This course covers the characteristics, economic utilization, and fundamentals of construction and maintenance of earth, sand-clay, gravel, and broken stone roads, and the essential properties and methods of testing of soils, gravels, and rock.

73. BRICK, CEMENT-CONCRETE, STONE BLOCK, AND WOOD BLOCK PAVEMENTS. *Two hours.*
Lectures and library reading.
This course covers the characteristics, economic utilization, and fundamentals of construction and maintenance of brick, cement-concrete, stone block, and wood block pavements, and the essential properties and methods of testing of brick, cement-concrete, stone block, and wood block.

74. BITUMINOUS MATERIALS. *Two hours.* (Not offered in 1921-22).
Lectures, library reading, and laboratory work.
Hydrocarbons; classification of bituminous materials; refining processes; petroleum; native and oil asphalts; rock asphalts; crude and refined tars; creosoting oils; tests for bituminous materials; interpretation of results of tests; factors governing specifications for bituminous materials; purchase, transportation, storage, and inspection of bituminous materials.

75. HIGHWAY ENGINEERING SEMINAR. *Two hours.*
Library research, and preparation and presentation of reports, papers, and briefs.
Assigned work on approved definite problems relating to administration, organization, economics, design, materials, construction, and maintenance in the field of Highway Engineering.

76. HIGHWAY ENGINEERING THEORY AND DESIGN. *Two hours.*
Lectures and library reading.
Theory and design of drainage systems, foundations, highway systems, the individual highway, location, intersections, widths, cross-sections, curves, and grades; selection of type of wearing course; comparison of roads and pavements; field methods of reconnoisance; efficient office methods.

77. HIGHWAY ENGINEERING FINANCING, ADMINISTRATION, AND ORGANIZATION. *Two hours.*
Lectures and library reading.
Long-term, short-term, and serial bonds; annual appropriations; local assessments; expenses to be financed; scope and character of organization; administrative control of construction, maintenance, street cleaning, and snow removal; planning boards and visible records; unit cost records.

78. GRADING MACHINERY AND OPERATION. *Two hours.*
Lectures and library reading.
Consideration affecting the purchase of grading machinery; fundamentals of different types of grading machines; efficient methods of using grading equipment; clearing and grubbing; economic comparison of methods of making excavations and embankments with different types of machines; grading organization.

79. AMERICAN AND ENGLISH HIGHWAY TRAFFIC LEGISLATION AND REGULATIONS. *Two hours.*
Lectures and library reading.
Legislation pertaining to weights, dimensions, and speeds of motor trucks, tractors, trailers, and motor-buses; franchises for highway transport routes; rate legislation; national, state, county, township, and municipal laws, licenses, taxes, and traffic regulations.

80. INTERRELATIONSHIP OF HIGHWAY, RAILWAY, AND WATERWAY TRANSPORT. *Two hours.*
Lectures and library reading.
Development of highway, railway, and waterway transportation; economic comparison of methods of transport of passengers and commodities; characteristics and efficiency of each type of transportation; influencing factors of distances, haulage, rates, kinds of freight, packing, equipment, and port, terminal, and warehouse facilities.

81. AMERICAN AND ENGLISH HIGHWAY TRANSPORT METHODS. *Two hours.*
Lectures and library reading.
History of American and English highway transportation methods; comparison of horse and motor transport; municipal haulage, municipal delivery systems, store door delivery, intercity haulage, long and short haulage outside of cities, rural motor express, return loads bureaus, motor truck parcel post, plant and factory haulage, army transport methods, horse transportation methods; efficient methods of packing, handling, loading, and unloading raw and manufactured materials.

82. HIGHWAY TRANSPORT MANAGEMENT, COSTS, AND RECORD SYSTEMS. *Two hours.*
Lectures and library reading.
Fundamentals of efficient management of the different highway transport methods; administration and organization of transportation companies; cost and record systems; elements of cost of operation of motor vehicles, including direct, overhead and lost time charges; relation of highways to operating cost.

83. HIGHWAY TRANSPORT SEMINAR. *Two hours.*
Library research, and preparation and presentation of reports, papers, and briefs.
Assigned work on special problems relating especially to such subjects as highway transport economics; interrelationship of highway transport, good roads, and rural development; consumers' organizations; community schools and the motorbuses; effect of roadways on vehicles.

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193. DRAWING

Professor GOULDING, Assistant Professors FINCH, BENNETT, ORBECK, PALMER, Mr. HEYDEN, Mr. HUDNUTT, Mr. CLARK, Mr. COLE, Mr. COOK, Mr. HANSEN, Mr. POTTER.

1. GEOMETRICAL DRAWING. *Two, three, or four hours.* Both semesters.
Arranged to meet the requirements of those desiring to teach courses in elementary mechanical drawing in the secondary schools and for those desiring a knowledge of the use of instruments and materials.

1*d*. INSTRUMENTAL AND FREE-HAND DRAWING. This course is planned for students of Dentistry. *One hour.* First semester only.
The time devoted to the course is taken up with practice in the use of instruments, lettering, and free-hand sketching, to the end that the student may be able to read and make working drawings of dental and other appliances and such sketches as may be necessary in illustrating his several subjects in Dental Anatomy and kindred courses.

4. DESCRIPTIVE GEOMETRY I. Lectures, conferences with instructor, and drawing room work. *Two hours.* Both semesters.
An exacting study of orthographic projection as applied to the solution of problems relating to the point, line, and plane, including instruction in the use of drafting instruments, drawing to scale, the common geometrical curves, and free-hand lettering.

4*a*. DESCRIPTIVE GEOMETRY AND SHADES AND SHADOWS. Recitations, conferences with instructors, and drawing. *Three hours.*
A special course consisting of most of the work of Drawing 4 and including Shades and Shadows, arranged to meet the needs of students of Architecture and Architectural Engineering.
This course should be taken in the first semester by all students entering in the fall.

5. DESCRIPTIVE GEOMETRY II. Lectures, conferences with instructor, and drawing room work. *Two hours.* Both semesters.
A short review of the most important point, line, and plane problems will be given, followed by problems relating to tangents and normals to lines and surfaces, tangent and normal planes to surfaces, intersection and development of surfaces, and a brief treatment of warped surfaces.
Course 5 must be preceded by Course 4, of which it is the continuation.

5*a*. PERSPECTIVE AND STEREOTOMY. Recitation, lectures, and drawing. *Two hours.*
This course is required of students of Architecture and Architectural Engineering. Course 5*a* must be preceded by Course 4*a*.

10. FREE-HAND LETTERING. *Two hours.* Both semesters.
This course is designed to give the student practice in the simple forms of letters used in the drafting room and the laying out of titles.

11. SPHERICAL PROJECTIONS. Recitations and drawing. *One hour.* Second semester only.
A study of the various projections of the sphere, for the purpose of mapping large portions of the earth's surface, including in the construction, use, and analysis of statistical charts. conic method.
Course 11 must be preceded by Courses 4 and 5.

12. STATISTICAL CHARTING. Lectures and drawing room work. *Two hours.*
A study of the statistical method and of charting in particular. The aim of the course is to give the student a thorough training in the construction, use, and analysis of statistical charts. The lectures will furnish the fundamental principles of statistics and of charting. These will be applied in the drawing room to industrial, social, transportation, or other statistical problems.

13. PATENT OFFICE DRAFTING. This course is to be taken without credit.
It is intended primarily for such students as wish to obtain a knowledge of methods employed in illustrating patent devices. The standard practice and demands of the U. S. Patent Office as well as foreign patent offices will be considered.

194. ELECTRICAL ENGINEERING

Professors PARKER, BAILEY, HIGBIE, LOVELL, CANNON, Assistant Professors STASON, DAVIDSON, MOORE, Mr. FAIRMAN, Mr. DREESE, Mr. ANDERSON, Mr. ATTWOOD.

1. ELEMENTARY ELECTRICAL DESIGN. Recitation, drawing, lectures. *Two hours.* Both semesters.

Course 1 must be preceded by Drawing 4. The course aims to acquaint the student with the different problems of mass production which affect the design of electrical machinery. Mechanical drawing is the tool by which the student fixes his ideas and conveys them. Reference reading in the library is done, and a lecture is given once a week.

2. ELECTRICAL APPARATUS AND CIRCUITS I. (Fundamentals.) Recitations and laboratory work. *Four hours.* Both semesters.

Course 2 must be preceded by Courses 1 and 2 in Physics and by Engineering Mechanics 1. For Electrical students only.

2*a*. This course is similar to Course 2, but is specially designed to fit the needs of non-electrical students. Work and credits are the same as in Course 2.

3. ELECTRICAL APPARATUS AND CIRCUITS II. (Theory.) Recitations and laboratory work. *Four hours.* Both semesters.

This course must be preceded by Course 2 in Electrical Engineering and is devoted partly to carrying forward the consideration of circuits and machines operating with continuous currents begun in Course 2. Most of Course 3, however, is spent in developing familiarity and facility in applying usefully and practically the physical and mathematical principles of circuits carrying alternating currents. Incidentally, the characteristics of the transformer are studied thoroughly as exemplifying electric and magnetic circuits, and also to some extent the synchronous generator is similarly studied.

3*a*. This course follows 2*a* and, like it, is intended for non-electrical students. It treats of the characteristics and application of machines using alternating currents.

4. ELECTRICAL APPARATUS AND CIRCUITS III. (Advanced Theory.) Recitations and laboratory work. *Four hours.* Both semesters.

The work consists in applying the principles studied in previous courses to the synchronous machine, the induction motor, the rotary converter, and to the various types of single-phase motors. Must be preceded by Course 3.

5. DESIGN OF ELECTRICAL MACHINERY AND APPLIANCES. Lectures, recitations, and drawing. *Four hours.* Both semesters.

Course 5 must be preceded by Courses 1, 3, and 14, and is the first of two Electrical Design courses. It may be followed in the second semester by Course 6. In Courses 5 and 6 designs are made of electromagnets, transformers, generators, and motors. Especial attention is given to the calculation of related parts, so as to produce results satisfactory, both theoretically and practically.

6. DESIGN OF ELECTRICAL MACHINERY AND APPLIANCES. Lectures and drawing. *Credit to be arranged.* Second semester only. This course is a continuation of Course 5.

7. ILLUMINATION AND PHOTOMETRY. Lectures, recitations, and laboratory work. *Two hours.* Both semesters.

Course 7 must be preceded by Physics 2E and Mathematics 4. It is devoted to a general study of the theoretical principles underlying measurements and calculations of light in its engineering application to illumination; of the types and inherent characteristics of lamps, and the methods whereby they are adapted to produce suitable illumination; and of the practical features of illumination design.

8. PRINCIPLES OF ELECTRIC TRACTION. Lectures and recitations. *Two hours.* First semester only. Must be preceded by Course 3.

The course covers traffic studies, train schedules, speed-time and power curves, locomotive train haulage, signal systems, cars and locomotives, control systems, traction systems, and the electrification of trunk lines.

9. SPECIAL LABORATORY PROBLEMS. *Hours and credit to be arranged.* Both semesters. Must be preceded by E. E. 3.

Special problems are assigned for laboratory investigation with the intent of developing initiative and resourcefulness, but not to the same extent as is expected in research work. To a large degree the students' own desires will control the subjects investigated.

10. ADVANCED THEORY OF ELECTRICAL MACHINERY AND CIRCUITS. Lectures, home work, and recitations. *Two hours.* Second semester only.

This course must be preceded by Course 3, and it is advisable, if possible, that it be preceded by Course 4. The course deals with the application of mathematical analysis to practical and theoretical problems.

11. POWER PLANTS. Transmission and distribution. Lectures, recitations, and problems. *Five hours.* Both semesters. Must be preceded by E. E. 3.

This course gives the student opportunity to apply to the problems of power plant and transmission design the elements of economics—as in the selection of apparatus, proportioning of details in an assembled whole, balancing initial and subsequent costs. Some attention is given to the interrelation of mechanical and electrical elements in design.

13. PRINCIPLES OF ELECTRIC COMMUNICATION. Recitations and laboratory work. *Four hours.* Both semesters. Not given in 1921-22.

Course 13 must be preceded by Course 3. This course deals with the main systems of communication in practical use, with reference to their principles and modes of application. The theory of speech transmission by electrical means is taken up, together with illustrative problems involving the use of alternating currents and electromotive forces at high frequencies.

14. MECHANISM OF ELECTRICAL MACHINES. Recitations and drawing. *Three hours.* Both semesters.

Course 14 must be preceded by Course 1 and by Engineering Mechanics 2. It is in continuation of Course 1, more stress being laid on the technology of production and on the elementary principles of the design of machine parts, with special reference to the mechanical principles underlying the selection of alternative methods of accomplishing given ends.

15. ADVANCED LIGHTING. Lectures, recitations, and laboratory work. *Two hours.*

Course 15 must be preceded by Course 7 and preceded or accompanied by Course 3. By examining, more fully than is possible in Course 7, the theoretical limits to performance of illuminants and systems of illumination, and the trend of development in practice of illumination engineering, it is attempted here to prepare the students for taking a part, possibly, in such development.

16. FLUX AND POTENTIAL. Lectures and recitations. *Three hours.*

17. ELECTROMECHANICS. Lectures, recitations, and problems. *Four hours.* Both semesters. Must be preceded by Course 3.

A mathematical and physical treatment of force actions and energy relations in electrostatic and electromagnetic fields, capacitance and inductance of conductors, analysis of complex waves, simple transients and oscillatory currents, the general equation for a circuit containing distributed resistance, inductance, capacitance, and leakage.

18. RESEARCH WORK IN ELECTRICAL ENGINEERING. *Hours and credit to be arranged.* Both semesters.
Course 18 is open to students receiving permission of the head of the department before classification, and is intended primarily for graduates. Students electing this course while working under the general supervision of a member of the staff of instruction are expected to plan and carry out the work themselves, and to make a report in the form of a thesis.

19. STUDY OF DESIGN—POWER PLANTS. Lectures and design problems. *Two hours.* Second semester only. Must be preceded by E. E. 11.
In this course studies are made of modern typical designs of generating stations and sub-stations to give intimate knowledge of the problems met with and the standard installations used. Some of the important electrical features are calculated and drawn up in detail. Hydraulic and steam plants are inspected on field trips.

20. STUDY OF DESIGN—ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEMS. *Two hours.* Second semester only. Must be preceded by E. E. 11.

22. RADIO TELEGRAPHY AND TELEPHONY. Lectures, recitations, and laboratory work. *Two hours.* Second semester only. Not given in 1921-22.

33. INDUSTRIAL ELECTRICAL ENGINEERING. Lectures and recitations. *Two hours.* First semester only.
This course must be preceded by E. E. 3.
Some of the topics studied in this course are individual and group drive by electric motors; selection of motors; power requirements for various kinds of machinery; electric hoists; electric welding; electric furnaces and temperature regulation; electric braking.

36. RATES AND COST ANALYSIS. Lectures and recitations. *One hour.* Second semester only.
This course must be preceded by E. E. 2. Open to seniors only.
Some of the topics studied in this course are: capitalization, fair return on investment, analysis of costs and value of electrical energy; customer charges, demand charges, energy charges; investigations of practical systems used in charging for electrical energy.

SUMMER SESSION

Courses 2, 2*a*, 3, 4, and 18, with probably some advanced courses, as described for the regular session, will be offered for the Summer Session of 1921.

195. ENGINEERING MECHANICS

Professors PATTERSON, MENEFEE, AIREY, Associate Professor VAN DEN BROECK, Assistant Professors STEVENS, SWINTON, OLMSTED, and Mr. LIDDECOAT.

1. STATICS. *Four hours.* Both semesters.
A study of the fundamental principles of mechanics and their application to the simpler problems of engineering science.
Course 1 must be preceded by Course 3 in Mathematics and Course 1E in Physics, and should be preceded or accompanied by Course 4 in Mathematics.

2. STRENGTH AND ELASTICITY OF MATERIALS. *Three hours.* Both semesters.
A study of the application of mechanical principles to the various problems of stress and strain in engineering materials. The general effects of force on elastic bodies, the bending of beams, twisting of shafts, behavior of struts and ties, etc., are studied in the light of the simpler accepted theories.
Course 2 must be preceded by Course 1.

2*a*. STRENGTH AND ELASTICITY OF MATERIALS. *Four hours.* Both semesters.
This course has the same class work as Course 2, with a laboratory period.
Course 2*a* must be preceded by Course 1.

3. DYNAMICS. *Three hours.* Both semesters.
Work and energy; the use of velocity, acceleration, and other diagrams to the study of dynamic problems relating to machines.
Course 3 must be preceded by Course 1.

4. HYDROMECHANICS. *Two hours.* Both semesters.
Fluid pressure and fluid motion; Bernoulli's Theorem; flow of water over weirs, through pipes, and in open channels; dynamic action of jets and streams.
Must be preceded by Course 1.

5. TESTING MATERIALS. *Two hours.* Both semesters.
The laboratory work is preceded by a critical study for five weeks of published tests of engineering materials, including steel and cast iron in tension, concrete columns in compression, cement in tension and compression, and wood in bending. Written reports are required in which especial emphasis is laid on the technic of report writing and the graphical presentation and interpretation of the data.
The remainder of the semester is devoted to laboratory tests on

steel, iron, wood, brick, and structural materials, including the standard cement tests, tests for voids in sand and stone, tests of reinforced and unreinforced concrete beams and granular metric analysis of sand.

Course 5 must be preceded by Courses 1 and 2.

6. STRENGTH OF MATERIALS—TESTING. *Three hours.* Both semesters.

The elementary theory of the strength of ties, struts, beams, and shafts. Laboratory practice in commercial testing and investigative methods.

Course 6 must be preceded by Courses 1 or 2. It is an abridgment of the work covered in Courses 2 and 5, and may not be elected by anyone who has passed, or intends to elect, either of these courses.

10. RESEARCH. *Hours and credit to be arranged.* Both semesters.

Course 10 must be preceded by Course 5.

SUMMER SESSION

Courses 1, 2, 2*a*, 3, and 4, as described above, are given in the Summer Session for 1921.

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196. ENGLISH*

Professor NELSON, Assistant Professors THORNTON and SCHNEIDER, Mr. LANGWORTHY, Mr. KLOCKSIEM, Mr. EGLY, Mr. WENGER, Mr. WALTON, Mr. LYMAN, Mr. TEN HOOR, Mr. DAHLSTROM.

(For a general description of the courses, see §§ 41 and 42.)

Group I. Courses designed to assist the student to self-expression, and to prepare him for his special work:

1. THEME-WRITING AND ORAL EXPOSITION. *Four hours.* Both semesters.

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* All regular students in the Colleges of Engineering and Architecture are required to take six hours of English. In the College of Engineering this consists of English 1 and a two-hour writing course in the junior or senior year, which must be chosen from the following: English 5, 6, 9, 10, or 14. *No other courses can be substituted.* In the College of Architecture the student may take in addition to English 1 any two-hour English course. This course may be taken at any time during the four years, unless the student elects one of the courses open to juniors and seniors only.

1*a*. THEME-WRITING AND ORAL EXPOSITION. *Two hours.* First semester.

This course, which corresponds to the first half of English 1, is for those students in Architecture who cannot take the regular work in English 1.

1*x*. THEME-WRITING. Both semesters.

This course, two hours a week, is taken without credit by all students who receive the grade of "d" in English 1, 1*a*, 2, or 2*a*.

2. THEME-WRITING AND ORAL EXPOSITION. *Two hours.* Both semesters.

This course, which is a continuation of Course 1, is intended primarily for freshmen and sophomores.

2*a*. THEME-WRITING AND ORAL EXPOSITION. *Four hours.* Second semester.

This course, which corresponds to the second half of English 1 and to English 2, is for those students in Architecture who have in their first semester taken English 1*a*.

3. PUBLIC SPEAKING FOR ENGINEERS. *Two hours.* Both semesters.

A study of the forms of public address of most practical value to engineers. The course will not only deal with the problems of organization, illustration, and effective presentation of technical material, but will also give the student frequent opportunity to present this type of material before an audience for criticism.

4. NOTE-TAKING. *Two hours.* Both semesters.

This course aims to give the student a practical method of note-taking, and to give him sufficient practice in the use of that method to assure him of more coherent results in those technical courses in which note-taking is necessary.

5*. SCIENTIFIC AND TECHNICAL PAPERS. *Two hours.* Both semesters. For juniors and seniors only.

The most efficient methods of collecting scientific and technical material, organizing it, and preparing it for either publication or oral presentation, will be outlined. The practice work will lay particular emphasis upon the effective handling of various types of illustrative material and the interpretation of technical subjects to audiences of non-technical listeners.

6.* REPORT-WRITING. *Two hours.* Both semesters. For seniors only.

The engineering report is studied as a special type of exposition to which are applicable the fundamental principles of all expository writing. The major assignments will be made, as

largely as possible, by the department of engineering in which the student is studying, and every effort will be made to correlate the work of the course with the technical work in which the student is engaged.

7. TECHNICAL JOURNALISM. *Two hours.* First semester only. This course includes an analysis of technical publications of the day; a study of the relation of the technical magazine to the engineering profession, and its use and function as compared with other types of magazines; studies and problems in the work of editing. Incidental attention is given to house organs, descriptive cataloguing, and advertising.

8. TECHNICAL JOURNALISM. *Two hours.* Second semester only. Open only to students who are doing work on the *Technic*.

9.* ADVERTISING AND COMMERCIAL CORRESPONDENCE. *Two hours.* Both semesters. For juniors and seniors only.

A study of fundamental business situations, with especial reference to effective written English. Advertising, general publicity, commercial correspondence. Lectures, reading, and assigned exercises. The lectures will be devoted primarily to the psychology and business usage involved.

10.* SALES. *Two hours.* Both semesters. For juniors and seniors only.

A study of fundamental business situations, with especial reference to effective spoken English. General business interviews, testimony, sales. Lectures, reading, and assigned exercises. The lectures will be devoted primarily to the psychology and business usage involved.

12.* BUSINESS ENGLISH—ADVANCED COURSE. *Two hours.* Both semesters.

A study of fundamental business situations, with special reference to the various relations of advertising to selling campaigns. Lectures, reading, and assigned exercises. Open only to those who have had a previous course in Business English or in the Psychology of Advertising.

14.* THE ENGINEER AND HIS READING. *Two hours.* Both semesters. For juniors and seniors only.

A consideration of the needs of the engineer as a member of society for interests outside his strictly technical field, and of the ideal values to be found in non-technical studies as a preparation for professional life. The course will include round-table discussions and the preparation of a definite number of prescribed papers on the topics developed in these discussions.

Group II. Courses especially designed for foreign students. (See Sec. 42.)

16. ENGLISH FOR FOREIGN STUDENTS. *Four hours.* First semester.
This course purposes: first, to deal simply and practically with the phonetics of English speech in a way which will serve to correct the difficulties of the individual student; second, to give sufficient drill in reading aloud to aid the student to acquire a correct pronunciation and to enlarge his vocabulary; third, to give him practice in conversation of a sort to meet his immediate needs in the classroom and in the life of the community about him. The work consists of phonetic exercises, conversation, dictation, speeches, visits with the instructor to the laboratories, libraries, etc., and at least one personal consultation period each week with the instructor.

17. ENGLISH FOR FOREIGN STUDENTS. *Four hours.* Second semester.
A continuation of Course 16, for students who will need special attention.

Group III. Courses designed to interest the student in reading and to develop in him a standard of critical judgment:

21. READING IN CONTEMPORARY LITERATURE. *Two hours.* Both semesters.
This course may be taken before a student has elected English 1.
An introduction to the study of the novel, the drama, and the short story, which form the subject matter of special courses. (See 22, 23, 24, 25, and 26.)

22. STUDIES IN THE NOVEL. *Two hours.* First semester.
The purpose of this work is to familiarize the student with the method and form of those English novels which have stood the test of time, and to develop in him a standard of taste which may apply for himself in the reading of the modern novel.

23. THE CONTEMPORARY NOVEL. *Two hours.* Both semesters.
An attempt is made in this course to find underneath the story, which has heretofore been the student's only interest, the deeper meaning and the social significance of certain recent fiction. Lectures, discussion, and written reports.

24. THE SHORT STORY. *Two hours.* Both semesters.
The magazine stories read by the student in a rather aimless and desultory fashion are compared with the best modern examples of this form, with the general purpose of guiding

the student's reading to a higher level of taste and enjoyment. Lectures, discussions, oral and written reports.

25. STUDIES IN THE DRAMA. *Two hours.* First semester only. Characteristic Greek, French, German, and English plays are read not only with reference to those qualities which make them landmarks in the development of the drama but as an introduction to the drama as a type of literature of especial interest to those who like to finish at one sitting whatever they read. The material chosen will be such as to prepare the student to judge the modern drama intelligently.

26. THE CONTEMPORARY DRAMA. *Two hours.* Both semesters. The general method employed in this course will be similar to that in Course 24. The material will be chosen from Ibsen, Sundermann, Maeterlinck, Rostand, Pinero, Bennett, etc., and a special effort will be made to have the student develop personal standards which will enable him to judge intelligently the various types of plays which the average theatre-goer will see.

27. SCIENTIFIC READING. *Two hours.* First semester only. This course aims to open to the student the great and fascinating literature in the field of pure science. Not only will the works of the great historic figures in this field, like Darwin, Huxley, Spencer, Burroughs, and Thoreau, be read, but the more recent works of men like Fabre, Maeterlinck, Beebe, and others who have done so much to make scientific thought accessible to the unscientific reader.

28. SCIENTIFIC READING. *Two hours.* Second semester only. This course follows the same general plan as the preceding. The authors read are, however, different, so that a student who desires both courses can elect them without duplicating the material studied.

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197. FINE ARTS

Professor H. R. CROSS

1. GENERAL INTRODUCTORY COURSE IN THE FINE ARTS. *Three hours.* Both semesters.

An investigation of the origin, development, and essential principles and technique of Architecture, Sculpture, Painting, and the minor arts, including a brief survey of their history from prehistoric times to the present. Text-book, S. Reinbach's

Apollo. Illustrated lectures, required reading, written tests, and reports on assigned subjects.

This course (or its equivalent, satisfactory to the instructor) is a prerequisite for all other courses in this department.

3. GREEK ART. *Three hours.* First semester only.

The history of the Fine Arts among the Greeks, to the Roman period, with a preliminary survey of Egyptian and Mesopotamian art. Special attention is given to the great sculptors of the fifth and fourth centuries, B. C. Illustrated lectures, required reading, written test, and reports on assigned topics.

4. ROMAN AND MEDIEVAL ART. *Three hours.* Second semester only.

The history of the Fine Arts in the Roman, Early Christian, Byzantine, and Medieval periods, with special attention to Roman and Gothic architecture. Illustrated lectures, required reading, written tests, and reports on assigned topics.

5. RENAISSANCE ART. *Three hours.* First semester only.

The history of the Fine Arts in the fifteenth and sixteenth centuries, with special reference to the development of Italian painting. Illustrated lectures, required reading, written tests, and reports on assigned topics.

6. LATE RENAISSANCE AND MODERN ART. *Three hours.* Second semester only.

The history of art in the seventeenth, eighteenth, and nineteenth centuries, with special reference to the French, English, and American schools of painting. Illustrated lectures, required reading, written tests, and reports on assigned topics.

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198. FORESTRY

Assistant Professor YOUNG

23. FORESTRY FOR ENGINEERS *Two hours.* Two lectures, M. and F. at 9. Room F-213, N. S. Bldg. Assistant Professor YOUNG.

Identification of commercial woods. Characteristics of our native woods and their suitability for construction. Methods of seasoning and storing timber. Wood preservation. Grading rules and specifications used in buying and selling timber. Economic importance of forests. Methods of planting for watershed protection, for snowbreaks and windbreaks.

This course has no prerequisites and is open to all students.

199. FRENCH*

Professors WAIT, LEE, Assistant Professors ADAMS, KENYON, Mr. JOBIN, Mr. BRITTON, Mr. GAISS, Mr. MCGUIRE, Mr. DRISCOLL, Mr. ANDERSON.

1. ELEMENTARY COURSE. *Four hours.* Both semesters.
Grammar and reading, with practice in writing and speaking French.

2. ELEMENTARY COURSE CONTINUED. *Four hours.* Both semesters.
Grammar and reading, with practice in writing and speaking French.

3. INTERMEDIATE FRENCH. *Four hours.* Both semesters.
Modern prose, conversation and composition, with a thorough review of grammar.

4. HISTORY OF FRENCH LITERATURE, CONVERSATION AND COMPOSITION. *Four hours.* Both semesters.

5. ADVANCED COMPOSITION AND CONVERSATION. *Two hours.* Both semesters.

6. FRENCH LITERATURE IN ENGLISH.
An outline of the development of French literature. Lectures, assigned readings, and reports.

9. FRENCH CHEMICAL READING. Two hours. Second semester only. Equivalent to Chemistry 20*a*.

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200. GEOLOGY

Professor HOBBS and Assistants

1*a*. INTRODUCTION TO GEOLOGY FOR ENGINEERING STUDENTS. *Three hours.* Both semesters. Lecture M. and F. at 11; laboratory Tu., W., or Th. at 3; quiz section Tu. at 10, W. at 10 or 11, or Th. at 10 or 11.
A general course especially adapted to the needs of Engineering students. The first part of the course is given over to dynamical and structural geology, and the remaining portion to an outline history of the different geological formations. One laboratory period weekly (one hour), one hour quiz.

15F. SOIL GEOLOGY. *Three hours.* Second semester.
A comprehensive survey of the subject, including the origin of soils, their physical and chemical constitution, the influence

* See Sec. 132 for modern language requirements for graduation.

of climate on soil fertility, irrigation and drainage, tillage, fertilizers, etc., and a consideration of the soils of the United States in relation to geologic, physiographic, and climatic factors.

Course 15F must be preceded by Course 1*a* and by Courses 1 and 9 in Mineralogy.

16*a*. ECONOMIC GEOLOGY (non-metals). *Three hours.* First semester. A general course treating of the nature, occurrence, and distribution of the non-metallic resources, such as coal, oil and gas, salt, gypsum, building stones, phosphate rock, etc. Geology 1*a* or 1E are prerequisites, while Mineralogy 1 and Geology 1*b* are strongly recommended.

16*b*. ECONOMIC GEOLOGY (metals). *Three hours.* Second semester. In this course the metallic mineral resources are treated in the same manner as are the non-metallic resources during the first semester. Although this course may be elected independently of Geology 16*a*, both are essential to a general survey of the subject. Prerequisites the same as for Geology 16*a*.

31. COMMERCIAL GEOGRAPHY, *Three hours.* First semester. Geographic elements in the production and exchange of the principal commodities of world commerce. An introductory study is made of the production of raw materials, such as of farm, range, forest, and mine, and of the localization of manufactures. The movement of world commerce is considered in a large way, including routes of trade, extent to which different countries participate in trade, and the location and significance of commercial centers.

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201. GERMAN*

Professors WAIT, LEE; Assistant Professor WILD, Mr. GAISS.

1. ELEMENTARY COURSE. *Four hours.* Both semesters. Grammar and reading, with practice in writing and speaking German.

2. ELEMENTARY COURSE CONTINUED. *Four hours.* Both semesters. Grammar and reading, with practice in writing and speaking German.

3. INTERMEDIATE GERMAN. *Four hours.* Both semesters. Modern prose, conversation, and composition, with a thorough review of grammar.

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* See Sec. 132.

4. READING OF GERMAN SCIENTIFIC AND TECHNICAL LITERATURE. Among the subjects considered are Chemistry, Physics, Geology, Mineralogy, etc.

5. ADVANCED COURSE IN GERMAN SCIENTIFIC AND TECHNICAL LITERATURE. *Two hours.* Both semesters.
Each student electing this course reads several books selected with reference to his special line of work. He is also directed to the various German Journals dealing with topics in which he is interested and required to report on what he has read.

9. GERMAN CHEMICAL READING. *Two hours.* First semester only. Equivalent to Chemistry 20.

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202. MATHEMATICS

Professors ZIWET, BUTTS, FIELD, RUNNING, LOVE, HILDEBRANDT; Assistant Professors STEVENS, HOPKINS, POOR, NELSON, ROUSE, DENTON; Mr. BLESSING, Mr. KAZARINOFF, Mr. SALLADE, Mr. JONES, Mr. OLSON, Mr. SIMMONS, Mr. LANDIS.

1. ANALYTIC GEOMETRY AND ALGEBRA. *Four hours.* Both semesters.

1*a*. TRIGONOMETRY. *Two hours.* Both semesters.

2. CALCULUS AND PLANE ANALYTIC GEOMETRY. *Four hours.* Both semesters.

2*a*. SOLID ANALYTIC GEOMETRY. *Two hours.* First semester.

3. CALCULUS AND SOLID ANALYTIC GEOMETRY. *Five hours* Both semesters.

3*a*. CALCULUS. *Five hours.* First semester.

4. CALCULUS AND DIFFERENTIAL EQUATIONS. *Five hours.* Both semesters.

4*a*. CALCULUS. *Three hours.* Both semesters.

4*b*. DIFFERENTIAL EQUATIONS. *Two hours.* Both semesters.

17. THEORY OF THE POTENTIAL. *Three hours.* First semester. Assistant Professor HOPKINS.
This course will consider the potential at a point exterior and interior to an attracting mass, the equations of Laplace and Poisson, the function of Green, and the problem of Dirichlet.

33. ADVANCED MECHANICS. *Three hours.* First semester. Professor ZIWET.
Motion of a rigid body, Lagrange's equations, Small oscillations, Stability.

34. HYDROMECHANICS. *Three hours.* Second semester. Professor ZIWET.
Equations of motion. Plane motion. Fluid resistance. Viscosity.

35. PROJECTIVE GEOMETRY. *Three hours.* First semester. Professor FIELD.
The elements of projective geometry with particular attention to their relation to descriptive geometry, and the applications to problems of engineering.

36. VECTOR ANALYSIS. *Three hours.* Second semester. Professor FIELD.
A study of the formal processes of vector analysis, followed by applications to problems in geometry and mechanics.

58. EMPIRICAL FORMULAS. *Two hours.* Second semester. Professor RUNNING.
Curve fitting. Graphical determination of constants in empirical formulas. Application of method of least squares. Graphical differentiation and integration. Numerical integration.

71. MATHEMATICAL THEORY OF PROBABILITY. *Two hours.* First semester. Professor RUNNING.
Errors of observation, Deduction of the law of error, Mathematical expectation, Law of large numbers, Statistical problems.

73. DIFFERENTIAL EQUATIONS. *Three hours.* First semester. Professor HILDEBRANDT.
A sequel to Course 4*b*. Solutions of differential equations by elementary methods and infinite series. Study of functions defined by differential equations.

74. PARTIAL DIFFERENTIAL EQUATIONS. *Three hours.* Second semester. Assistant Professor POOR.
The equations of Laplace and Poisson, Systems of partial differential equations. Applications.

75. ADVANCED CALCULUS. *Three hours.* Either semester. Assistant Professor NELSON.

Review of the fundamental theory of elementary calculus. Taylor's theorem. Explicit and implicit functions. Simple, multiple and improper integrals. Functions defined by integrals and other selected topics.

78. THEORY OF FUNCTIONS OF THE REAL VARIABLE. *Three hours.* Second semester. Professor HILDEBRANDT.

The real number system. Limits. Consideration of functions relative to their continuity, differentiability and integrability properties.

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203. MECHANICAL ENGINEERING

Professors COOLEY, ANDERSON, ZOWSKI, MIGGETT, BURSLEY, EMSWILER, FESSENDEN, WILSON, HAWLEY; Assistant Professors GREINER, MICKLE, LAY, NICKELSEN, SHERZER, KEELER, Mr. WATSON, Mr. GOOD, Mr. JAGODZINSKI, Mr. KESSLER, Mr. MORLEY.

Courses 1 to 10 inclusive are required for Mechanical Engineers.

1. MACHINE DRAWING. *Two hours.* Both semesters.

This is primarily an elementary course in "Drafting Room Practice" in which particular attention is given to the quality and technique of the drawings. The student makes neat, detailed, free-hand sketches, in approximately correct proportions, of the various parts of machines. On these sketches are placed all those dimensions, accurately made, that are necessary for the reproduction of complete shop drawings. From these sketches the student is required to finish at least five complete sets of drawings, tracings and blue prints. Two hours credit. Two three hour periods per week.

Course 1 must be preceded by Course 5 in Drawing.

2. ELEMENTS OF MACHINE DESIGN. *Three hours.* Both semesters. Two recitations and one three-hour drawing period, per week.

This is an elementary course in the practical application of theory to Machine Design. Forces acting in various parts of machines are carefully determined and combined, stresses accurately computed and the Principles of Design applied to the various parts. A brief review of "The Strength of Materials" is first required. Then, in each of the following, theory is carefully applied to practical design: riveted joints,

cotters and keys, bolts, nuts and screws, couplings, axles and shafts, journals, bearings, gearing.

Course 2 must be preceded by Course 1 in Engineering Mechanics and Course 1 in Mechanical Engineering or Course 1 in Civil Engineering and preceded or accompanied by Course 2 in Engineering Mechanics.

3. HEAT ENGINES. *Four hours.* Both semesters.

Four recitations and one lecture per week are given to the study of the general principles involved in the action of the various forms of heat engines. This is an elementary course required for all engineering students. It relates especially to the steam engine and boiler, the steam turbine and the gas engine. Attention is given to the different types of engines, boilers and gas engines. The general problem of a modern power plant is considered for the benefit of those who do not devote further time to the subject.

Course 3 must be preceded by Courses 1 and 2 in Physics and by Coure 3 in Mathematics.

4. HYDRAULIC MACHINERY. *Three hours.* Both semesters.

Two hours class room, one hour laboratory work. In this course is taken up the theory, construction and operation of all principal types of hydraulic machinery in a more general way.

Course 4 must be preceded or accompanied by Course 4 in Engineering Mechanics. Mechanical and Marine Engineers must take Course 4 in conjunction with Course 8.

5. THERMODYNAMICS. *Three hours.* Both semesters.

This course embraces the study of the principles governing the action of heat engines, steam, hot air and gas engines, air compressors, compressed air engines, refrigerating apparatus and steam turbines.

Course 5 must be preceded by Course 3.

6. THEORY OF MACHINE DESIGN. *Four hours.* Both semesters.

Lectures, recitations and drawing room work.

This course is a continuation of Course 2. It is, however, more advanced in its character and gives more attention to machine parts subjected to wear and to dynamic forces. A thorough and comprehensive study is made of machine parts transmitting power. In the drawing room work are made the computations, the assembly and the working drawings of (1) a machine based on statistical machine design principles, (2) a machine based on the principles of the theory of elasticity and dynamics.

Course 6 must be preceded by Course 2 and preceded or accompanied by Course E. M. 3.

7. MECHANICAL LABORATORY. First Course. *Two hours.* Both semesters.

This is an elementary course, and precedes all other courses given in the Mechanical Engineering laboratory. The work consists of elementary tests of a steam engine, steam turbine, gas or oil engine, power pump, and steam boiler. The use and calibration of the instruments used in Mechanical Engineering work are exemplified in connection with the calculation of results and tests of the apparatus named above.

Course 7 must be preceded or accompanied by Course 3, preceded by Course 1 in Engineering Mechanics, and accompanied by Course 10 in Chemical Engineering.

8. MECHANICAL LABORATORY. Second Course. *Three hours.* Both semesters.

This course is devoted to the experimental study of a steam turbo-generator, an oil engine, a fan, a steam injector, an air compressor, a refrigerating machine, a steam power plant, and several forms of hydraulic machinery.

Course 8 must be preceded by Course 7.

9. POWER PLANTS. *Three hours.* Both semesters.

This course consists of lectures, recitations, problems, and reports dealing with the design, operation and economics of power plants. Considerable attention is given to the cost of producing power and the determination of rates.

Course 9 must be preceded by Course 3 and must be preceded or accompanied by Course 4 in Engineering Mechanics.

Open only to seniors and post-graduates.

9*a*. DESIGN OF POWER PLANTS. *Three hours.* Second semester.

The student is given the usual data furnished the engineer and is then expected to select the proper machinery to meet the needs of this power house. After selecting the machinery he then makes the general design for the power house, including setting and piping plans for all the principal machines to be installed.

Course 9*a* must be preceded by Course 9 and preceded by Course 4 in Engineering Mechanics.

Open only to seniors and post-graduates.

10. THEORY OF MACHINE MOVEMENTS. *Two hours.* Both semesters.

Theory of machine movements, gears, linkages, cams, parallel motions, intermittent motions, study of instantaneous centers, periodic centers of motions and effect of acceleration, with assigned drawing problems to be done at home

Course 10 must be preceded by Course 3 in Engineering Mechanics.

11. STEAM BOILERS. *Three hours.* First semester.
In this course is treated the commercial types of boilers, stokers and superheaters, and the principles of boiler economy and operation. Also the combustion of fuels, the theory of heat transference, the purchase of coal by specifications and the storage of coal. Special attention is given to feed water treatment. A study is made of the problems of design.
Course 11 must be preceded by Course 3.

11*a*. DESIGN OF STEAM BOILERS. *Three hours.* Second semester.
In this course is taken up the complete design of steam boilers of different types. It includes the calculation and design of all important details.
Course 11*a* must be preceded by Course 6 and preceded or accompanied by Course 11.

12. STEAM RECIPROCATING ENGINES. *Two hours.* Second semester.
In this course is taken up the theory of reciprocating steam engines with particular attention to the thermodynamic action. Consideration is given to the various commercial types and the problems of design.
Course 12 must be preceded by Course 5.

12*a*. DESIGN OF STEAM RECIPROCATING ENGINES. *Three hours.* Second semester.
In this course is taken up the complete design of a steam engine. It includes the calculation and design of the important details.
Course 12*a* must be preceded by Course 6 and preceded or accommanied by Course 12.

13. STEAM TURBINES. *Three hours.* Both semesters.
A course in the advanced study of the principles of the flow of fluids, kinetic effects, and thermodynamics, with the steam turbine used as a curent example. The fundamental differences in principle of the different types of turbines; the field of application of the steam turbine; and the influence of high vacuum together with the condensing equipment developed for turbine work, are all given extensive attention.
Course 13 must be preceded by Course 5.

15. INTERNAL COMBUSTION ENGINES AND GAS PRODUCERS. *Three hours.* Both semesters.
A course of lectures and recitations is given covering the complete theory of the internal combustion engine and gas producer. Computations are made for different types of internal combustion engines. Details of construction and modern regulating devices are studied.
Course 15 must be preceded by Course 5 and preceded or accompanied by Course 6.

15*a*. DESIGN OF INTERNAL COMBUSTION ENGINES. *Three hours.* Second semester only.

In this course is taken up the complete design of standard types of internal combustion engines. Particular attention is given to the regulating mechanisms.

Course 15*a* must be preceded or accompanied by Course 15, and must be preceded by Course 6.

16. WATER TURBINES. *Three hours.* First semester only.

In this course is taken up the complete theory, construction and operation of the different types of water turbines. Opportunity is given for advanced work to graduate students and those who wish to make a specialty of turbine design.

Course 16 must be preceded or accompanied by Engineering Mechanics 4, or by Mechanical Engineering 4.

16*a*. DESIGN OF WATER TURBINES. *Three hours.* Second semester only.

In this course is taken up the complete design of water turbines of different types. Particular attention is given to the design of turbine runners, layout of runner buckets, guide vanes and regulating mechanism and also to the design of other turbine elements such as draft tubes, turbine casings and thrust bearings. Opportunity is given for advanced work to graduate students and those who wish to make a specialty of turbine design.

Course 16*a* must be preceded by Course 6 and preceded or accompanied by Course 16.

17. PUMPING MACHINERY. *Three hours.* Second semester only.

In this course is taken up the complete theory, construction and operation of reciprocating and centrifugal pumps. Opportunity is given for advanced work to graduate students and those who wish to make a specialty of the design of pumps.

Course 17 must be preceded by Course 4.

17*a*. DESIGN OF PUMPING MACHINERY. *Three hours.* Second semester only.

In this course a complete design is made of a centrifugal or reciprocating pump. In the design of centrifugal pumps, special attention is given to the layout of impellers, diffusors and casings. Opportunity for advanced work is offered to graduate students and those who wish to make a specialty of the design of pumping machinery.

Course 17*a* must be preceded by Courses 4 and 6.

18. HEATING AND VENTILATION. *Two hours.* First semester only.

An elementary course of lectures and recitations covering the

treory of heat as applied in heating. The design and construction of hot air, direct and indirect steam, hot water, and fan systems of heating are considered.
Course 18 for Architects only.

19. REFRIGERATION AND COMPRESSED AIR. *Two hours.* Second semester only.
A course for advanced students covering the application of the theories of thermodynamics to refrigeration, and compressed air. This course also includes the study of constructive details of refrigerating plants and compressed air systems, and their operation.
Course 19 must be preceded by Course 5.

20. MECHANICAL HANDLING OF MATERIALS. *Two hours.* Both semesters.
Lectures, recitations, problems, reports, and inspection of systems in use. The work covers first the features of design and installation and later the application to various classes of plants, processes, and materials. The following subjects are considered: cranes and derricks, hand and electric travelers, inclined and vertical hoisting, haulage systems, aerial and surface cableways, conveyors of all classes. Special attention is given to the use of wire rope in the above systems and to the kind of power best adapted to their drive.
Course 20 must be preceded by Course 2 and by Course 2 in Engineering Mechanics.

20*a*. DESIGN OF HOISTING AND CONVEYING MACHINERY. *Three hours.* Both semesters.
In this course the student designs complete hoisting machines and systems for handling materials. A considerable number of the parts are detailed completely, but more attention is given to the computation and general layout of the system.
Course 20*a* must be preceded by Course 6 and preceded or accompanied by Course 20.

21*a*. DESIGN OF MACHINE TOOLS. *Three hours.* Second semester only.
The student will design a complete modern machine tool. The magnitude and direction of forces acting on the cutting tools are calculated and all parts of the machine are proportioned to resist these forces. Investigations of special metal-working processes and machines may be undertaken.
Course 21*a* must be preceded by Course 6.

22. RESEARCH WORK IN THE MECHANICAL LABORATORY. *Two or three hours.* Both semesters.
The course offers an opportunity for students to pursue advanced experimental study along any line of work in which they may

be specializing, in accordance with the idea embodied in the group system of studies. The work of the course consists of investigations for securing data on the more difficult problems of mechanical engineering. Students electing this course are left largely to their own resources in planning and carrying out the work.

Course 22 must be preceded by Course 8.

23. HYDRAULIC MACHINERY. Advanced laboratory work. *Two or three hours as arranged.* Both semesters.

Tests and investigations of more difficult nature are made especially on the larger water turbines, centrifugal pumps, hydraulic rams, and the complete 150 H. P. high pressure automatically regulated hydro-electric plant.

Course 23 must be preceded by Course 4.

24. PRIME MOVERS. *Three hours.* First semester only.

This course is offered primarily for Business Administration and Forestry students. It embraces a study of the steam engine, gas engine, and water turbine, together with the study of the various methods of transmitting the power from these prime movers. This subject is covered in a popular way and, in addition, attention is given to the operation of the various machines.

This course should be preceded by Courses 1 and 2 in Physics.

25. HEATING AND VENTILATION. *Two hours.* Second semester.

A course of lectures and recitations covering the theory of heating and ventilation as applied to the types of heating and ventilating systems.

Must be preceded by Course 3.

25*a*. DESIGN OF HEATING AND VENTILATING SYSTEM. *Three hours.* Second semester.

The student is given the usual data furnished the heating and ventilating engineer, and is then expected to select a system to meet the requirements. After selecting a system he then makes the general layout of the piping, ducts, and auxiliary apparatus, together with all computations as to sizes of prinpal parts.

Course 25*a* must be preceded or accompanied by Course 25.

29. AUTOMOBILES AND MOTOR TRUCKS. *Three hours.* Both semesters.

A general course, covering the fundamental principles of operation and design of automobiles and motor trucks, and their application in current practice.

1. Engine general, operating cycles, valves and valve timing, carburetion, ignition systems, oiling systems, cooling, rating and characteristic curves.
2. Clutch.
3. Transmission and drive shaft.
4. Rear axle and differential.
5. Front axle and steering mechanism.
6. Brakes and springs.
7. Engine and car testing and performance curves.
8. Car operation and control.
9. Current models.

Illustrated lectures, text recitations, laboratory demonstrations. Not open to freshmen.

30. AUTOMOBILE AND MOTOR TRUCK ENGINES *Three hours.* First semester.

In this course is begun the theory and design of automobile and motor truck engines. It includes the crank case, cylinder block, pistons, connecting rods, crank shaft, flywheel, cam shaft, cams, timing gears, valves, and valve mechanism, oiling system, cooling system. Lectures, text recitations, computations and drawing sections.

Course 30 must be preceded by Courses 6 and 29.

30*a*. DESIGN OF AUTOMOBILE AND MOTOR TRUCK ENGINES. *Three hours.* Second semester.

This course is a continuation of Course 30 and must be preceded by it.

31. AUTOMOBILE AND MOTOR TRUCK CHASSES. *Three hours.* First semester.

In this course is begun the theory and design of automobile and motor truck chasses. It includes frame and brackets, clutch, transmission, drive shaft, rear axle, front axle, steering mechanism, and springs. Lectures, text recitations, computations and drawing sections.

Course 31 must be preceded by Courses 6 and 29.

31*a*. DESIGN OF AUTOMOBILE AND MOTOR TRUCK CHASSES. *Three hours.* Second semester.

Course 31*a* is a continuation of Course 31 and must be preceded by it.

32. AUTOMOBILE TESTING. *Two hours.* Both semesters.

Experimental laboratory and road study of automobiles and motor trucks, and their component parts. Engine tests covering general operation and construction, maximum horse-power,

fuel consumption, thermal efficiency, mechanical efficiency, heat balance; study of timing, cooling, oiling systems, ignition systems, carburetion, indicator cards, and characteristic curves; tests on power transmission efficiencies; road tests covering car performance, including speed range, acceleration and fuel consumption.

Course 32 must be preceded by Course 7 and preceded or accompanied by Course 29.

33. ADVANCED AUTOMOBILE TESTING AND RESEARCH. *Two or three hours.* Both semesters.

This course affords an opportunity for advanced experimental work and research upon special problems involved in some automobile unit or in the complete automobile or motor truck. Where the problems are comprehensive, several students may be grouped into one squad, where they are left largely to their own resources in the planning of apparatus and the carrying out of the work.

Must be preceded by Course 32.

34. ADVANCED AUTOMOBILE DESIGN AND RESEARCH. *Credit and hours to be arranged.* Both semesters.

This course affords an opportunity for advanced design and research upon special problems critical in the design of some automobile unit or of the complete automobile or motor truck.

Must be preceded by Courses 30*a* and 31*a*, or their equivalent.

35. SCIENTIFIC SHOP MANAGEMENT. *Three hours.* Both semesters. Lectures, recitations, and laboratory.

This course includes the study of the application of the principles of the Taylor System of Scientific Management to shop and other industries. It includes lectures, assigned reading, reports, and discussions on functional foremanship, routing, time and motion study, proper sequence and methods of operations, use of instruction cards, mnemonic classification, stores systems, tool rooms, costs, etc. A certain amount of laboratory and field work will also be required in order to familiarize the student with the application of the principles obtained in the classroom.

This course is open to seniors and graduates in the College of Engineering, and in the course in Business Administration in the College of Literature, Science, and the Arts.

36. SCIENTIFIC SHOP MANAGEMENT. *Two or three hours.* Both semesters.

This course is a continuation of Course 35 and includes the assignment of particular problems to students for their individual study and solution.

37. SPECIAL TOPICS ON THE INTERNAL COMBUSTION ENGINE. *Two hours.* Both semesters.
In this course it is intended to bring the student in touch with the latest developments in the theory, design, and construction in the internal combustion engine field.
This course must be preceded by Course 15.

38. INTERNAL COMBUSTION ENGINEERING. Laboratory Research Work on Internal Combustion Engines. *Credit and hours to be arranged.*
Must be preceded by M. E. 8 and M. E. 15.

39. INTERNAL COMBUSTION ENGINEERING. Research Design of Internal Combustion Engines. *Credit and hours to be arranged.*
Must be preceded by 15*a*, or accompanied by Courses 15*a* and 37.

41. AUTOMOBILE ENGINEERING SEMINAR. *One hour.* Both semesters.
In this course the student prepares a paper on current topics of the automobile industry and one covering an investigation of some special subject. A discussion of these papers is made by the class.
Must be preceded or accompanied by Course 29.

50. GYROSCOPIC ACTION AND CRITICAL SPEEDS. *Two hours.* Both semesters.
Fundamental principles. Quantitative discussion for simple case, *i. e.*, constant precessional velocity. Principles of applications to stabilizing of ships—active and passive types. Brennan's and Schelowsky's Monorail Systems. Principles, construction, and sources of error in the Sperry and Anschutz Gyro-Compasses.
Synchronous action in general. Mathematical study of simple ideal cases of critical speeds. Empirical treatment of complex cases.
Laboratory work with models of active and passive types of gyroscopic stabilizers; also on determination of critical speeds.
Course 50 must be preceded by Course 3 in Engineering Mechanics.

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204. MILTARY SCIENCE AND TACTICS

First Semester

1. Infantry drill, guard duty, military courtesy and discipline, military hygiene, organization, physical training. *One hour.* Professor ARTHUR.

Course 1 or equivalent training must precede all other courses.
COAST ARTILLERY.

3. Basic. May reading and sketching, coast artillery materiel. *One hour.* Assistant Professor SHIPPAM. Open to all students.

5. Advanced. Orientation, fire control materiel, infantry combat. *Two hours.* Assistant Professor SHIPPAM. Must be preceded by Course 3.

7. Advanced (continued). Gunnery. *Two hours.* Assistant Professor SHIPPAM.
Must be preceded by Course 5.
SIGNAL CORPS.

13. Basic. Military telegraphy, field radio sets. *One hour.* Assistant Professor HOORN. Open to students in Electrical Engineering.

15. Advanced. Communication engineering, field engineering, telephone net construction. *Two hours.* Assistant Professor HOORN.
Must be preceded by Course 13.

17. Advanced (continued). Communication engineering, organization and tactics of all arms. *Two hours.* Assistant Professor HOORN.
Must be preceded by Course 15.
INFANTRY.

23. Basic. Military map reading and sketching, infantry weapons. *One hour.*

25. Advanced. Field engineering, infantry combat. *Two hours.*
Must be preceded by Course 23.

27. Advanced (continued). Minor tactics. *Two hours.*
Must be preceded by Course 25.

Second Semester

2. Ceremonies, infantry drill, infantry weapons, first aid, small arms firing, physical training. *One hour.* Professor ARTHUR.
Precedent to all other second semester courses.
COAST ARTILLERY.

4. Basic. Heavy artillery materiel, infantry drill and ceremonies. *One hour.* Assistant Professor SHIPPAM.

6. Advanced. Motor transportation, sanitation. *Two hours.* Assistant Professor SHIPPAM.
Must be preceded by Course 4.

8. Advanced (continued). Administration, employment of artillery, field engineering, military law, military policy. *Two hours.* Assistant Professor SHIPPAM.
Must be preceded by Course 6.
SIGNAL CORPS.

14. Basic. Map reading and sketching, military telephony. *One hour.* Assistant Professor HOORN.

16. Advanced. Communication engineering. *Two hours.* Assistant Professor HOORN.
Must be preceded by Course 14.

18. Advanced (continued). Hippology, military law, message centers, military policy, minor tactics, staff organization. *Two hours.* Assistant Professor HOORN.
Must be preceded by Course 16.
INFANTRY.

24. Basic. Infantry drill, infantry weapons, minor tactics. *One hour.*

26. Advanced. Minor tactics, infantry auxiliary weapons, infantry drill and ceremonies. *Two hours.*
Must be preceded by Course 24.

28. Advanced (continued). Administration, military law, musketry, military policy. *Two hours.*
Must be preceded by Course 26.

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205. MINERALOGY AND PETROGRAPHY

Professors KRAUS, HUNT, Assistant Professor PECK

1. ELEMENTS OF MINERALOGY. *Two hours.* Both semesters.
Includes the elements of crystallography, and the physical and chemical properties, occurrence, uses, and determination of the more common minerals. Lectures and laboratory work.
For Course 1 a knowledge of elementary inorganic chemistry is necessary.

2. GENERAL MINERALOGY. Lectures and laboratory work. *Five hours.* First semester only.
Principles of crystallograpry, physical and chemical properties,

origin, formation, decomposition, distribution, uses, and determination of the more important minerals.

Students who have successfully completed Course 1 may elect this course as Course 2*a* and receive *three hours* credit.

Course 2 must be preceded by Courses 2 and 3 in Chemistry.

4. DETERMINATIVE MINERALOGY. Laboratory work. *Two hours.* Both semesters.

This course is intended for students who have finished Course 1 and wish to become more proficient in the determination of minerals.

5. QUALITATIVE BLOWPIPE METHODS. *Two hours.* First semester only.

The use of blowpipe reactions upon charcoal and plaster tablets, as well as other chemical methods useful in the determination of minerals. Lectures and laboratory work.

Course 5 should be preceded by Course 2, or Courses 1 and 4.

9. LITHOLOGY. *Two hours.* Both semesters.

The lectures include, aside from a review of the rock-forming minerals, a discussion of the classification, origin, and methods of determination of the more important rocks. In the laboratory the student is required to determine by means of the macro-physical properties a large number of rock specimens. Field excursions will also be made in order to acquire facility in the rapid determination of rocks in the field. Lectures and laboratory work.

Course 9 must be preceded by Mineralogy 1 and Geology 1.

12. QUANTITATIVE BLOWPIPE METHODS. *Two hours.* First semester only.

Reading and laboratory work. Practice in assaying by blowpipe methods of various kinds of ores, especially those of gold and silver.

Course 12 must be preceded by Course 5.

16. USEFUL MINERALS AND BUILDING AND DECORATIVE STONES. Designed especially for students of Architecture. Laboratory work, three hours a week, to be arranged. *Three hours.* Second semester only.

This course is designed primarily for students of Architectural Engineering. The first half of the course treats the physical and chemical properties, uses and determination of the common rock-forming minerals, and of those ores from which the metals and materials commonly used for building purposes are obtained. The second half is devoted to a discussion of the origin, modes of occurrence, description, and uses

of the common rocks, with special emphasis upon those used for structural and decorative purposes. Lectures are also given on the methods of quarrying, finishing, and testing of building stones.

For this course a knowledge of elementary inorganic chemistry is necessary.

17. GEMS AND PRECIOUS STONES. *Two hours.* Lectures and demonstrations. Second semester only.

This course discusses the general properties, occurrence, determination, and history of the various minerals used as gems and gem minerals. The various methods of distinction, especially from imitations and synthetic gems, will also be considered. No previous training in mineralogy or the sciences is required, although an elementary knowledge of chemistry and physics is highly desirable.

SUMMER SESSION

Courses 1, 4, 5, 8, and 9 will be offered in 1921. For other courses, see announcement of the Summer Session.

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206. NAVAL ARCHITECTURE AND MARINE ENGINEERING

Professors SADLER, BRAGG, Assistant Professor LINDBLAD

1. NAVAL ARCHITECTURE. Structural Design. Lectures and recitations. *One hour.* First semester.

This course comprises a discussion of the principal features of construction of all types of ships; classification societies' rules; preparation of working plans.

2. NAVAL ARCHITECTURE. Ship Calculations. Lectures and recitations. *Three hours.* Second semester.

The following are the topics discussed: methods of determining areas, volumes, centers of gravity of ship-shaped bodies, displacement, centers of buoyancy, metacenters, and trim; freeboard and tonnage; launching; calculation of bending moments and stresses in vessels under various conditions.

3. NAVAL ARCHITECTURE. Stability of Ships and Preliminary Design. *Three hours.* First semester.

Course 3 must be preceded by Course2, and includes investigations of the stability of vessels and means of determining the same; discussions upon the rolling and seagoing qualities of

ships; and methods of reducing rolling. The latter part of the course is devoted to estimates and calculations involved in the design of ships.

4. NAVAL ARCHITECTURE. Resistance and Propulsion. *Three hours.* Second semester.

In this course all items affecting the resistance and propulsion of various ships' forms; investigations of the theory and practice involved in the design of propellers; methods of conducting trial trips, etc., are discussed.

5. NAVAL ARCHITECTURE. Structural Drawing. *Two hours.* First and second semesters.

This course includes the laying off of a vessel and the preparation of the principal working structural plans, such as midship section, deck plating, bulkheads, and stern frame.

6. NAVAL ARCHITECTURE. Ship Drawing and Design. *Three hours.* First and second semesters.

The lines of a vessel of an average type are drawn and all the calculations are made which are necessary for plotting curves of form, launching curves, and strength curves.

7. NAVAL ARCHITECTURE. Ship Drawing and Design. *Three hours.* First and second semesters.

In this course the student is given the general features of a vessel and prepares a complete design of the same, including all the general plans and calculations.

8. MARINE BOILERS. Lectures and recitations. *One hour.* First semester.

The design and construction of marine boilers and their accessories are discussed.

9. MARINE ENGINES. Lectures and recitations. *Two hours.* First semester.

Course 9, which must be preceded by Course 3 in Mechanical Engineering and Course 1 in Engineering Mechanics, includes the questions relating to the design, construction, and balancing of triple and quadruple expansion engines. Condensers, air pumps, turning, and reversing engines are also discussed. Each student makes all of the preliminary calculations for the design of a marine engine.

10. MARINE BOILER DRAWING AND DESIGN. *Three hours.* Both semesters.

In this course a Scotch marine boiler of general type is designed.

11. MARINE ENGINE DRAWING AND DESIGN. *Three hours.* Both semesters.

The complete general plans of a triple or quadruple expansion engine are prepared, together with all calculations for the same.

12. NAVAL ARCHITECTURE. Experimental Tank.

13. NAVAL ARCHITECTURE. Specifications and Contracts.

14. NAVAL ARCHITECTURE. Shipyard Plants.

15. NAVAL ARCHITECTURE. Advanced Reading and Seminary.

16. NAVAL ARCHITECTURE. Advanced Drawing and Design.

17. MARINE ENGINEERING. Advanced Reading and Seminary.

18. MARINE ENGINEERING. Advanced Reading and Design.

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207. PHILOSOPHY

Professor WENLEY, Assistant Professors SELLARS, PARKER

(Owing to the redistribution of courses and hours in the Department of Philosophy and Psychology, students are asked to refer to the Announcement of the College of Literature, Science, and the Arts for final information relative to 1921-22.)

The courses in Philosophy of most direct value and interest to Engineering students appeal to two classes of students, as follows:

(1) To students of Science, who desire to understand the theory, postulates, and general mental conceptions employed by the Natural Sciences, particularly Physics and Chemistry. The courses bearing on these problems are 1 and 3*a*. Philosophy 1 deals with the general relations between Science and Philosophy as two complementary standpoints in human experience. For those who have time it should be taken along with Course 3*a*.

(2) To students of Architecture, who desire to understand the general theory of beauty, and to know something of the history of Æsthetic doctrine and of the points of view developed in the several great stages of artistic creation. Course 16 in the first semester and Course 6 in the second semester and devoted exclusively to these subjects. Students of Architecture should elect both courses, beginning ,if possible, with Course 6 (second semester), and continuing with Course 16 in the first semester of the following year.

For full description of courses, see Announcement of the College of Literature, Science, and the Arts.

1. PHILOSOPHICAL INTRODUCTION. *Three hours.* First semester. Lectures and discussion sections.
Engineering students are advised to elect the course as given in the first semester.
The object of this course is to explain to beginners, in the most elementary manner possible, the meaning, interest, and scope of Philosophy; to compare its outlook with other standpoints, such as those to the average man (common sense), and especially of science (including Philosophy).

3*a*. THE PHILOSOPHICAL IMPLICATIONS OF THE FUNDAMENTAL CONCEPTIONS OF NATURAL SCIENCE. *Two hours.* First semester only.
This course is designed for students of Physics and Chemistry. It is open to all who desire to grasp the presuppositions of the scientific standpoint, and who are interested in the progress of modern thought. It presupposes some knowledge of science, but not of philosophy. The Postulates of Science. The place of general concepts in Science. The main conceptions employed in the syntheses of Physics, Chemistry, and Biology—what they imply, how they subserve knowledge of Nature, their necessary conditions and limits

6. THE HISTORY OF ÆSTHETICS. *Three hours.* Second semester.
The development of Æsthetic theory in relation to the contemporaneous social, philosophical, and artistic movements. This course is of primary interest to students of Architecture and Art.

16. ÆSTHETICS. *Two hours.* First semester.
The definition, forms, and standards of Beauty. The relation between Æsthetic values and Ethical and Religious values. This course is of primary interest to students of Architecture and Art.
Should be preceded by Course 6.

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208. PHYSICS

Professors RANDALL, WILLIAMS, COLBY, SMITH, HENDERSON, Assistant Professors RICH, SLEATOR, and LINDSAY, Dr. KENT, Dr. SAWYER, Dr. SHELDON, Dr. FAZEL, Mr. GEIGER, Mr. ST. PETER, Mr. COOLEY, Mr. GUNN, Mr. PARSONS.

Z. PHYSICS FOR ADMISSION. This course is intended for students who have not presented the required unit of entrance Physics. It is required for admission to Courses 1 and 1E. *No credit will be allowed for this course.* Four times a week, first semester. M., W., Th., and Fri., at 5.

1. GENERAL PHYSICS—MECHANICS, SOUND, AND HEAT. Lectures and recitations four times a week, and laboratory work. Both semesters.

1*a*. PHYSICAL PROBLEMS. Once a week. Both semesters.
Students in Architecture 1 and 2 elect 1 and 1*a* for *four hours* credit.

1E. MECHANICS, SOUND, AND HEAT. Lectures, recitations, and laboratory work. *Five hours.* Both semesters.
For Courses 1 and 1E a knowledge of plane trigonometry is indispensable. No student is admitted to the class who has not had a preparatory course in Physics.
In Course 1E at least half the semester is devoted to Elementary Mechanics; the remainder of the time to Sound and Heat; all with experimental illustrations. All members of the class have one period a week in the laboratory.

2. GENERAL PHYSICS—MAGNETISM, ELECTRICITY, AND LIGHT. Lectures and recitations, four times a week, and laboratory work. Both semesters.

2*a*. PHYSICAL PROBLEMS. Once a week. Both semesters.
Students in Architecture 1 and 2 elect 2 and 2*a* for *four hours* credit.

2E. MAGNETISM, ELECTRICITY, AND LIGHT. Lectures, recitations, and laboratory work. *Five hours.* Both semesters.
Course 2E must be preceded by Course 1E and by Course 2E in Chemistry, or an equivalent. It is a continuation of Course 1E and takes up the fundamental phenomena and laws of these subjects, with ample class illustrations. Laboratory work as in Course 1E.
Courses 1E and 2E are required from all Engineering students. Students transferring their credits from the College of Literature, Science, and the Arts will be required to offer Courses 1, 1*a*, and 2, 2*a* as equivalents of Courses 1E and 2E.

5. ELECTRICAL MEASUREMENTS. Lectures, recitations, and laboratory work. *Four hours.* First semester.
In the class work the principles of electrical behavior are critically studied and discussed. The laboratory exercises are designed to illustrate and emphasize these principles, and to give the student some personal experience in the careful use of electrical measuring instruments. The course includes the modern methods of measuring current, resistance, electromotive force, and power, and the calibration of the instruments employed.

5E. ELECTRICAL MEASUREMENTS. Lectures and laboratory work. *Four hours.* Both semesters.

The course includes the modern methods of measuring current, resistance, electromotive force, capacity, inductance, and hysteresis of iron, and the calibration of the instruments employed. Course 5E must be preceded by 1E and 2E, or their equivalents.

6. ELECTRICAL MEASUREMENTS. Lectures and laboratory work. *Four hours.* Second semester.

This is a continuation of Course 5, and includes measurements of capacity, self and mutual inductance, and the fundamental measurements with alternating currents. Especial attention is given to the theory of the magnetic circuit and the determination of the magnetization and hysteresis curves of iron and steel.

A working knowledge of the calculus is required.

11. LABORATORY WORK IN HEAT. *Three hours.* First semester.

An experimental course accompanied by lectures, covering the fundamental principles of heat and the methods of heat measurements. The course will meet the needs of either technical students or those specializing in Physics.

14. ELECTRON THEORY AND RADIOACTIVITY. *Two hours.* Lectures and laboratory work.

The laboratory work deals largely with radioactive substances. The distinguishing characteristics of alpha rays, beta rays, and gamma rays are studied, and the half-life periods of several substances are determined by each student.

15, 16. ELECTROCHEMICAL PHYSICS. Class and laboratory work. *Two hours.* Throughout the year.

Course 15 must be preceded by Course 2E in Physics and Course 2E in Chemistry. A course in qualitative analysis is also desirable.

These courses are designed (a) to meet the needs of those preparing to teach physics and chemistry, (b) to furnish a basis for the application of electrochemical principles to practical problems in chemistry and electricity, and (c) to prepare for research in electrochemical physics.

18. MEASUREMENT OF HIGH TEMPERATURES. *Three hours.* Second semester.

An experimental course accompanied by lectures, covering the theory and practice of the present methods of high temperature measurements. The work involves the use of thermocouples, resistance thermometers, and the modern types of optical and total radiation pyrometers. For technical students and those specializing in Physics.

20. ARCHITECTURAL ACOUSTICS. *Two hours.*

Lectures, with illustrative problems on sound transmission, distribution, and absorption, and an experimental study of the acoustical properties of certain rooms.

24. THEORY OF LIGHT. *Two hours.*

The essential phenomena of optics, including interference and diffraction, dispersion, absorption, polarization, and double refraction.

25. THEORY OF HEAT. *Two hours.* First semester only.

Course 25 must be preceded by Course 2E.

27, 28. ELECTRICITY AND MAGNETISM. *Two hours.* Throughout the year.

These courses must be preceded by Course 2E. A knowledge of the calculus is required. They are devoted to a mathematical as distinguished from an experimental study of electrical phenomena.

33. VACUUM TUBES IN RADIO COMMUNICATION. *Two hours.* Lectures and laboratory work.

The theory of the transmission of electricity through gases will be treated in this course, together with a study of the different types of tubes used in radio work. The characteristics of such tubes will be determined experimentally and the electric circuits employed in their use will receive considerable attention.

Prerequisites: Course 5 in Physics and the Calculus.

37. GERMAN READING. *Two hours.* First semester.

In this course the subject of Physics is studied in German to acquaint the student with the technical terms used in modern German Physics.

This course may be taken only by such students as convince the instructor of their satisfactory preparation.

Course 37 is continued in the second semester as Course 38, *two hours.*

SUMMER SESSION

Course Z, intended for students preparing for entrance to the College of Engineering, and Courses 1, 1E, 2, 2E, 1*a*, 2*a*, 5, 5E, 6, 6E, 9, 12, 14, 17, 30, and 31, as described for the regular session, will be offered in the Summer Session of 1921.

209. POLITICAL ECONOMY AND BUSINESS ADMINISTRATION

Professors ADAMS, TAYLOR, FRIDAY, SHARFMAN, PATON, GRIFFIN, Assistant Professor CALHOUN, Mr. LUBIN

The first two courses in Political Economy listed below—1E and 38E—are designed especially for students in the College of Engineering. In addition, there is enumerated a number of courses in Political Economy and Business Administration which will prove of interest and value to such students of Engineering as are able to devote a larger amount of time to outside fields of study. For a more detailed announcement of these courses and for additional courses in the field of economics, consult the Annual Announcement of the College of Literature, Science, and the Arts.

1E. ELEMENTS OF ECONOMICS. Engineers' Course. Lectures and quiz. *Three hours.* Both semesters.

This course is especially designed to meet the needs of students whose work lies in professional departments, particularly Engineering. It will be devoted largely to a consideration of the fundamental economic principles. Some attention will be given, however, to the important practical problems of the economic world, particularly insofar as they illustrate these principles.

No student can receive credit for this course and Course 1 or Course 1*a*.

38E. PRINCIPLES OF ACCOUNTING. Course for Engineers. Quiz sections and laboratory work. *Three hours.* Second semester only.

1. ELEMENTS OF POLITICAL ECONOMY I. Principles. Lectures and quiz. *Five hours.* Both semesters.

The object of this course is to ground the student in the principles of economic science.

This course should precede all other courses in Political Economy except 1*a* and 1E.

2. ELEMENTS OF POLITICAL ECONOMY II. Current Problems. Lectures and quiz. *Three hours.* Second semester only.

This course is a continuation of the Elements of Political Economy given in the first semester. Students who have taken Course 1*a* or 1E during the first semester will be permitted to elect this course.

The purpose of this course is to apply economic principles to current social and industrial problems and to make clear the historic background of such problems. The subjects discussed will include an outline of the development of industrial society, crises and depressions, taxations, the tariff prob-

lem, immigration, the labor problem, and a comparative study of programs of social reform which spring from industrial conditions.

3. LABOR PROBLEMS. Lectures and quiz. *Three hours.* First semester only.

The aim of this course is to familiarize the student with the problems connected with the conditions of employment of the wage-earnings classes and to consider the solutions of these problems offered by social reforms, labor organizations, and socialism.

4. PRINCIPLES OF PUBLIC FINANCE. Lectures, readings, and discussion. *Three hours.* First semester only.

This course treats of public expenditures, revenues, and debts. Some attention will also be given to budgets and treasury organization, but the stress of the course will fall on the principles and problems of taxation. Course 1 or 1*a* is a prerequisite, or else special permission of the instructor.

6. RAILWAY PROBLEMS. Lectures, readings, and discussion. *Three hours.* Second semester only.

This course considers the social and industrial significance of modern transportation, traces the development of American railway transportation, analyzes the chief railway problems in the United States, with special reference to the nature of railway competition, and the theory and practice of rate-making, and devotes particular attention to the regulation of railways by the Interstate Commerce Commission.

9. BANKING, MONEY, AND FOREIGN EXCHANGE. Lectures and quiz. *Three hours.* Both semesters.

This is a general course designed to meet the needs of persons who desire to become acquainted with the most important features of the institution of banking, with special reference to American conditions.

This course must be preceded by Course 1 or an equivalent.

15. CORPORATIONS. Lectures, reading, and discussion. *Three hours.* First semester only.

This course undertakes a study of corporations as an element in industrial society, laying special emphasis upon the so-called trust problem and questions of government regulation of industry.

It deals with the forms of business organization, with particular stress on the nature and history of corporations and their significance in modern life. While it offers an account of the promotion, capitalization, and reorganization of corporations, questions of finance are for the most part subordinated

to a consideration of the economic aspects of industrial combination, such as its effects upon efficiency, wages, profits, and prices. The course is concluded by a study of the Sherman Anti-Trust Act, as interpreted by the leading decisions under it, and a discussion of the recent trust legislation.

16. PUBLIC SERVICE INDUSTRIES. Lectures, readings, and discussion. *Two hours.* Second semester only.
This course considers the nature of public service industries, such as railroads, street railways, gas and electric companies, telephone and telegraph companies, and their relation to the state and to the municipality. The problem of public ownership and public control is given careful study on the basis of American and European experience, with special consideration of commission regulation in the United States.
Course 6 must precede or accompany this course.

32. INDUSTRIAL ORGANIZATION AND MANAGEMENT. Lectures and quiz. *Three hours.* Both semesters.
A study of the organization and management of individual business undertakings, with special emphasis upon the principles of "Scientific Management." Consideration is given to the launching of an enterprise and its financing, to the location and design of the plant, and to the organization of an administrative staff. The functions of the departments concerned with purchasing, accounting, production, traffic, selling, and credit receive attention in turn. Special study is given to the various systems of managing and remunerating labor.

34. EMPLOYMENT MANAGEMENT. Lectures and quiz. *Two hours.* Second semester only.
This is an advanced course in the employment, training, control, and compensation of labor. It is especially designed for those students who wish to prepare themselves for positions as employment managers.
Course 32 must precede or accompany this course.
Juniors and seniors in other departments may be admitted without this prerequisite, by special arrangement.

36. RAILWAY OPERATION. *Three hours.* First semester only.
Students who elect this course will be expected to elect 36*a* in the second semester. It is designed for students who have a professional interest in railway operation and administration, and who desire to gain some knowledge of the fundamental principles of accounts and statistics as applied to railway construction, maintenance, operation, and valuation. It must be preceded by Courses 1, 2, 6, and 38.

36*a*. RAILWAY ACCOUNTS. Three hours. Second semester only. This course is a continuation of Course 36.

37. CORPORATION FINANCE. Lectures, reading, and discussion. *Three hours.* First semester only.
This course aims to study the organization and inter-corporate relations of modern railway and industrial enterprises, with special reference to problems of finance. It deals with such subjects as the nature and varieties of stocks and bonds, the distribution and price movements of corporation securities, corporate promotion, capitalization, and reorganization. Concrete cases, in the railway and industrial field, are carefully analyzed and discussed.
Course 15 must preced or accompany this course.

38. PRINCIPLES OF ACCOUNTING. Lectures, quiz, and laboratory period. *Four hours.* Both semesters.

40. COST ACCOUNTING. Lectures and problems. *Three hours.* Both semesters.

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210. SHOP PRACTICE

Acting Supt. Professor J. AIREY; Shop Instructors, Mr. YEATMAN, Mr. SWEET, Mr. STEVENSON, Mr. TELFER, Mr. HASTINGS

The shop courses consist of actual practice in the shops, together with classroom work, consisting of demonstrations, oral instruction, and recitations, for which outside preparation is made from text-books.

Courses 1, 2, 3, and 4 may be continued by advanced students as Courses 1*a*, 2*a*, 3*a*, and 4*a*.

Special arrangements are made for students who wish to take more advanced shop courses or who desire to prepare themselves for teaching these subjects. § 50.

1. WOODWORK. *Two hours.* Both semesters.
Bench, lathe, and simple pattern work. One-half day per week in shop, one hour per week in classroom during shop period.

2. METAL WORK. *Two hours.* Both semesters.
Forge, bench, and machine work. One-half day per week in shop, one hour per week in classroom during shop period.

3. FOUNDRY. *Four hours.* Both semesters.
Two half days per week in foundry. One recitation per week from text-books. Instruction and actual practice is given in various classes of molding, core-making, melting and pouring, or casting, of metals.
Must be preceded by Courses 1 and 2.

4. MACHINE SHOP. *Four hours.* Both semesters.
Four half days per week in the shop and one recitation per week during shop period from text-books. Operation of standard machine tools, lathes, planers, drills, milling, and grinding machines, bench work in metals, jig and tool work. Must be preceded by Courses 1 and 2.

5. INSTRUMENT MAKING. *Two hours.* Second semester only.
One-half day per week. Use of small tools in making apparatus for various work in scientific laboratories.

6. PATTERN MAKING. *Two hours* (*elective*). Both semesters.
Pattern making (advanced) consists of designing wood patterns from working drawings, and pattern construction.

SUMMER SESSION

The above courses are all offered in the Summer Session of 1921 as 1*s*, 2*s*, 3*s*, 4*s*, 5*s*, and 6*s*.

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211. SPANISH*

Assistant Professors ADAMS, KENYON, Mr. ABAIADEJO, Mr. BRITTON, Mr. LUZUNARIS, Mr. ANDERSON

1. ELEMENTARY COURSE. *Four hours.* Both semesters.
Grammar and reading, with practice in writing and speaking Spanish.

2. ELEMENTARY COURSE CONTINUED.. *Four hours.* Both semesters.
Grammar and reading, with practice in writing and speaking Spanish.

3. READING OF STANDARD SPANISH WORKS. *Four hours.* Both semesters.
Conversation, composition, business forms and correspondence.

4. A CONTINUATION OF COURSE 3. *Four hours.* Both semesters.

5. ADVANCED COMPOSITION AND CONVERSATION. *Two hours.* Both semesters.

6. SPANISH LITERATURE IN ENGLISH. *Two hours.* Both semesters.
An outline of the development of Spanish literature. Lectures, assigned readings, and reports.

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* See Sec. 132.

212. SURVEYING

Professor JOHNSTON, Associate Professors MERRICK, CAREY, Assistant Professors ATWELL, BRODIE, BOUCHARD, MITCHELL, Mr. MCFARLAN, Mr. SLOCK, Mr. YOUNG.

1. SURVEYING. Lectures, text-books, recitations, field practice. *Three hours.* First semester only.
   This course covers the elementary operations required in making surveys for engineering works. The following subjects are treated: Verniers; linear measurements; note-keeping; angle reading; traverse surveying; computing areas; straight line; circular curves; differential leveling; continuous leveling; profile; vertical curve.

2. SURVEYING. Continuation of Course 1. Lectures, text-books, recitations, field practice, drawing. *Four hours.* Second semester only.
   This course embraces topographic field work; mapping from notes made in transit and plane table surveys; theory of cross-section work and earthwork calculations; triangulation design and care of instruments.
   Courses 1 and 2 are designed for students of Civil Engineering and are prerequisites to the work at Camp Davis. They are open to all students who come properly prepared.

4. SURVEYING. Use of Instruments. Lectures, text-books, recitations, field practice. *Two hours.* Both semesters.
   This course must be preceded by Course 2 in Mathematics.
   This course embraces: linear measurement; field notes; reading verniers; reading angles; traverse surveying; computing areas; platting; leveling; platting profile; running straight line; staking out buildings and setting grade stakes. The course is designed to give Engineering students, aside from those taking Civil Engineering, a training in the fundamentals of surveying.
   This course is open to all students who come properly prepared.

5. LEAST SQUARES. *Two hours.* Both semesters.
   The theory of Least Squares. Its application to the adjustment and comparison of engineering data. Particular attention is given to the treatment of field and laboratory notes of various kinds. Examples from actual surveys and measurements are used to exemplify the theory. Special attention is given to the determination of empirical formulæ.

6. GEODETIC SURVEYING. Lectures, reading, recitations, problems. *Two hours.* Both semesters.
   This course should be preceded by Courses 1, 2, and 3 in Surveying, and Course 3E in Astronomy.

7. MUNICIPAL SURVEYING. *Two hours.* Both semesters.
This course must be preceded by Course 3 in Surveying.
Lectures, text, field and drawing room work; surveys for the location of streets, fixing grades, paving, sewers, property surveys, and the planning and laying out of new subdivisions and additions. A study of the state laws governing surveys of this nature is included.

8. THE SURVEYOR AND THE PUBLIC. *Two hours.* Both semesters.
Offered for seniors and post-graduate students.
General laws and decisions relating to the work of the surveyor; his responsibility to employers and to the public, and his proper place in city, county, and state administrations.

9. RAILWAY SURVEYING. Text-books, recitations, field practice, track problems. *Two hours.* Second semester only.
Course 9 should be preceded by Courses 1, 2, and 3 in Surveying.

10. ENGINEERING PHOTOGRAPHY AND CAMERA SURVEYING. *Two hours.* Both semesters.
Lectures; field and laboratory work; history of photography; chemistry of photography; cameras; lenses; exposure of plates; development of negatives; printing, enlarging and reducing; lantern slides; color work; mapping and field sketching.
This course is open to third and fourth-year students who have completed Course 1 or Course 4 in Surveying, a course in general Chemistry, Course 1 in Physics, and who are qualified in Drawing.

12. SURVEYING. Drawing. Lectures, text-books, recitations, field practice. *Four hours.* First semester only.
Linear measurements; field notes; reading verniers; reading angles; traverse surveying; computing areas; platting; leveling; making profiles; vertical curves; running straight lines; staking out buildings and setting grades stakes.

13. SURVEYING. *Four hours.*
Running parallel with Course 2. For students of Forestry.

SUMMER SESSION

3. SURVEYING. Summer Camp. *Eight hours.* Camp fee, $10.00; Summer Session fee, $30.00. § 14.
This course is given at Camp Davis, on Douglas Lake, thirteen miles southwest of Cheboygan, Cheboygan County, Michigan.
This course includes azimuth, plane table and stadia surveys;

railroad and land surveys; triangulation; cross-section work, and hydrographic surveys.

Particular attention is also given to the care and adjustment of instruments.

Office work includes the making of maps and diagrams and the keeping of permanent records of work performed.

The students are given instruction in camp construction and maintenance and in many things which relate to the welfare of those who spend their lives in the open.

This course is open only to those who have completed Courses 1 and 2 or 12 and 13 in Surveying at the University of Michigan, or equivalent courses of other schools. Course 3E in Astronomy is also a prerequisite.

4*s*. SURVEYING. Use of Instruments. *Two hours.*

This course is given at Ann Arbor, and covers work embraced in Course 4.

SUMMARY OF STUDENTS

1920-1921

COLLEGE OF ENGINEERING

	1st Year	2nd Year	3rd Year	4th Year	Specials	Totals
Civil Engineering	..	122	113	77	19	331
Mechanical Engineering.	..	204	167	123	3	497
Electrical Engineering..	..	145	90	43	2	280
Chemical Engineering...	..	109	86	69	1	265
Marine Engineering	..	22	16	18	..	56
Aero Engineering	..	9	15	9	2	35
Unclassified, first year..	565	..	..	..	..	565
Totals.....	565	611	487	339	27	2029

COLLEGE OF ARCHITECTURE

Architecture 1	5	11	11	4	..	31
Architecture 2	35	22	17	7	..	81
Architecture 3	26	12	11	12	..	61
Special Students	..	..	..	..	10	10
Totals.....	66	45	39	23	10	183

Undergraduates, College of Engineering.....	2029
Undergraduates, College of Architecture.....	183
Students in Colleges of Engineering and Architecture enrolled in Summer Session of 1920.....	459
Students in Engineering registered in the Graduate School.. .	55
Number of Students (not counted twice) in Engineering and Architecture.....	2373

GENERAL INDEX

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THE BULLETIN INCLUDES THE FOLLOWING PUBLICATIONS:—

The Annual Report of the President.

The Catalogue of the University.

The Annual Announcements of the College of Literature, Science, and the Arts, the Colleges of Engineering and Architecture, the Medical School, the Law School, the College of Pharmacy, the Homœopathic Medical School, the College of Dental Surgery, the Graduate School, and the Summer Session.

Other Announcements of the several departments of instruction, Reports and Communications of University officers, etc.