Bulletin of the
UNIVERSITY OF MINNESOTA

Institute of Technology 1953–1955

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INSTITUTE OF TECHNOLOGY

General Information

The Institute of Technology consists of four schools: the College of Engineering, the School of Architecture, the School of Chemistry, and the School of Mines and Metallurgy.

The curricula are designed to prepare the student for leadership in his chosen field. Each curriculum provides the student, first, with a basic training in the fundamentals of science and mathematics, upon which foundation the more specialized professional courses in his selected area are based. In addition, the student takes a liberal program in the life sciences, liberal arts, and humanities. Effort is made to develop the ability of the student to understand and be able to apply fundamental principles to problems he may meet after graduation, rather than training him in the detailed aspects of highly specialized industrial and professional practice.

College of Engineering

The College of Engineering had its origination in the College of Agriculture and Mechanics Arts which was authorized by a legislative act in 1868. In 1871, courses in civil and mechanical engineering were first offered. With the reorganization of the University in 1872 the College of Mechanics Arts was established. It successively became the College of Engineering, Metallurgy, and the Mechanics Arts in 1892, the College of Engineering and Mechanics Arts in 1897, the College of Engineering and Architecture in 1916, and College of Engineering in 1949. In 1887, a course in electrical engineering was first offered. Agricultural engineering started in 1925 and aeronautical engineering in 1928. Combined curricula in engineering and business administration were established in 1934. The five-year engineering curricula were started in 1946. In 1948 an applied mathematics curriculum was established. The Technical Aid Program was started in 1949. Industrial engineering and the cooperative work-study plan began in 1950.

The departments of this college are located in Main Engineering, Electrical Engineering, Mechanical Engineering, Aeronautical Engineering, and the Experimental Engineering buildings on the Minneapolis Campus and the Agricultural Engineering Building on the St. Paul Campus. The Hydraulic Laboratory is situated at the St. Anthony Falls on the Mississippi River about a mile upstream from the Minneapolis Campus. The Rosemount Research Center is located at Rosemount, Minnesota, about ten miles from the Minneapolis Campus. The Engineering Library and the college administration offices are located in the Main Engineering Building. The Engineering Library contains the books, reports, and journals, both foreign and domestic, indispensable to the modern engineer, particularly in the fields of graduate study and research. It is one of five departmental libraries set up to meet the needs of the Institute of Technology.

School of Chemistry

The School of Chemistry was established in 1897 as a School of Analytical and Applied Chemistry, subsidiary to the College of Science, Literature, and the Arts. In 1904 it was made a separate unit of the University; in 1919 its present name was adopted and its administration was correlated with that of the College of Engineering and Architecture under one dean. In 1935 it became one of the four units in the Institute of Technology.

The curricula in chemistry and chemical engineering were developed from the beginning of the school. The curriculum in physics was established in 1936.

The Department of Chemistry occupies a large modern building 180 x 200 feet, having six floors. Its laboratories are designed to afford facilities for instruction in the various branches of chemistry. The Chemistry Library is well provided with complete sets of journals and compendia of chemical literature, among which are important sets not frequently found in university libraries. Many special laboratories for private research have been provided and ample facilities are available for graduate work leading to the higher degrees.

The Department of Chemical Engineering is located in the Chemical Engineering Building. It is a new five-floor structure equipped with extensive modern laboratory facilities and lecture rooms.

School of Mines and Metallurgy

The School of Mines and Metallurgy was established by the Board of Regents in 1888, upon recommendation of the general faculty of the University. A course in mining and metallurgy was announced in 1899. The school was affiliated with the College of Engineering under the name of the College of Engineering, Metallurgy, and the Mechanics Arts, until 1897, when the School of Mines was made an independent college. In 1926 the name was changed to School of Mines and Metallurgy. In 1935 it became one of the four units in the Institute of Technology.

The school occupies the building provided by the Legislature of 1913. This building contains the library of the school together with the offices, classrooms, drafting rooms, and laboratories necessary to administer the courses in mining, metallurgy, metallography, and petroleum engineering. For other fields of work necessary to the completion of well-rounded curricula, advantage is taken of the instruction afforded by various departments in other units of the University.

The mining districts of Minnesota are within a few hours of Minneapolis by rail or road. The heartiest cooperation exists between the officials of the various mining companies and the school. As a result, the mining properties are at all times open to parties from the school for observation and study trips. Practical surveying, geological field work, and underground work are carried on in one or more of the districts.

Ample opportunity for field work in metallurgy is also available. Numerous fabrication and heat treating plants are located in the Twin Cities. Plants for the study of smelting and other processes can be reached with not more than an overnight trip by rail.

Students in the School of Mines and Metallurgy have, therefore, all

the advantages afforded by a large university combined with ample opportunity for field observation and experience.

School of Architecture

A course in architecture has been offered since the inception of the College of Agriculture and Mechanics Arts. A Department of Architecture was established in the College of Engineering and Mechanics Arts by the Board of Regents in 1913. The name was changed to the School of Architecture in 1925. It was affiliated with the College of Engineering and Architecture until 1949 at which time it became one of the four separate units in the Institute of Technology.

The school is located on the third and fourth floors of the Main Engineering Building and includes drawing and design rooms, classrooms, studios, exhibition rooms, a shop, and a library.

Experimental Laboratories and Special Research Facilities

In addition to the regular departmental facilities, the Institute of Technology has a number of special facilities for research and technical investigations. The St. Anthony Falls Hydraulic Laboratory located on the Mississippi River, the Mines Experiment Station, and the Rosemount Research Center are equipped to carry out large-scale investigations in cooperation with industry, associations, technical societies, and the government. Opportunities for part-time employment and graduate fellowship are provided for many advanced students by these projects.

Curricula and Degrees

Five-year degrees are offered in each of the four schools and colleges of the Institute of Technology. In the College of Engineering there are curricula in aeronautical, agricultural, civil, electrical, industrial, and mechanical engineering, and applied mathematics. The School of Chemistry offers curricula in chemistry, chemical engineering, and physics. The School of Mines and Metallurgy offers curricula in geological, metallurgical, and mining engineering, and geophysics. The School of Architecture offers a five-year curriculum in architecture and a six-year curriculum in cooperation with the College of Science, Literature, and the Arts.

In cooperation with the School of Business Administration any one of the above curricula may be combined with business administration leading to a degree in the Institute of Technology and a degree in the School of Business Administration. The institute also offers the first two years of the four-year curriculum in engineering and business administration (industrial administration) given by the School of Business Administration.

Cooperative work-study programs are offered in mechanical and industrial engineering leading to the Bachelor's degree.

A professional degree in engineering may be conferred upon a candidate who has obtained a Bachelor's or advanced degree from the Institute of Technology provided he has practiced his profession for at least eight years with at least four of these in responsible charge of important work. The Engineer degree will be granted principally in recognition of the attainment

of professional engineering competence and judgment by the candidate. Application for the degree should be made to the dean of the Institute of Technology not later than October 1 preceding the June commencement at which it is to be awarded. Detailed statements of professional experience, evidence of professional work and/or activity in the planning and direction of engineering work will be required. If accepted, the applicant will be requested to prepare and present a professional thesis which may not be a mere description of engineering work of usual character nor a digest of existing literature, but shall be based upon the candidate's direct contribution and relation to the work presented in the thesis. He will then be notified by a special Engineer Degree Committee as to the acceptability of his thesis and of the fulfillment of the technical requirements for the degree.

The Law School and Departments of Civil, Electrical, and Mechanical Engineering of the Institute of Technology have arranged for a joint program leading to the degrees of bachelor of laws and bachelor of science undesignated in the Institute of Technology. The details of the program may be obtained in the institute bulletin under the departmental curricula.

Cooperative Work-Study Plan

A cooperative five-year work-study plan of engineering education combining both theoretical and practical training into a single integrated program is offered in industrial and mechanical engineering. Alternate periods of university study and supervised work in industry will be pursued. At the end of the second year, students selected for this program will be divided into two sections. While the first section is attending class for a quarter, the second will be at work on an industrial assignment in industry. The two sections alternate or exchange places with each other every quarter.

Two students will be selected for every industrial job which becomes available. It is expected that the magnitude and difficulty of the work performed by each pair of students will be continually increased over the training period. At the end of each quarter of industrial training, the company will send a report on the student to the school. The student will also submit a written report on his work.

While at work the student is an employee of the company in every sense and is subject to the rules and regulations of the firm. The rate of pay for cooperative students will vary greatly and will be dependent upon such factors as ability, previous experience, personality, and economic conditions. In general, cooperative students will be paid on the same scale as regular employees who do the same type of work.

First and second year students in industrial and mechanical engineering should contact their department for information on this program and the procedure for submitting applications. Transfer students from other universities or colleges intending to major in these curricula are also eligible to submit applications. Candidates will be selected on the basis of scholastic ability, personal qualifications, and fitness for work.

Admission

High school preparation for admission to the Institute of Technology should include courses in elementary algebra, plane geometry, and either higher algebra or solid geometry—both if possible.

Students desiring to transfer from an accredited college or university will be admitted if they have a C average or better based on at least one year's work. Where possible this work should include mathematics, chemistry, English, physics, and drawing as outlined for the first year in the Institute of Technology.

Students who have completed less than a year of college work must satisfy the admissions requirements as specified for the high school graduate.

Detailed information concerning admission, entrance requirements, advanced standing, and expenses will be found in the *Bulletin of General Information* which will be sent to any address upon application to the Dean of Admissions and Records.

Advanced Standing

Students who have pursued courses of study in other colleges or universities of recognized standing may receive advanced standing credits in accordance with the policies of this University and the Institute of Technology. (See Requirements for Graduation.)

No credit will be given in those courses in which a grade of D has been obtained.

Students entering the School of Chemistry in the first or second year of the chemistry or chemical engineering curriculum will not be allowed elective credit for courses taken outside the School of Chemistry. Students in the third year of the chemistry or chemical engineering curriculum may transfer from outside the School of Chemistry a maximum of one-fourth, in the fourth year a maximum of one-half, in the fifth year a maximum of three-fourths of the total number of elective credits required for graduation.

Registration

In order to register, all new students must present an admission certificate and an English classification card (freshmen only) or a record of advanced standing (transfer students). Those entering the College of Engineering or the School of Architecture will begin their registration in the Main Engineering Building (135 E). Those entering the School of Chemistry will begin their registration in the Chemistry Building (127 C), while those entering the School of Mines and Metallurgy will begin in Appleby Hall (103 AH). Registration instructions furnished by the Office of Admissions and Records and published on bulletin boards in the buildings mentioned above should be followed.

Unit of Credit

The standard unit of credit in the University is the quarter credit, or simply, the *credit*. It corresponds to one class period per week for one quarter. This class period may be a one-hour lecture or recitation, or a two- or three-hour class in laboratory, drawing, surveying, or computations. In any case 1 credit is supposed to require three actual hours of the average student's time per week for one quarter. One hour of recitation is assumed to require two hours of preparation or study. A two-hour laboratory period may require one hour of home work to complete the credit. A three-hour period usually carries 1 credit without additional work outside of class.

Credit for Outside Work

Credit for work done outside of the regular classes may be obtained by comprehensive examination. Students are urged to request permission to take examinations in specific courses where the material has been thoroughly mastered. By use of the comprehensive examination the superior student may be able to accelerate his educational progress.

The comprehensive examination will be of such thorough and searching character as to determine whether the student has done all the work of the course. It should require at least three times the work of the usual final examination and will be conducted by a committee appointed by the head of the department in which the course is given.

Permission to take the comprehensive examination must be obtained from the Committee on Student Scholastic Standing, and a fee of $5 for each special examination must be paid unless it be taken within six weeks after first entering the University.

Extension Courses

Courses in engineering and chemistry are offered by the General Extension Division of the University in evening classes and by correspondence study. Those who are unable to attend the regular university courses may obtain valuable instruction in this manner. For information as to the credits which will be accepted toward a degree in the Institute of Technology, please refer to the section of this bulletin under Extension Courses.

Attendance

It is expected that all students will be regular in attendance at all class exercises and that they will do all the work of their courses. Neglect of work, as indicated by irregularity in attendance or low scholarship, will be sufficient reason for exclusion from class. Any student who has unexcused absences equal to the number of credits in a course, but in no case less than two, may be dropped from the class with a record of failure in the course.

Requirements for Graduation

The Bachelor's degree with departmental designation will be awarded to those students with honor point averages of 1.00 or better who have completed all of the required work and have the total number of credits specified in their curricula. For students who have an honor point average of 1.80 or better, an additional degree, the bachelor of science undesignated, will be awarded upon application at the same time as the Bachelor's degree with designation except in architecture, the cooperative work-study program, and any of the combined curricula.

It is possible for students to enter the Graduate School after completing the fourth year of their curricula. One of the requirements for admission to the Graduate School is a Bachelor's degree. A degree, the bachelor of science undesignated, may be obtained in the Institute of Technology by submitting a petition to the faculty in the third quarter (second quarter in the School of Chemistry) of the fourth year. The awarding of this degree will require an honor point average of 1.80 or better, completion of all the work includ-

ing the proportional part of the non-technical required courses in the first four years of the curriculum, the recommendation of his undergraduate department, and evidence of acceptance for graduate study. A total of 200 credits is required in the College of Engineering and 204 and 215 credits respectively in chemistry and chemical engineering. The total required credits in the School of Mines and Metallurgy is the total credits of the first four years of the curriculum.

Students entering with advanced standing from other colleges or universities must spend at least one year in residence here before they will be recommended for graduation. If the term of residence is only one year, it must be the senior year. In any case such a student must spend two "quarters" of his senior year in residence.

Honor Point Average Requirements and Quality Credits

An honor point average of at least 1.00 is required for graduation in the Institute of Technology.

The honor point average is defined as the total number of earned honor points divided by the total number of credits earned and failed. Each credit with the grade of A carries three honor points; each credit with the grade of B, two honor points; each credit with the grade of C, one honor point. The grades of D and F carry no honor points.

Only credits and honor points earned at the University of Minnesota are used in calculating the honor point average.

Any student who has an accumulative honor point average of less than 1.00 will be placed on probation. Students on probation may have to cancel their registration if their work does not improve.

Only credits and honor points earned since the summer of 1949 are used in calculating these honor point average requirements.

SPECIAL REQUIREMENTS OF THE SCHOOL OF CHEMISTRY

Students in the School of Chemistry must obtain a grade of C or better in all courses in analytic and inorganic chemistry, mathematics, and physics which are listed as required work in the first two years of their curricula. If grades of D or F are obtained, the courses must be repeated the next time they are offered.

An honor point average of at least 1.00 is required for *each* of the five years. This is a prerequisite to entrance into the required courses of the succeeding year.

As a special recognition of superior work, quality credits may be earned in the School of Chemistry on the basis of 1 credit for every 10 honor points in excess of a C average for work taken in this University. Quality credits may apply toward the credit requirement for graduation. Superior students who have accumulated sufficient quality credits may be able to register for graduate work in addition to undergraduate work their last quarter in school.

Inspection Trips

Inspection trips are required of seniors in agricultural, chemical, electrical, industrial, and mechanical engineering; industrial plants and other establishments of interest are visited. For the expense of these trips, check with the departmental office.

Field trips in the School of Mines and Metallurgy are required at the end of the third and fourth years as indicated in the various curricula. A trip of about six weeks' duration is taken to the iron ranges in northern Minnesota for the purpose of mine surveying and field work in geologic mapping. A three-week trip, starting in early September, is made to principal mining areas of the country to study mining and metallurgical plants and operations. A geology trip, requiring four weeks, embracing standard types of geological field work, is made to the Black Hills region. The petroleum students take a two-week trip to the principal oil producing areas of Oklahoma and Kansas. The ferrous metallurgy trip includes inspection of principal iron and steel plants, fabrication plants, and heat treating plants in the Middle West. These last two trips are taken during spring vacation. For the period 1953-55, these trips will be offered only in the even year—1954.

Fellowships and Assistantships

There are numerous fellowships and assistantships in the Institute of Technology open to graduates. Teaching assistantships with a stipend of $1,404 for one-half time are available in chemical engineering, chemistry, civil engineering, electrical engineering, applied mathematics, mechanics and materials, mechanical engineering, and mines and metallurgy. Research assistantships at $1,404 for one-half time are available in the Engineering Experiment Station. Various fellowships with stipends from $1,000 to $2,100 are open to graduate students in chemical engineering, chemistry, aeronautical engineering, civil engineering, electrical engineering, mechanical engineering, mining engineering, metallurgical engineering, and physics.

Application for fellowships and assistantships should be made to the department concerned. Information as to procedures and forms to submit may be obtained from either the Graduate School or the department.

Scholarships and Awards

Many scholarships and prizes are awarded to students in the Institute of Technology. Requests for information or applications should be addressed to the head of the department or school concerned. Information regarding scholarships available to Minnesota high school graduates entering the University may be found in the *Bulletin of General Information*. The Bureau of Student Loans and Scholarships in Eddy Hall will also supply information regarding these matters.

College of Engineering and School of Mines and Metallurgy Scholarships:

David Grimes Scholarship
Donor: Philco Corporation
Qualifications: Student in electrical engineering
Amount: $500.00 each, five awards annually

Douglas Aircraft Scholarship
Donor: Douglas Aircraft Company, Inc.
Qualifications: Senior student in aeronautical or mechanical engineering
Amount: $600.00

Iron Mining Industry of Minnesota Scholarships
Donor: Iron Mining Industries of Minnesota
Qualifications: Students in mining and metallurgy
Amount: Several awards up to $300.00 each

John Morse Foundation Scholarship
Donor: John Morse Memorial Foundation
Qualifications: Three 4th-year and three 5th-year students in mechanical or electrical engineering
Amount: $500.00 each, six awards annually

Lake Superior Mining Institute Scholarships
Donor: Lake Superior Mining Institute
Qualifications: Students in mining and metallurgy
Amount: Several awards up to $300.00

Louis Allis Company Engineering Scholarship
Donor: Louis Allis Company
Qualifications: Senior students in electrical engineering; awarded in the junior year
Amount: An annual scholarship of $500.00

Northwestern Section, American Society of Civil Engineers Scholarship
Donor: Northwestern Section, American Society of Civil Engineers
Qualifications: Senior student, civil engineering, member of student organization of American Society of Civil Engineers
Amount: $200.00

Radio Corporation of America Scholarship
Donor: National Broadcasting Company, Inc.
Qualifications: Student in engineering or in mathematics
Amount: $800.00

Socony-Vacuum Oil Company Scholarship
Donor: Socony-Vacuum Oil Company, Inc.
Qualifications: Student in civil engineering
Amount: $750.00

Square-D Scholarship
Donor: Square-D Company
Qualifications: Students in engineering who have completed three years of engineering work
Amount: $350.00

School of Architecture (Applications and requests for information should be addressed to the Head of the School of Architecture.)

A. C. Ochs Brick and Tile Company Scholarship
Donor: A. C. Ochs Brick and Tile Company
Qualifications: Architectural ability and financial need
Amount: $200.00

C. H. Johnston Scholarship
Donor: Office of C. H. Johnston, Architects and Engineers
Qualifications: Architectural ability and financial need
Amount: $200.00

Flour City Scholarships
Donor: Flour City Ornamental Iron Company
Qualifications: Architectural ability and financial need
Amount: Several scholarships annually from $100.00 to $400.00

Johns Hopkins Scholarship in Interior Design
Donor: Friends of the late Johns Hopkins
Qualifications: Study of interior design
Amount: $300.00

Magney, Tusler and Setter Scholarship
Donor: Magney, Tusler and Setter, Architects and Engineers
Qualifications: Architectural ability and financial need
Amount $200.00

Thomas F. Ellerbe Prize or Scholarship
Donor: The Co-operative Foundation
Qualifications: Excellence in study of buildings for co-operatives
Amount: $300.00

Gargoyle Club Prize
Donor: Gargoyle Club, St. Paul
Qualifications: Best thesis submitted during academic year
Amount: $50.00 (in books)

George B. Melcher Prize
Donor: Flour City Ornamental Iron Company
Qualifications: Best work in design problem involving use of metal
Amount: $100.00

Illuminating Engineering Society Prize
Donor: Twin City Section, Illuminating Engineering Society
Qualifications: Best work in design problem involving study of lighting
Amount $85.00 and five society memberships

Alpha Rho Chi Medal
Donor: Alpha Rho Chi Fraternity
Qualifications: Architectural ability and student leadership

American Institute of Architects Medal
Donor: American Institute of Architects
Qualifications: Highest scholastic standing in graduating class during an academic year

Prizes are awarded by the Northern section of the American Society of Civil Engineers, the Minnesota Chapter of the American Society of Mechanical Engineers, Tau Beta Pi, Chi Epsilon, Eta Kappa Nu, Pi Tau Sigma, Phi Lambda Upsilon, Twin City Alumni Association of Alpha Chi Sigma, the Chemistry faculty, Northern States Power Company, and the Aeronautical Sciences Prize.

Placement Service

A placement service is maintained for the use of the graduating classes and the alumni. Without assuming the responsibility of finding employment for the graduate, every effort is made to assist graduates in securing the type of opening best suited for their aptitudes, training, and interests.

Reserve Officers Training Corps

A program of courses is available in Air Science and Tactics, Military Science and Tactics, and Naval Science leading to a commission in the Air Force Reserve, Army Officers Reserve Corps, or the Naval Reserve, respectively.

In the Institute of Technology it is possible to complete the requirements for a commission and also the Bachelor's degree in the normal time allotted for each engineering curriculum. This is accomplished by substituting ROTC credits for elective credits and for some of the non-technical required courses.

It is particularly desirable to enter the basic ROTC program in the fall quarter of the freshman year although it may be possible to enter at a later date. New students are urged to consider carefully the advantages of ROTC prior to entering the University so that it may be included in the fall quarter's program of courses.

Many of the courses in the military programs are particularly adapted for students in the Institute of Technology. All engineeing students should investigate the Naval Reserve, Air Force Reserve, Antiaircraft Artillery, and the Transportation Corps. Civil engineering students should consider the Corps of Engineers, mechanical engineering students the Ordnance Department, electrical engineering and physics students the Signal Corps.

Detailed information concerning requirements, opportunities, and courses in these programs may be found in the *Bulletin of General Information*, the special *Bulletin of Army-Navy-Air ROTC*, on page 112 of this bulletin, and from the professors of air, military, and naval science in the Armory.

Student Loans

The Bureau of Student Loans and Scholarships in the Office of the Dean of Students has been established to aid students in need of financial assistance or help in planning a sound financial program. Application for financial aid should be made directly with this office in 211 Eddy Hall.

Societies

Branches of the following national professional societies are maintained at the University of Minnesota by students and faculty members: American Chemical Society, American Institute of Chemical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Agricultural Engineers, and the Institute of the Aeronautical Sciences. In addition there are the Architectural Society, the School of Mines and Metallurgy Society, and the University of Minnesota Flying Club.

Changes in Bulletin

The faculties of the Institute of Technology reserve the right to change their curricula and to cancel or change without notice any course printed in this bulletin. The bulletin is a statement of present conditions, and is subject to modification in any particular by faculty action.

Institute of Technology

AT THE UNIVERSITY OF MINNESOTA

COLLEGE OF ENGINEERING

Aeronautical Engineering
Agricultural Engineering
Applied Mathematics
Civil Engineering
Electrical Engineering
Industrial Engineering
Mechanical Engineering
Technical Aid

SCHOOL OF CHEMISTRY

Chemical Engineering
Chemistry
Physics

SCHOOL OF MINES AND METALLURGY

Geophysics
Geological Engineering
(Mining and Petroleum Options)
Metallurgical Engineering
Mining Engineering
(Mining and Petroleum Options)

SCHOOL OF ARCHITECTURE
Architecture

COMBINED CURRICULA

with the School of Business Administration
and with the Law School

Basic Curricula

for

College of Engineering
School of Chemistry
School of Mines and Metallurgy
School of Architecture

COLLEGE OF ENGINEERING

First Year

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 11†, 12, 13—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Analytic Geometry	5	5	5
Draw. 4§, 5, 6—Engineering Drawing	3	3	3
Phys. 11, 12, 13—General Physics	5	5	5
Engl. 4, 5, 6—Written and Spoken Communication	3	3	3
G.E. 21—Orientation	1	.....	.....
Total credits	17	16	16

Second Year

I.T.M. 24, 25—Calculus I: Differential; Calculus II: Integral	5	5	.....
M.&M. 26—Engineering Statics	.....	.....	5
I.T.M. 80—Elementary Differential Equations	.....	.....	3
Phys. 14, 50—Intermediate General Physics	4	4	.....
Phys. 51¶—Intermediate General Physics / Org.Chem. 16¶—Carbon Compounds	.....	.....	4
Inorg.Chem. 14, 15—Inorganic Chemistry	4	4	.....
Laboratory**	1	1	1
Non-Technical Requirements*—Group I or II	3–4	3–4	3–4
Total credits	17–18	17–18	16–17

* See *Non-Technical Required Courses*, page 68.

† I.T.M. 9, Higher Algebra, zero credits, to be taken instead of I.T.M. 11 if higher algebra is not presented as an entrance unit.

§ Draw. 10, Solid Geometry, zero credits, to be taken instead of Draw. 4 if solid geometry is not presented as an entrance unit.

¶ Either Phys. 51 or Chem. 16 must be taken. See the departmental curriculum for the department in which you are at present planning to enter.

** See the departmental curriculum for the department in which you are at present planning to enter for the recommendations for the courses to use for laboratory credits.

SCHOOL OF CHEMISTRY

First Year

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 11†, 12, 13	College Algebra and Trigonometry I; College Algebra and Trigonometry II; Analytic Geometry	5	5	5
Engl. 4, 5, 6	Written and Spoken Communication	3	3	3
Draw. 7§, 8	Engineering Drawing	3	3	....
G.E. 21	Orientation	1	....	....
Inorg.Chem. 9, 10 or 6, 7¶	General Inorganic Chemistry	5	5	....
Inorg.Chem. 12	Semimicro Qualitative Analysis	....	....	5
P.H. 3**	Personal Health	....	....	2
	Total credits	17	16	15

Second Year

For second and succeeding years see *Chemical Engineering*, page 33; *Chemistry*, page 36; and *Physics*, page 65.

SCHOOL OF MINES AND METALLURGY

First Year

I.T.M. 11†, 12, 13	College Algebra and Trigonometry I; College Algebra and Trigonometry II; Analytic Geometry	5	5	5
Draw. 4††, 5, 6	Engineering Drawing	3	3	3
Inorg.Chem. 4, 5 or 1, 2§§	General Inorganic Chemistry	4	4	....
Inorg.Chem. 11	Semimicro Qualitative Analysis	....	....	4
G.E. 21	Orientation	1	....	....
Engl. 4, 5, 6	Written and Spoken Communication	3	3	3
Non-Technical Requirements*	Section A	....	3	....
	Total credits	16	18	15

Second Year

I.T.M. 24, 25	Calculus I: Differential; Calculus II: Integral	5	5	....
M.&M. 84	Engineering Mechanics	....	....	5
Phys. 7, 8, 9	General Physics	5	5	5
Non-Technical Requirements*	Group I	3	3	....
Non-Technical Requirements*	Group II	3–4	3–4	....
Electives (Technical or Non-Technical)		....	....	6
	Total credits	16–17	16–17	16

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* See *Non-Technical Required Courses*, page 68.

† I.T.M. 9, Higher Algebra, zero credits, to be taken instead of I.T.M. 11 if higher algebra is not presented as an entrance unit.

§ Draw. 10, Solid Geometry, zero credits, to be taken instead of Draw. 7 if solid geometry is not presented as an entrance unit.

¶ Take Inorg.Chem. 6, 7 if chemistry was not taken in high school.

** Not required of students taking NROTC or ROTC.

†† Draw. 10, Solid Geometry, zero credits, to be taken instead of Draw. 4 if solid geom etry is not presented as an entrance unit.

§§ Take Inorg.Chem. 1, 2 if chemistry was not taken in high school.

SCHOOL OF ARCHITECTURE

First Year

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 11†, 12, 13—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Analytic Geometry	5	5	5
Engl. 4, 5, 6—Written and Spoken Communication	3	3	3
Approved Electives	7	7	7
Total credits	15	15	15

In choosing the approved electives, preference should be given to history, economics, G.E. 21, political science, sociology, and foreign language. Inorganic chemistry must be included if not taken in high school.

SPECIAL REGULATIONS

Removal of deficiencies—Applicants may be admitted with deficiencies in either higher algebra or solid geometry but not both. These deficiencies together with Preparatory English must be removed the *first quarter* in residence or the student will not be able to continue in the Institute of Technology.

English—Students assigned to Preparatory English by their English assignment card must complete this course their first quarter in school. No credit is given for this course. Registration for this course is in the General Extension Division in Nicholson Hall. A fee of $15.00 is charged for it.

† I.T.M. 9, Higher Algebra, zero credits, to be taken instead of I.T.M. 11 if higher algebra is not presented as an entrance unit.

Aeronautical Engineering

A five-year curriculum is offered which leads to the degree of bachelor of aeronautical engineering, B.Aero.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation.

The course in aeronautical engineering is intended to provide instruction and training for students who wish to enter this field of engineering as a profession. With the rapid development of aviation in recent years, aeronautical engineering has assumed a prominent and important position among the engineering professions. The production, development, and use of equipment requires a thorough knowledge of the most recent developments in the aeronautical sciences, including high altitude and supersonic flight problems. Aeronautical engineers are required in all stages of the process, from the research work preliminary to improvements in design to the actual construction, testing, operation, and maintenance. Students trained in aerodynamics and the designing of light structures have been in demand in recent years in many industries.

Because of the extensive developmental work being done, new opportunities in the field of aeronautical engineering are continually being created.

The aeronautical engineering course is similar to other professional engineering courses. The first two years of the course are the same and interchangeable with those of agricultural, civil, electrical, geological, mechanical, metallurgical, mining, and petroleum engineering. The fundamental studies are the same. As a result, the graduates in aeronautical engineering should be prepared to enter various branches of the engineering field if, for any reason, they should prefer to do so.

As in other technical courses, so in aeronautical engineering, mathematics plays an important part. No student should enter this course who feels poorly prepared in mathematics.

It should be understood that this is a professional engineering course and not a training course for airplane pilots. It deals with the preparation of students for research, design, construction, operation, management, and maintenance of aircraft from the standpoint of the engineer, scientist, or manager. However, practical flight training is important for aeronautical engineers, and students are urged to take advantage of their opportunities to obtain it through the University of Minnesota Flying Club, the U.S. Air Force, the National Guard, the Naval Reserve, or the division of Flight Activities of the University.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined curriculum of engineering and business administration. Students with an honor point average of 1.80 may apply for bachelor of science degree undesignated at the end of the fourth year to accelerate graduate studies.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in aeronautical engineering elect the following courses in the second year:

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 80—Elementary Differential Equations	.....	.....	3
Aero.E. 4, 5, 6—Laboratory	1	1	1
Phys. 51—Intermediate General Physics or Org.Chem. 16—Carbon Compounds	.....	.....	4
THIRD YEAR			
Aero.E. 1—Aeronautics	3	.....	.....
Aero. 142—Aircraft Installation I	.....	2	.....
Aero.E. 158—Physics of the Atmosphere	.....	2	.....
Aero.E. 140—Aeronautical Laboratory	.....	.....	4
Hydr. 101—Fluid Mechanics	3	.....	.....
M.&M. 127—Engineering Dynamics	.....	5	.....
M.&M. 128—Mechanics of Materials	.....	.....	5
M.E. 21—Kinematics and Mechanisms	3	.....	.....
M.E. 131, 132—Thermodynamics	.....	3	3
Draw. 28—Drafting	2	.....	.....
M.E. 18—Materials and Processing	3	.....	.....
Non-Technical Requirements*—Group II or I	3	3	3
Electives†	1	3	3
Total credits	18	18	18
FOURTH YEAR			
Aero.E. 83—Stresses in Simple Structures	4	.....	.....
Aero.E. 100, 101, 102—Aerodynamics	3	3	3
Aero.E 115—Airplane Stresses	.....	3	.....
Aero.E. 110—Vibration and Flutter	.....	.....	3
Aero.E. 141—Aerodynamics Laboratory	.....	.....	2
E.E. 46, 47—Electrical Engineering Survey and Aeronautical Radio	3	3	.....
I.T.M. 167—Selected Topics in Mathematics for Senior Aeronautical Engineers	3	.....	.....
M.E. 150A—Internal Combustion Engines	.....	4	.....
M.E. 151A—Advanced Internal Combustion Engines	.....	.....	2
Non-Technical Requirements*—Group III	3	3	3
Electives†	.....	.....	3
Total credits	16	16	16
FIFTH YEAR			
Aero.E. 120, 121, 122—Airplane Design	2	2	2
Aero.E. 130—Aerodynamic Design Laboratory	2	.....	.....
Aero.E. 131, 132—Airplane Design Laboratory	.....	2	2
Aero.E. 106—Advanced Aerodynamics	.....	3	.....
Aero.E. 143—Aircraft Installations II	3	.....	.....
Aero.E. 190, 191—Seminar	.....	1	1
Aero.E. 135—Airplane Static Testing	.....	.....	2
Aero.E. 155—Aeronautical Calculations	.....	.....	2
Engl. 85, 86—Advanced Technical Communication	3	3	.....
M.E. 158—Aero Engine Testing	.....	.....	2
M.E. 157—Gas Turbine and Jet Propulsion Power Plants	3	.....	.....
G.E. 103—Professional Problems	.....	1	.....
Non-Technical Requirements*	.....	.....	3
Electives†	3	3	3
Total credits	16	15	17

* See *Non-Technical Required Courses*, page 68.

† At least 9 elective credits should be taken within the Institute of Technology. Substitution of courses from allied fields or ROTC programs may be made on the recommendation of the student's adviser and approval by the department head.

Agricultural Engineering

A five-year curriculum, in cooperation with the College of Agriculture, Forestry, and Home Economics, is offered which leads to the degree of bachelor of agricultural engineering, B.Ag.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation.

Agricultural engineering includes four fields of activity: farm power and machinery, farm structures, rural electrification, and soil and water conservation. The curriculum is arranged to permit the student by proper choice of electives to concentrate his study in one of the above fields or to broaden his training by taking work in all four.

The work in farm power and machinery includes management of power and machinery to produce good results under specified farm conditions, design and construction of machinery to meet field requirements, and the application of gasoline, diesel, and steam power to meet agricultural requirements.

The work in rural electrification includes electric circuits, electrical machinery, lighting, and applications of electricity to agricultural needs.

The work in farm structures includes the study of building materials; the design, construction, and location of houses, animal shelters, crop storage, and service buildings for the farmstead; and insulation and ventilation of farm buildings.

The work in soil and water conservation includes the development of unused but potentially productive land by drainage or irrigation; the improvement and conservation of land already under cultivation by means of drainage, soil erosion control, water conservation, and supplemental irrigation; and the design, construction, and operation of the works needed to accomplish these benefits.

The field of agricultural engineering offers a variety of opportunities among which the following are prominent: as executives, development and design engineers, publicity and sales managers, and technical field experts for manufacturers of farm machinery, equipment, and building materials; as managers of large farms requiring extensive machinery and equipment; as advisers and technicians with power companies or with government agencies in the development of rural electric service; as engineering specialists with agencies of the federal, state, and local governments, with educational institutions, and with consulting engineers, contractors and development companies requiring experts in the fields of land drainage, erosion control, irrigation, water utilization, farm power and machinery, application of electricity to agriculture, and farm structures.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined curriculum of engineering and business administration. In this curriculum business courses may be substituted for non-technical required courses, group I and group III (page 68), English 85-86, and electives.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in agricultural engineering elect the following courses in the second year:

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Phys. 51—Intermediate General Physics	.....	.....	4
Ag.En. 8, 9, 10—Laboratory	1	1	1
Non-Technical Requirements*—Group I	3	3	4

THIRD YEAR

Ag.En. 21—Elements of Surveying	.....	.....	5
M.&M. 127—Engineering Dynamics	.....	5	.....
M.&M. 128—Mechanics of Materials	5	.....	.....
M.&M. 141—Materials Testing Laboratory	1	.....	.....
C.E. 31—Stresses in Structures	3	.....	.....
C.E. 32—Design in Steel	.....	3	.....
M.E. 13—Metal Processing	2	.....	.....
M.E. 21—Kinematics and Mechanisms	.....	3	.....
M.E. 22—Mechanisms of Automatic Machinery	.....	.....	3
M.E. 24—Elements of Machine Design	.....	.....	3
Hydr. 102—Fluid Mechanics	.....	.....	4
Hydr. 104—Hydraulics Laboratory	.....	.....	1
Econ. 8, 9—General Economics	3	3	.....
Soil. 4—Soils	.....	3	.....
Agricultural sequence (see page 26)	3	.....	.....
Total credits	17	17	16

FOURTH YEAR

Ag.En. 18—Agricultural Automotives	.....	3	.....
Ag.En. 51—Soil and Water Conservation	.....	3	.....
Ag.En. 52—Elements of Farm Machinery	3	.....	.....
Ag.En. 53—Farm Structures	.....	.....	3
Ag.En. 61—Irrigation	.....	.....	3
Ag.En. 172—Applied Electricity	.....	.....	3
Ag.Ec. 102—Farm Organization	.....	3	.....
E.E. 36, 37—Electrical Engineering Survey	3	3	.....
M.E. 14—Metal Cutting	2	.....	.....
M.E. 131—Thermodynamics	3	.....	.....
Rhet. 22—Public Speaking	.....	.....	3
Non-Technical Requirements*—Group II or I	3	3	.....
Agricultural sequence (see page 26)	3	.....	3
Electives	.....	3	3
Total credits	17	18	18

FIFTH YEAR

Ag.En. 36—Rural Sanitation and Water Supply	.....	3	.....
Ag.En. 63—Farm Structures Laboratory	3	.....	.....
Ag.En. 150—Inspection Trip	.....	.....	1
Agricultural engineering electives (see page 26)	3	3	3
C.E. 101—Contracts and Specifications	.....	.....	3
C.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	.....	3	3
Geol. 5—Engineering Geology	3	.....	.....
Non-Technical Requirements*—Group III	3	3	3
Electives	3	3	3
Total credits	15	16	16

* See *Non-Technical Required Courses*, page 68.

Agricultural Sequences

In addition to required courses listed in the curriculum, 9 credits listed in the curriculum as Agricultural Sequence must be completed in one or more fields of agriculture. Courses from the following list are suggested and when possible completion of one of these sequences is recommended.

Agronomy: Agron. 1, 21, 23
Animal Husbandry: A.H. 1, 56, 57
Dairy: D.H. 1, 101, A.H. 56
Soils: Soil. 5, 108
Weed Control: Agron. 1, 135, Pl.Path. 3

Engineering Electives

A minimum of 9 credits (listed in curriculum as agricultural engineering electives) must be taken from the following list of agricultural engineering courses offered as electives: Ag.En. 73, 106, 107, 111, 112, 113, 125, 126, 167, 171.

Additional electives appropriate to the student's interest and as prerequisites for advanced courses should be selected from the preceding or from the following list of courses.

Other courses may be taken as electives with the approval of the adviser.

Farm Power and Machinery: M.E. 12, 23, 121, 132, 150, 151, 152, 159, 180; Met. 156; Hydr. 190, 191.

Rural Electrification: Ag.Ec. 25, 144; E.E. 38, 151; I.T.M. 90; M.E. 132, 160, 180; Phys. 146.

Farm Structures: C.E. 33, 130, 131, 132, 141, 146, 147; Hydr. 190; Draw. 21, 37, 38; I.T.M. 154; M.E. 132, 160, 180; Ag.Ec. 107.

Soil and Water Conservation: Agro. 1, 21, 23; C.E. 146, 159, 160; Hydr. 183; Soil. 5 103, 108.

Applied Mathematics

A five-year curriculum is offered which leads to the degree of bachelor of applied mathematics, B.Appl.Math.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of 250 credits for graduation.

This course of study is designed to prepare the student for those positions in industry which require the use of more mathematics than is offered in the usual engineering curricula. It provides a fundamental study in physics and in some engineering field selected by the student, and a more advanced study of the courses in mathematics and mechanics.

Students who maintain an honor point average of 1.80 or better throughout the first four years of the course may elect, upon petitioning therefore, to receive a bachelor of science degree (without departmental designation) at the end of the fourth year. This will permit honor students who so desire to register in the Graduate School in the fifth year and pursue work toward a Master's degree. Alternatively they may pursue the regular work of the applied mathematics curriculum leading to the degree of bachelor of applied mathematics at the end of the fifth year.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined curriculum of engineering and business administration.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in applied mathematics elect the following courses in the second year:

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 2, 3, 4	Laboratory	1	1	1
Phys. 51	Intermediate General Physics	.....	.....	4

THIRD YEAR

M.&M. 127	Engineering Dynamics	5	.....	.....
M.&M. 128	Mechanics and Materials	.....	5	.....
M.&M. 141	Materials Testing Laboratory	.....	1	.....
I.T.M. 150, 152, 153	Calculus III: Intermediate Calculus; Calculus IV, V: Advanced Calculus	3	3	3
Hydr. 103	Fluid Mechanics	.....	.....	5
Hydr. 104	Hydraulics Laboratory	.....	.....	1
Non-Technical Requirements*	Group II or I	3	3	3
Option†		3	3	3
Electives		3	2	2
	Total credits	17	17	17

* See *Non-Technical Required Courses*, page 68.

† Option is to be selected from one of the engineering departments in the Institute of Technology.

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 132, 133, 134—Industrial Statistics	3	3	3
I.T.M. 142, 143—Vector and Matrix Theory with Applications	3	3	.....
I.T.M. 156—Elements of Tensor Analysis	.....	.....	3
I.T.M. 168—Elementary Theory of Complex Variables	.....	3	.....
I.T.M. 169—Mathematical Theory of Flow	.....	.....	3
M.E. 131—Thermodynamics	3	.....	.....
I.T.M. 184—Elementary Numerical Analysis in Engineering	3	.....	.....
I.T.M. 151—Ordinary Differential Equations	.....	3	.....
I.T.M. 99—Mathematical Problem Seminar	.....	.....	3
Non-Technical Requirements*—Group III	3	3	3
Elective	2	2	2
Total credits	17	17	17

FIFTH YEAR

I.T.M. 161, 162, 163—Analytical Dynamics	3	3	3
M.&M. 181, 182, 183—Applied Elasticity	3	3	3
Phys. 101, 103, 105—Theoretical Physics	5	5	5
Engl. 85, 86—Advanced Technical Communications	3	3	.....
G.E. 103—Professional Problems	.....	1	.....
Non-Technical Requirements*	.....	.....	3
Elective	3	2	3
Total credits	17	17	17

* See *Non-Technical Required Courses*, page 68.

Architecture

The School of Architecture offers the following curricula:

Five-Year Professional Curriculum

This curriculum leads to the bachelor of architecture (B.Arch.) degree in the Institute of Technology. It requires normally one year of prearchitectural college work in any accredited institution, followed by four years in the School of Architecture. It is intended for students who expect to enter the practice of architecture in any of its recognized phases. When supplemented by practical experience, it qualifies graduates for admission to registration examinations according to the laws of the various states.

Four-Year General Curriculum

This curriculum leads to the degree of bachelor of arts (B.A.) with a major in architecture in the College of Science, Literature, and the Arts. It requires normally two years of prerequisite work in the Junior College. Two additional years in the Senior College are normally required to complete the major sequence offered by the School of Architecture. It is intended for students who wish to combine some study of architecture with their general education. This curriculum does not in itself constitute terminal professional training. It does, however, provide an advantageous approach to professional training in the special fields of architecture, city planning, landscape architecture, and decorative, industrial, or interior design. With appropriate modifications, it provides the first four years' work of the six-year professional curriculum in architecture described below. For further details see the *Bulletin of the College of Science, Literature, and the Arts.*

Six-Year Professional Curriculum

This curriculum combines the general and professional curricula in a six-year program leading to the B.A. and B.Arch. degrees. It includes normally four years of registration in the College of Science, Literature, and the Arts to complete a modified version of the major in architecture sequence, followed by two years in the School of Architecture to complete the requirements for the B.Arch. degree.

Admission Procedures

As high school preparation for the architectural curricula, higher algebra and solid geometry are essential; physics, chemistry, history, and foreign language are strongly recommended; instrumental and freehand drawing are advantageous.

Enrolment as a candidate for the B.Arch. and B.A. degrees in the four-, five- and six-year curricula listed above requires approval by the School of Architecture.

A prerequisite for such approval is completion of prearchitectural college work as follows:

For the Five-Year Professional Curriculum:

Completion of a first year of prearchitectural college work as described below.

For the Four-Year General Curriculum:

Completion of two years of prearchitectural college work, as prescribed for the major in architecture sequence in the *Bulletin of the College of Science, Literature, and the Arts.*

For the Six-Year Professional Curriculum:

Completion of the requirements for the B.A. degree with the major in architecture in the College of Science, Literature, and the Arts, normally four years of work as described below.

Upon completion of the required prerequisite work, application shall be made to the School of Architecture for enrolment in the desired curriculum. Application forms may be obtained from the school or from the Office of Admissions and Records. They must be submitted not later than July 15 preceding the beginning of the academic year for which admission is sought. Approval will be based on a consideration of (1) the student's scholastic standing in previous high school and college work; (2) his maturity and experience; (3) his professional aptitude and objective; and (4) the work space and instructional facilities available in the School of Architecture.

Description of Professional Curricula

The professional curricula prescribe courses in three general divisions. The first is theory, presenting the technical, analytical, and historical knowledge on which architecture is based. The second is drawing and the allied means of visual communication. The third and principal division is continued practice in all phases of architectural design.

Whether the professional student elects the five-year or the six-year curriculum will depend on the time and means at his disposal. He will find it highly desirable to take as much general work as possible. College work taken at institutions other than the University of Minnesota can readily be adjusted to the professional curriculum. In any such work, college algebra, trigonometry, and analytic geometry should be included as essential prerequisites to certain courses in structural design. Selections from language, history, economics, political science, sociology, and physics are recommended. Prospective students should note that it normally takes four years to complete the required technical work regardless of how much college work they may have to their credit, and should calculate their time accordingly.

Five-Year Curriculum

The five-year curriculum provides, in addition to basic professional training, opportunity for a certain amount of specialization in general design, building construction and equipment, city planning, interior design, or business administration. This specialization is accomplished by (1) a choice of electives, (2) options in architectural design, and (3) the choice of a thesis subject.

In addition to the prescribed courses, sufficient approved electives must be taken to make a minimum total of 225 credits. The first year consists of prearchitectural college work, which may be taken at the University of Minnesota or elsewhere, and whose satisfactory completion is a prerequisite for the student's admission to the second year's work as a candidate for the B.Arch. degree.

The specific requirements are listed in the following program. This program is typical for students who have completed high school with acceptable credits in higher algebra, solid geometry, and Preparatory English, and who maintain a normal rate of progress after admission to college and architectural school.

FIRST YEAR
(Prearchitectural)

The first year may be taken at—

1. Any accredited institution other than the University of Minnesota.
2. At the University of Minnesota in the College of Science, Literature, and the Arts.

3. At the University of Minnesota in the first year course offered for prearchitects by the Institute of Technology.

Prospective students are urged to consult advisers in the School of Architecture in 310 Main Engineering as to:

(a) Which of the plans listed above is best suited to their needs.
(b) Their program of prearchitectural studies.

The following courses offered by the University of Minnesota, or their equivalents if taken elsewhere, are required for the bachelor of architecture degree, and should be included in the first year of prearchitectural work:

College Algebra, Trigonometry, and Analytic Geometry (Math. 6, 7, and 30 or I.T.M. 11, 12, and 13) ..... 15 credits
English Composition (Engl. 4, 5, and 6) ..... 9 credits
Approved electives, totaling approximately ..... 21 credits

In choosing these courses, preference should be given to history, economics, political science, sociology, and foreign language. Inorganic chemistry must be included if not taken in high school.

Normal total for first year ..... 45 credits

SECOND YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Arch. AD-I—Architectural Design, Grade I	6	6	6
I.T.M. 91, M.&M. 92, 93—Calculus, Mechanics for Architects, and Mechanics of Materials	4	4	4
Art 23A, 24A, 25A—Drawing and Painting I	2	2	2
Phys. 1, 2, 3—Introduction to Physical Science	3	3	3
Total credits	15	15	15

THIRD YEAR

Arch. 57, 58, 59—Building Materials and Methods	4	4	4
Arch. AD-II—Architectural Design, Grade II	6	6	6
C.E. 38, 39, 41—Structural Design in Steel, Steel and Timber, Concrete	3	3	3
Art 60A, 61A, 62A—Drawing and Painting II	2	2	2
Total credits	15	15	15

FOURTH YEAR

Arch. 51, 52, 53—History of Architecture	4	4	4
Arch. 71, 72, 73—Building Equipment	3	3	3
Arch. AD-III—Architectural Design, Grade III	8	8	8
Total credits	15	15	15

FIFTH YEAR

Arch. 104—City Planning	3	.....	.....
Arch. 105—Professional Relations	.....	3	.....
Arch. AD-IV—Architectural Design, Grade IV	9	9	.....
Arch. AD-V—Thesis	.....	.....	12
Approved electives	3	3	3
Total credits	15	15	15

Six-Year Curriculum

This curriculum is intended for students who wish to combine with their professional training more general education than is offered by the five-year professional curriculum in architecture. It leads normally to the bachelor of arts degree with a

major in architecture at the end of four years and the bachelor of architecture degree at the end of six years.

The work of the first four years constitutes a modified version of the curriculum prescribed for the College of Science, Literature, and the Arts major in architecture. The following procedures and program of studies should be adhered to in order to complete the work required for the two degrees in the proper sequence and in the normal time:

FIRST AND SECOND YEARS

The first two years of work may be taken at the University of Minnesota in the Junior College of the College of Science, Literature, and the Arts, or at other accredited institutions. During this period the student should complete the requirements for entrance to the Senior College of the College of Science, Literature, and the Arts as stated in its bulletin. These requirements should include the following:

High school or college equivalents of Math. 1, Higher Algebra and Solid Geometry. Inorg. Chem. 1-2 or 6-7 if the student does not have high school credit for chemistry.

COURSE NO. TITLE	CREDITS
Math. 6-7, 30—Trigonometry, Algebra, and Analytic Geometry	15
Phys. 1a-2a-3a—Introduction to Physical Science	12
Art 23A, 24A, 25A—Drawing and Painting I	6

Approved electives to make a minimum total of 90 credits.

THIRD AND FOURTH YEARS

During these years the student is registered in the Senior College of the College of Science, Literature, and the Arts as a candidate for the bachelor of arts degree with a major in architecture. To register as such, the student must secure the approval of the School of Architecture. The required application forms may be obtained either from the School of Architecture or from the Office of Admissions and Records. They must be submitted not later than July 15 preceding the beginning of the academic year for which admission is sought.

The following courses should be included:

	CREDITS
Arch. AD-I, AD-II—Architectural Design I, II	36
Arch. 51-52-53—History of Architecture	12
Art 60A-61A-62A—Drawing and Painting II	6
I.T.M. 91, M.&M. 92-93—Calculus, Mechanics for Architects, Mechanics of Materials	12
C.E. 38-39-41—Structural Design 9 credits or Arch. 57-58-59—Building Materials and Methods 12 credits	9 or 12

Approved electives and minor sequences to make a minimum total of 180 credits acceptable for the bachelor of arts degree.

FIFTH AND SIXTH YEARS

During these years the student is registered in the Institute of Technology as a candidate for the bachelor of architecture degree. To register as such, the student must secure the approval of the School of Architecture and transfer to the Institute of Technology. Application must be made in the same manner as prescribed above for admission to the third and fourth years' work.

The following courses should be included:

	CREDITS
C.E. 38-39-41—Structural Design 9 credits or Arch. 57-58-59—Building Materials and Methods 12 credits	9 or 12
Arch. AD-III—Architectural Design, Grade III	24
Arch. AD-IV—Architectural Design, Grade IV	18
Arch. AD-V—Thesis	12
Arch. 71-72-73—Building Equipment	9
Arch. 104—City Planning	3
Arch. 105—Professional Relations	3

Approved electives to make a minimum total of 270 credits for the two degrees.

Chemical Engineering

A five-year curriculum is offered which leads to the degree of bachelor of chemical engineering, B.Ch.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of 260 credits.

Chemical engineering deals with the unit operations, such as crushing, grinding, sifting, mixing, fluid flow and heat flow, filtration, evaporation, drying, distillation, extraction, absorption, crystallization, and the organic processes that are so vital in making any industry based on a chemical transformation of matter a commercial success. The chemist uses these operations in the laboratory, but in order that the engineer can apply them to large-scale industrial processes he must have a thorough understanding of the fundamental physicochemical, chemical, and engineering principles on which they are based. The study of such principles constitutes that branch of engineering known as chemical engineering. For this purpose the chemical engineer must be thoroughly trained in the various branches of chemistry, physics, and mathematics and have a good training in the fundamentals of mechanical, electrical, and chemical engineering so that he can design, construct, and successfully operate a plant using these unit operations.

The chemical engineer is primarily a producer. It is his province to develop a process from the laboratory stage through semiworks equipment to the production stage which uses engineering materials for the manufacture of unit process equipment in accordance with fundamental chemical engineering principles.

As many industries are based on some chemical process, the chemical engineer is much in demand. He may be engaged in the manufacture of inorganic products—the mineral acids, alkalies, ammonia, paint pigments, fertilizers; in the organic industries—dyes, explosives, textiles, fibers, rubber, soap, lacquers, solvents, plastics, medicinals; in the manufacture of gases—coal gas, carbureted blue gas, hydrogen, acetylene, helium; in the electrochemical industries such as the manufacture of graphite, calcium carbide, carborundum and other abrasives, wet and dry batteries, electroplating; in the metallurgical industries; and even in the food industries such as the manufacture of sugar, flour, salt, starch, and refrigeration, dehydration, and canning. There are many others such as leather, paper, petroleum, glass, and cement.

In these industries the chemical engineer does investigational work, development work, design of equipment, and plant operation. Some enter the field of sales engineering and technical writing.

FIRST YEAR

See Curriculum for the School of Chemistry on page 20.

SECOND YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
I.T.M. 24, 25, 80—Calculus I: Differential; Calculus II: Integral; Elementary Differential Equations	5	5	3
M.&M. 84—Engineering Mechanics	....	....	5
Phys. 7, 8, 9—General Physics	5	5	5
Anal.Chem. 2, 1—Quantitative Analysis	5	5	....
Non-Technical Requirements*—Group I or II	3	3	4
Total credits	18	18	17

THIRD YEAR

Chem.E. 100—Chemical Engineering Stoichiometry	3	....	....
Chem.E. 101, 102, 103—Unit Operations	3	5	5
Org.Chem. 61, 62, 63—Elementary Organic Chemistry	4	4	3
Org.Chem. 64—Elementary Organic Chemistry Laboratory	....	....	3
Met. 160—Metallography	....	3	....
Phys.Chem. 101, 102, 103—Physical Chemistry	3	3	3
Non-Technical Requirements*—Group II or I	4	4	4
Total credits	17	19	18

FOURTH YEAR†

Chem.E. 111, 112, 113—Unit Operations Laboratory	2	2	2
Chem.E. 119, 120—Chemical Engineering Thermodynamics	3	3	....
Chem.E. 131, 132—Industrial Technology	3	3	....
Chem.E. 187§—Chemical Engineering Inspection Trip (spring vacation)	....	2	....
Phys.Chem. 104, 105, 106—Physical Chemistry Laboratory	2	2	2
M.&M. 85—Mechanics of Materials	....	....	3
M.&M. 87—Materials Testing Laboratory	....	....	1
Non-Technical Requirements*—Group IV	5	5	5
	or	or	or
	3	3	3
Electives	3	3	3
	or	or	or
	5	5	5
Total credits	18	20	16

Summer Session

Chem.E. 151, 152—Chemical Manufacture (Inorganic); Chemical Manufacture (Organic) (alternate years; offered 1954) ..... 6 credits

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* See *Non-Technical Required Courses*, page 68.

† Fourth-year students with an honor point average greater than 1.8 who are planning to pursue graduate study should consult their advisers at the beginning of their fourth year on their course of study for the degree of bachelor of science undesignated. These students may find it desirable to take German or other approved foreign languages as one of their electives. Further details are found in the section *Requirements for Graduation*.

At the end of the fourth year, students with an honor point average considerably greater than 1.00 should consult their advisers regarding the possibility of arranging a special course of study to follow in the fifth year.

§ Students register in the winter quarter for the inspection trip taken between the winter and spring quarters. The balance of the course work is completed during spring quarter.

FIFTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Chem.E. 80—Chemical Engineering Materials	2	.....	.....
Chem.E. 117, 118—Chemical Engineering Process and Plant Design	.....	3	3
Chem.E. 121—Chemical Engineering Economics (or I.E. 173—Engineering Economic Analysis)	3	.....	.....
Chem.E. 181, 182, 183§—Senior Thesis	3	3	3
	or	or	or
	0	0	0
E.E. 36, 37, 38—Electrical Engineering Survey	3	3	3
Engl. 85, 86—Advanced Technical Communication	.....	3	3
Electives§	4	3	3
	or	or	or
	7	6	6
Total credits	15	15	15

List of Advisers for Seniors

Chemical Engineering: Professors Amundson, Ceaglske, Piret, Stoppel, Earle, Isbin, Madden, Preckshot.

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§ Generally students with grade point averages above 1.5 will enroll in the sequence Chem.E. 181, 182, 183—Senior Thesis. This restriction may be relaxed depending on the size of the senior class. Others will select 9 credit hours of technical or scientific electives. The following courses are suggested:

COURSE NO. TITLE	CREDIT HOURS
M.E. 40, 41—Heat Engines	3 each
M.E. 160, 180—Heating, Ventilation, and Air Conditioning; Refrigeration	3 each
M.E. 199; Chem.E. 171, 172— Servomechanisms; Instrumentation and Control	3 each
Hydr. 104—Hydraulics Laboratory	1
Ag.Biochem. 119, 129—Colloids; Colloids Laboratory	3 and 2
Bact. 53—General Bacteriology	5
Chem.E. 153, 154, 155—Special Problems	3 or more
I.E. 150, 171, 181—Elements of Industrial Engineering and Management; Quality Control; Industrial Relations	3 each
Met. 161, 162—Advanced Metallography	2 or 3 credits each
Pet.E. 111, 112, 131—Oil Field Development; Oil Field Production; Petroleum Refining	3, 3, 2
Phys. 50—General Physics	5
Org.Chem. 101, 102—Intermediate Organic Chemistry; Characterization of Organic Compounds	3 each
Inorg.Chem. 103, 104, 105—Advanced Inorganic Chemistry	3 each
G.E. 103—Professional Problems	1

Chemistry

A five-year curriculum is offered which leads to the degree of bachelor of chemistry, B.Chem.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 255 credits.

This professional course in chemistry is designed to provide thorough training in the fundamentals of chemistry and related subjects. It serves as a basis for further specialization and a foundation for graduate work. Its graduates secure positions in practical chemistry, research, teaching, in chemical industries, the government service, in colleges and laboratories, etc.

Students with an honor point ratio of 1.50 may petition for admission to the combined curriculum of engineering and business administration. In this curriculum business courses may be substituted for non-technical required courses, group I, group II, group III (page 68), English 85-86, and Electrical Engineering 38.

FIRST YEAR

See curriculum for the first year on page 20.

SECOND YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Inorg.Chem. 13—Semimicro Qualitative Analysis	5	.....	.....
Anal.Chem. 1, 2—Quantitative Analysis	.....	5	5
I.T.M. 24, 25—Calculus: Differential and Integral	5	5	.....
M.&M. 84—Engineering Mechanics	.....	.....	5
Phys. 7, 8, 9—General Physics	5	5	5
Non-Technical Requirements*—Group I or II	3	3	4
Total credits	18	18	19

THIRD YEAR

Org.Chem. 61, 62, 63—Elementary Organic Chemistry	4	4	3
Org.Chem. 64—Elementary Organic Chemistry Laboratory	.....	.....	3
Phys.Chem. 101, 102, 103—Physical Chemistry	3	3	3
Phys.Chem. 104, 105, 106—Physical Chemistry Laboratory	2	2	2
Ger. 24, 25, 26—Chemical German or Ger. 27, 28, 29†—Chemical Prose	3	3	3
Non-Technical Requirements*—Group II or I	4	4	4
Total credits	16	16	18

* See *Non-Technical Required Courses*, page 68.

† Ger. 27-28-29 is for those who have had two years of German in high school or one year of German in college. Others should take Ger. 24-25-26.

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Anal.Chem. 131—Applications of Indicators	3	.....	.....
Anal.Chem. 132§—Electrometric Measurements and Titration	.....	3	.....
Org.Chem. 101—Intermediate Organic Chemistry	.....	3	.....
Org.Chem. 102—Characterization of Organic Compounds	4	.....	.....
Inorg.Chem. 104, 105—Advanced Inorganic Chemistry	.....	3	3
Non-Technical Requirements*—Group III	5	5	5
	or	or	or
	3	3	3
Electives	5	3	9
	or	or	or
	7	5	11
Total credits	17	17	17

FIFTH YEAR

Anal.Chem. 104¶—Qualitative Inorganic Microanalysis	3	.....	.....
Anal.Chem. 107¶—General Technical Analysis	.....	2	.....
Anal.Chem. 140¶—Water Analysis	.....	2	.....
Anal.Chem. 127¶—Optical Methods in Analytical Chemistry	2	.....	.....
Phys.Chem. 116, 117**—Advanced Physical Chemistry	3	3	.....
E.E. 38††—Electrical Engineering Survey	.....	.....	3
G.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	3	3	.....
Ger. 41, 42, 43§§—Readings from German Chemical Periodicals	2	2	2
Seminar¶¶	1	1	1
Electives	3	3	11
Total credits	17	17	17

NOTE. Near the close of the fourth year, each student will choose a major adviser from the list below. In consultation with the adviser, he will plan a program of work for the entire senior year, based normally upon concentration of electives around a chosen field of chemistry.

Students who are planning to take graduate work are urged to take French or other approved foreign languages as one of the electives in the fourth or fifth year.

List of Advisers for Seniors

Inorganic Chemistry: Professors Heisig, Pervier, Maynard.
Analytical Chemistry: Professors Kolthoff, Sandell, Meehan.
Organic Chemistry: Professors Smith, Lauer, Koelsch, Arnold, Parham.
Physical Chemistry: Professors Lipscomb, Livingston, Crawford.

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* See *Non-Technical Required Courses*, page 68.

§ Anal.Chem. 105 may be substituted for Anal.Chem. 132.

¶ Senior Thesis, 10 credits, is required of all students whose honor point average is greater than 1.50 and is open only to those meeting this requirement. Anal.Chem. 104, 107, 127, and 140 (9 credits) are required of all whose honor point average is less than 1.50. These courses are not required of those whose honor point average exceeds 1.50.

** Other courses (6 credits) in advanced physical chemistry may be substituted with the approval of the Division of Physical Chemistry or the major adviser.

†† Recommended course; may be replaced by electives, with the approval of adviser.

§§ Ger. 41-42-43 is not required of those who have had Ger. 27-28-29.

¶¶ Students in the five-year curriculum are required to attend a divisional seminar during each quarter of the fifth year (not necessarily the same divisional seminar for all three quarters). These seminars are Inorg.Chem. 52-53-54, Anal.Chem. 135-136-137, Org.Chem. 151-152-153, Phys.Chem. 150-151-152, and Chem. E. 191-192-193.

Specialization in Bacteriology, Biochemistry, and Geology

For the benefit of students in chemistry who may desire to specialize in related fields, minor groups of electives have been arranged in bacteriology, biochemistry, and geology which may be taken in the last two years in addition to the required courses of the regular chemistry curriculum. The completion of one of these groups will qualify the chemistry graduate to enter graduate work toward the Ph.D. degree in that department, thus providing an exceptionally strong foundation in chemistry for specialization in the chosen field.

Minor in Bacteriology

FOURTH YEAR

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Zool. 14, 15†	General Zoology	3	3	
Bact. 53	General Bacteriology			5

FIFTH YEAR

Bact. 121,122	Physiology of Bacteria	3	3	
Bact. 123	Bacterial Metabolism			3

Minor in Biochemistry

FOURTH YEAR

Zool. 14, 15†	General Zoology	3	3	
Bact. 53	General Bacteriology			5

FIFTH YEAR

Ag.Biochem. 119	Colloids	3		
Ag.Biochem. 129	Colloids Laboratory		2	

Three credits in Ag.Biochem. 120 or 121 should be taken in the winter quarter. Five or six credits in Ag.Biochem. 122, 123, 132, or 133 should be taken in the spring quarter.

NOTE. Humanities 21, 22, and 23 should be taken in the fourth year. Inorg. Chem. 104 should be taken in the winter of the fifth year.

Minor in Geology

FOURTH YEAR

Geol. 1, 2	General Geology	3	3	
Geol. 23, 24	Mineralogy	4	4	

FIFTH YEAR

Geol. A, B	General Geology Laboratory		2	2
Geol. 121	Crystallography	3		

† Nine credits in botany may be substituted for Zool. 14-15.

Civil Engineering

Two five-year curricula are offered: Civil Engineering and Sanitary Engineering Option.

In addition to the prescribed courses, sufficient electives must be taken to total at least 250 credits for graduation.

The curriculum in civil engineering is designed to prepare the student for professional attainment in three principal ways. First, a thorough background in the basic sciences to enable him to develop progressively; second, a diversity of applied course work to aid in selecting his major field of endeavor, for balance in his professional training and in order to enable him to present economic value to his early employers; and finally, a broad understanding of the social regime under which he must live and of its relationship to his professional work.

The main divisions of the Civil Engineering Department include highway engineering and soil mechanics, hydraulic engineering, sanitary engineering, structural engineering, and surveying. Within these general fields course work deals with material involving recognition and formulation of the problem. Techniques and procedures of analysis and design are presented along with the economics of construction, operation, and maintenance. Aspects of research and recent developments are illustrated. By electing appropriate courses the student may specialize in any of these areas.

Students who entered in the fall of 1952 are required to take the five-year program having a common two years as published in this bulletin. Students entering before that time will follow the old five-year curriculum as published in the 1951-53 bulletin.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined curriculum of engineering and business administration.

The combined curricula in civil engineering and law are also available to qualified students.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in civil engineering elect the following courses in the second year:

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
C.E. 1, 2, 3	Civil Engineering Laboratory	1	1	1
Org.Chem. 16	Carbon Compounds	.....	.....	4

THIRD YEAR

M.&M. 127—Engineering Dynamics			5
M.&M. 128—Mechanics of Materials	5		
M.&M. 141—Materials Laboratory	1		
Hydr. 103—Fluid Mechanics		5	
Hydr. 104—Hydraulics Laboratory		1	
C.E. 18, 19, 20—Surveying	3	3	3
C.E. 31—Stresses in Structures	3		
C.E. 32—Design in Steel		3	
C.E. 33—Design in Timber			3
C.E. 34—Drafting Room Practice			3
Geol. 5, 6—Engineering Geology	3	3	
Non-Technical Requirements*—Group II or I	3	3	3
Total credits	18	18	17

Summer Camp

C.E. 23—Surveying Camp ..... 9 credits

FOURTH YEAR

C.E. 130, 131, 132—Statically Indeterminate Structures; Structural Analysis; Structural Design	3	2	2
C.E. 51, 52—Highways and Pavements	3	3	
C.E. 53—Elements of Soil Mechanics			3
C.E. 24—Railway Engineering			3
C.E. 160—Applied Hydraulics	3		
C.E. 161—Hydrology		3	
C.E. 170, 171—Water Supply; Sewerage and Sewage Treatment		3	3
C.E. 146—Concrete and Concrete Materials			3
M.E. 42—Heat Engines	4		
E.E. 42—Electrical Engineering Survey		3	
Non-Technical Requirements*—Group III	3	3	3
Total credits	16	17	17

FIFTH YEAR

C.E. 141, 142—Reinforced Concrete; Reinforced Concrete Design	3	3	
C.E. 147—Foundations			3
Engl. 85, 86—Advanced Technical Communication	3	3	
C.E. 101—Contracts and Specifications	3		
C.E. 103—Professional Problems		1	
Non-Technical Requirements*			3
Technical Electives§	6	6	4
Total credits	15	13	10

Sanitary Engineering Option

The option in sanitary engineering should be selected by the beginning of the fifth year in the civil engineering curriculum. If the selection of this option is made before or during the fourth year, the courses identified with a dagger in the list of fifth-year courses in sanitary engineering may be substituted, upon approval, for any of the following: C.E. 24, 34, 52, 146. This will enable students under the sanitary engineering option to graduate with 250 credits instead of the 256 credits that would be required for those electing the option in the fifth year. This selection would also

* See *Non-Technical Required Courses*, page 68.

§ Taken in Institute of Technology, or others by departmental approval.

permit a wider choice of elective courses in the fifth year or of early entrance to the Graduate School.

FIFTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
C.E. 141—Reinforced Concrete	3	.....	.....
C.E. 172†—Sanitary Laboratory	3	.....	.....
C.E. 173, 174, 175—Sanitary Engineering Problems (Water) (Sewage and Industrial Wastes); Industrial Waste Disposal	3	3	3
C.E. 176, 177, 178—Sanitary Engineering Seminar	1	1	1
G.E. 101—Contracts and Specifications	.....	3	.....
G.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	.....	3	3
P.H. 100†—Elements of Preventive Medicine and Public Health	5	.....	.....
P.H. 102†—Environmental Sanitation	3	.....	.....
Bact. 53†—General Bacteriology	.....	5	.....
Total credits	18	16	7

† See statement under Sanitary Engineering Option.

Combined Curricula of Civil Engineering and Law

These curricula enable the student to obtain two degrees, one in the Institute of Technology and one in the Law School, in a period of approximately seven years. To be eligible for admission to the Law School, the students must complete the modified four-year civil engineering program outlined below and qualify for the bachelor of science degree undesignated. Then the regular law program covering ten quarters of work will be taken leading to the degree of bachelor of laws.

FIRST YEAR

Same as the first year in the College of Engineering.

SECOND YEAR

Same as the second year in civil engineering except Psy. 1, 2, 3 should be taken for the non-technical requirement.

THIRD YEAR

C.E. 18, 19, 20, 31, 32, 33, 51, 53, 160; M.&M. 127, 128, 141; Hydr. 103, 104; Econ. 8, 9; Pol.Sci. A, B.

FOURTH YEAR

C.E. 130, 141, 146, 147, 161, 170, 171; G.E. 103; E.E. 42; Engl. 85, 86; Hist. 70, 71, 72; Phil. 2A, 3A; Geol. 5.

Electrical Engineering

A five-year curriculum is offered which leads to the degree of bachelor of electrical engineering, B.E.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation.

There are several optional courses offered in the fifth year in the specialized fields of communications, electronics, and power.

Students who maintain an honor point ratio of 1.80 or better throughout the first four years of the course may upon petitioning and upon receiving the recommendation of the Electrical Engineering Department continue in the fifth year in the Graduate School with major work in electrical engineering leading to the M.S. degree. To gain entrance to the Graduate School a bachelor of science degree (without departmental designation) will be granted at the end of the fourth year.

Students with a leaning toward the business and management aspects of electrical engineering and who desire such work may petition for admission to the combined five-year course with business administration. This combined course and the conditions of eligibility are described under the engineering and business administration curricula.

A curriculum combined with law is offered enabling the student to obtain two degrees, a bachelor of science degree, and a bachelor of laws degree. This program will normally take seven years. Detailed information may be obtained from the departmental office.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in electrical engineering elect the following courses in the second year:

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
E.E. 12, 14, 16—Elements of Electrical Engineering Laboratory	1	1	1
Phys. 51—Intermediate General Physics	.....	.....	4

THIRD YEAR

E.E. 109—Electric and Magnetic Fields	3	.....	.....
E.E. 111, 113, 115—Electrical Engineering	5	3	3
E.E. 112, 114, 116—Electrical Engineering Laboratory	2	1	1
E.E. 117, 119—Engineering Electronics	.....	3	3
E.E. 118, 120—Engineering Electronics Laboratory	.....	1	1
M.&M. 85—Mechanics of Materials	.....	.....	3
M.&M. 87—Materials Testing Laboratory	.....	.....	1
M.&M. 127—Engineering Dynamics	.....	5	.....
Hydr. 101—Fluid Mechanics	3	.....	.....
Non-Technical Requirements* Group II or I	3	3	3
Total credits	16	16	15

* See *Non-Technical Required Courses*, page 68.

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
E.E. 121, 123, 125—Electrical Engineering	3	3	3
E.E. 122, 124, 126—Electrical Engineering Laboratory	2	2	2
E.E. 161, 162, 163—Electric Communication	4	4	4
M.E. 21, 40, 41—Kinematics and Mechanisms; Heat Engines	3	3	3
Non-Technical Requirements*—Group III	3	3	3
Electives	3	3	3
Total credits	18	18	18

FIFTH YEAR

Electrical Engineering Option (see below)	6	6	6
E.E. 127, 128, 129—Transient Electrical Phenomena	3	3	3
E.E. 100†—Inspection Trip	2	.....	.....
G.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	.....	3	3
Technical electives§	5	3	3
Total credits	16	16	15

Electrical Engineering Options

One option unit must be completed. An additional half option may be taken as an elective, however.

Communication Option			
E.E. 164, 165, 166—Communication Circuits	3	3	3
E.E. 167, 168, 169—Radio Communication	3	3	3
Electronics Option			
E.E. 131, 133, 135—Electronic Circuit Design	3	3	3
E.E. 157, 158, 159—Industrial Electronics	3	3	3
Power Option			
E.E. 132, 134, 136—Type Study of Electric Machines	3	3	3
E.E. 138, 139, 140—Power Systems	3	3	3

Curricula Combined with Law

These curricula enable the student to obtain two degrees, one in the Institute of Technology and one in the Law School in a period of approximately seven years. To be eligible for admission to the Law School, the student must complete the modified four-year electrical engineering program outlined below and qualify for the bachelor of science degree. Then the regular law program covering ten quarters of work will be followed. This leads to the degree of bachelor of laws.

The regular curriculum in electrical engineering will be followed for the first two years except that Psy. 1, 2, 3 must be elected from Group I in the non-technical elective area. The special curriculum for the remaining two years of study in the Institute of Technology is regular with the exceptions shown below.

THIRD YEAR

Omit Non-Technical Requirements—Group II or I and add Econ. 8 and 9; Pol.Sci. A and B.

FOURTH YEAR

Omit M.E. 40, 41, Non-Technical Requirements—Group III and add Hist. 70, 71, 72; Phil. 2A, 3A; Engl. 85, 86.

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* See *Non-Technical Required Courses*, page 68.

† Summer work of an engineering character taken in the third and fourth years, not less than 750 hours, will be accepted on petition as a substitute. An approved written report thereon will carry 2 credits. Consult your adviser.

§ In Institute of Technology, including physics and geology.

Engineering and Business Administration

As a result of the vast industrial expansion which has taken place in the United States, a need has arisen for engineers with more training in economics and business administration than is normally possible in the regular engineering curricula. To meet this need two special curricula have been developed, the combined curricula in engineering and business administration, and the four-year program in engineering and business administration (industrial administration).

Combined Curricula in Engineering and Business Administration

The combined curricula in engineering or chemistry and business administration enable the student to complete the requirements for two degrees, one in the Institute of Technology and one in the School of Business Administration in a period of approximately five years. In the Institute of Technology each department will allow business courses to be substituted for natural science, social science, humanities, English 85, 86 and electives to satisfy the requirements for the Bachelor's degree unless indicated to the contrary in the curriculum. The School of Business Administration accepts 74 credits of business subjects listed on the following page as satisfying the requirements for the degree of bachelor of business administration. Required courses have been waived in both colleges with the understanding that the courses in the two colleges will be carried simultaneously and supplement each other. The work is to be completed as a unit and both degrees obtained at the same commencement period.

Application for admission to this program may be made by filing a petition with the Committee on Student Scholastic Standing for the combined engineering and business curricula, located in 133 Main Engineering Building. An honor point average of 1.50 in each field, i.e., engineering and business, based on at least two quarters of work in the Institute of Technology, is required for entrance into and for continuation in this program. Freshmen should submit applications at the beginning of their third quarter in school while advanced standing students should apply after completing two quarters in the Institute of Technology. It is not desirable to delay in submitting an application because the total enrolment in this program is restricted to 160 students.

After being officially admitted, the student will be registered in both the Institute of Technology and the School of Business Administration for the entire program. Registration each quarter is subject to the approval of the advisers in both the School of Business Administration and the Institute of Technology. The business courses are intended to be spread over the last four years as indicated below. Not more than 28 credits of business subjects should be left to the fifth year.

The following order and distribution of business courses by years are suggested. When necessary, approval to vary this schedule should be obtained from the adviser in the School of Business Administration.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

It is recommended that students in the combined curricula in engineering and business administration elect the following courses in the second year:

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Laboratory course offered by the department in which the student desires to major	1	1	1
Org.Chem. 16—Carbon Compounds, or Phys. 51—Intermediate General Physics, as recommended by the department in which the student desires to major	.....	.....	4
Econ. 8-9—General Economics; Econ. 28—Business Law (in lieu of the non-technical requirements)	3	3	3
THIRD YEAR			
B.A. 54-55—Elementary Accounting, Combined Course	4	4	.....
B.A. 77†—Survey in Marketing	.....	.....	3
FOURTH YEAR			
B.A. 58—Elements of Public Finance	.....	3	.....
B.A. 70**—Statistics Survey	3	.....	.....
B.A. 71—Transportation: Services and Charges I	.....	.....	3
B.A. 89§—Production Management	.....	.....	3
B.A. 74—Business Statistics	.....	3	.....
B.A. 66—Managerial Costs	.....	.....	3
Econ. 64—The Economics of Money and Banking	3	.....	.....
B.A. 167—Introduction to Industrial Relations	.....	3	.....
Econ. 73—Manpower Economics and Labor Problems	3	.....	.....
FIFTH YEAR			
Econ. 75—Corporation Finance	3	.....	.....
Econ. 80-81—Intermediate Economic Analysis	3	3	.....
B.A. 180-181-182G¶—Senior Topics: Production Management	3	3	3
Econ. 85—Government Regulation of Business	.....	.....	3
Two of the following:			
B.A. 133—Standard Costs	.....	.....	3
B.A. 170**—Methods Analysis and Work Measurement	.....	3	.....
B.A. 171**—Motion Study Applications	.....	.....	3
B.A. 173—Market Analysis and Research	.....	3	.....
Psy. 130—Vocational and Occupational Psychology	.....	3	.....
Econ. 149—Business Cycles	3	.....	.....
Total credits		74	

Master of Business Administration

Any engineering graduate who has taken the courses in Group A (next page) as an undergraduate, or who will satisfy the requirements in these undergraduate courses after graduation, may be accepted as a candidate for the degree of master of

† Econ. 185 may be substituted for B.A. 77.

§ Industrial and mechanical engineering students substitute I.E. 150 for B.A. 89 and replace the latter with an approved business course, preferably B.A. 173. Credits will not be given for both I.E. 150 and B.A. 89.

¶ Industrial engineering–business administration five-year students take B.A. 184 in place of B.A. 180G.

** Industrial engineering students substitute I.T.M. 90 for B.A. 70, I.E. 153 for B.A. 170, and I.E. 154 for B.A. 171, and add 9 credits of approved business or economics courses. Other engineering students may make similar substitutions if they wish.

business administration upon the completion of 45 credits in the courses included under Group B, or with approved substitutions.

The requirements of the Graduate School must be met in the Group B courses. He must maintain a B average in these courses and must take an oral examination in the Core Group and in his field of specialization.

GROUP A

Econ. 8-9, 28, 85; B.A. 58 or Econ. 189, B.A. 54-55, 70, 71, 77, B.A. 89 or 187.

GROUP B

Econ. 103-104, 142, 149, 155, 161; B.A. 112, 133, 152, 167, 180-181-182G, 184; Psy. 130; B.A. 170 or I.E. 153.

Four-Year Curriculum in Engineering and Business Administration (Industrial Administration)

This curriculum has been arranged for students who wish to prepare for positions in industry which require some basic technical training plus instruction in business administration. Such positions are found in fields of purchasing, sales and sales promotion, cost accounting, employment and rate setting, and production control.

The work in the first two years of this curriculum is taken while registered in the Institute of Technology. The work in the last two years is taken while registered in the School of Business Administration.

Transfer is made to the School of Business Administration at the beginning of the junior year. A minimum of 97 credits including an honor point ratio of 1.00 is required for admission.

Elective credit earned in the Institute of Technology or any other accredited school during the first two years may be applied toward the elective requirement in the junior and senior years of this curriculum.

Completion of all the required work and a total of 187 credits leads to the degree of bachelor of business administration which is given by the School of Business Administration.

FIRST YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Draw. 4§, 6—Engineering Drawing	3	.....	3
Engl. 4, 5, 6—Written and Spoken Communication	3	3	3
G.E. 21—Orientation	1	.....	.....
I.T.M. 11†, 12, 13—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Analytic Geometry	5	5	5
M.E. 12—Casting Processes	.....	2	.....
Phys. 11, 12, 13—General Physics	5	5	5
Total credits	17	15	16

SECOND YEAR

B.A. 54, 55—Elementary Accounting: Combined Course	.....	4	4
Econ. 3—Elements of Money and Banking	.....	5	.....
Econ. 5—Elements of Statistics	.....	.....	5
Econ. 8, 9—General Economics	3	3	.....
I.T.M. 91—Calculus	4	.....	.....
Inorg.Chem. 14, 15—General Inorganic Chemistry	4	4	.....
M.&M. 84—Engineering Mechanics	.....	.....	5
M.E. 13, 14—Metal Processing; Metal Cutting	2	.....	2
Phys. 14—Intermediate General Physics	4	.....	.....
Total credits	17	16	16

† I.T.M. 9, Higher Algebra, zero credits, to be taken instead of I.T.M. 11 if higher algebra is not presented as an entrance unit.

§ Draw. 10, Solid Geometry, zero credits, to be taken instead of Draw. 4 if solid geometry is not presented as an entrance unit.

THIRD AND FOURTH YEARS

The work of the junior and senior years is offered in the School of Business Administration, where stress is laid upon the adaptation of the student's curriculum to his future plans. In order to make this aim effective, every student is assigned to an adviser who makes a study of his needs and helps him frame a program.

The programs of study summarized below will therefore be varied as each particular case dictates. In some cases the student will be advised to elect subjects in other schools and colleges of the University in order to obtain a well-rounded preparation for his prospective career.

Core Group Requirements

The following courses constitute a core of material which must be covered by all students. In addition to these courses, there are certain required subjects in the various sequences. Unless an exception is specifically noted in connection with a sequence, all courses listed in this group will be required.

Exceptions may be made in individual cases upon petition approved by the adviser and the chairman of the Committee on Student Scholastic Standing.

	Credits
1. Business Law (B.A. 51 and either 52 or 53)	6
2. Accounting and Statistics	
One advanced course in accounting	3
Business Statistics (B.A. 74)	3
3. Economic Theory and Methods	
Intermediate Economic Analysis: Income and Employment (Econ. 80)	3
Intermediate Economic Analysis: Firms and Households (Econ. 81)	3
4. Basic Functional and Background Courses	
Manpower Economics and Labor Problems (Econ. 73)	3
Economics of Money and Banking (Econ. 64)	3
Corporation Finance (Econ. 75)	3
Transportation: Services and Charges I (B.A. 71)	3
Survey in Marketing (B.A. 77)	3
Production Management (B.A. 89)	3
Elements of Public Finance (B.A. 58)	3
Government Regulation of Business (Econ. 85)	3
	42

Geological Engineering

A five-year curriculum is offered which leads to the degree of bachelor of geological engineering, B.Geol.E. There are two options: Mining and Petroleum.

A total of 241 credits, exclusive of summer field trips, is required for graduation.

The curriculum in geological engineering is designed to prepare students for responsible positions in geological departments of exploration, oil, or mining companies, or to engage in consulting geological practice.

Many ore deposits are of no particular value economically at the present time, either because the cost of mining is excessive or because there is no known method of separating the minerals in the ore at a profit. In addition to thorough courses in geology, the mining geologist must be familiar with the various methods of mining and know something of the possibilities of ore dressing to recover the valuable minerals. A knowledge of the fundamental principles of the smelting and refining of metals is a decided asset in his work.

The search for and evaluation of oil fields at ever-increasing depths demand a thorough knowledge of the formation and geologic environment of petroleum deposits. Furthermore, a thorough understanding of reservoir characteristics is essential to the estimation of productive potentials and reserves. Hence, a fundamental training in field exploration and production practices is necessary to complement the courses in geology.

The Department of Geology is well supplied with working collections of minerals, crystal models, rocks, thin sections, ores and economic minerals, fossils, and other illustrative material used in connection with the courses in paleontology, stratigraphy, and historical geology. Large, well-lighted, and fully equipped laboratories are available for the basic courses of mineralogy, rock study, and petrology. Special equipment is available for studies in sedimentation, rock analysis, and x-ray studies of minerals.

Geophysics courses are recommended to supplement this curriculum. Geophysics aids in geological interpretations, provides knowledge of the earth's crust, and is used in the discovery of mineral deposits and petroleum. Geophysics courses may be substituted for electives to be chosen from courses offered by the College of Science, Literature, and the Arts or, with approval, for prescribed credits.

Students taking the combined curriculum with business administration may substitute business courses for non-technical required courses, group I, group II, group III (page 68), and electives.

FIRST AND SECOND YEARS

See curricula for first two years of the School of Mines and Metallurgy on page 20.

THIRD YEAR

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Min. 11, 12, 13	Surveying	3	3	2
Min. 14	Surveying Field Work	.....	.....	5
Geol. 1, 2	General Geology (Physical and Historical)	3	3	.....
Geol. 23, 24	Mineralogy	4	4	.....
Geol. 25	Rock Study	.....	.....	2
Anal.Chem. 9	Quantitative Analysis	.....	3	.....
Hydr. 102	Fluid Mechanics	.....	.....	4
Hydr. 104	Hydraulics Laboratory	.....	.....	1
I.T.M. 90	Elementary Engineering Statistics	.....	3	.....
Non-Technical Requirements*	(toward 31-credit total)	6	.....	2
Total credits		16	16	16

Mining Option in Geological Engineering

Third Year Summer Field Trips

Min. 15—Mine Surveying Field Work ..... 6 credits
Geol. 100—Field Work in Northern Minnesota ..... 3 credits

FOURTH YEAR

Geol. 106—Petrography	3	.....	.....
Geol. 110, 111—Economic Geology	.....	3	3
Geol. 125—Structural Geology	3	.....	.....
Geol. 131, 132—Petrology	.....	4	4
Geol. 144—Geologic Maps	.....	3	.....
Geophys. 110—Introduction to Exploration Geophysics	.....	.....	3
Min. 111, 112, 113—Elements of Mining	3	3	3
Met. 110, 111—Mineral Dressing	4	4	.....
M.&M. 85—Mechanics of Materials	.....	.....	3
Non-Technical Requirements*—Group III	3	3	.....
Total credits	16	20	16

Summer Field Trip

Geol. 150—Field Geology. Detailed systematic work conforming with standards of official surveys. Preparation of geologic maps, structure sections, reports; paragenesis of ores and their relations to geologic structure. Field: Black Hills, South Dakota ..... 6 credits

FIFTH YEAR

Geol. 101—Sedimentation	3	.....	.....
Geol. 107—Invertebrate Paleontology	3	.....	.....
Geol. 112—Petroleum Geology	.....	.....	3
Geol. 140—Applied Petrography	.....	3	.....
Geol. 151, 152—Stratigraphy	.....	3	3
Geol. 166—Mineralography	.....	3	.....
Geophys. 108—Introduction to General Geophysics	3	.....	.....
Min. 106—Mine Mapping	.....	2	.....
Min. 141—Mineral Economics	3	.....	.....
Min. 142—Surface Mining	.....	3	.....
M.E. 131—Thermodynamics	.....	.....	3
Engl. 85, 86—Advanced Technical Communication	3	3	.....
G.E. 103—Professional Problems	.....	1	.....
Total credits	15	18	9

* See *Non-Technical Required Courses*, page 68.

Credits beyond the curricula requirements may be taken with special permission. Recommended courses are the following:

I.T.: G.E. 101; I.E. 150; M.E. 14, 24, 50, 128, 132, 198; Met. 11, 106, 107, 112, 156; Min. 121, 122, 126, 127, 143, 160; Pet. 111, 112, 135.

S.L.A.: Econ 8, 9; B.A. 54, 55; Geol. 118, 121, 145, 153, 161; Phys. 50.

Petroleum Option in Geological Engineering

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
	Third Year Summer Field Trip			
Min. 15	Mine Surveying Field Work			6 credits
Geol. 115	Field Work in Southeastern Minnesota			3 credits
	FOURTH YEAR			
Geol. 106	Petrography	3	.....	.....
Geol. 107	Invertebrate Paleontology	3	.....	.....
Geol. 112	Petroleum Geology	.....	.....	3
Geol. 118	Geomorphology	3	.....	.....
Geol. 125	Structural Geology	3	.....	.....
Geol. 144	Geologic Maps	.....	3	.....
Geol. 151, 152	Stratigraphy	.....	3	3
M.E. 131	Thermodynamics	.....	3	.....
Min. 106	Mine Mapping	.....	2	.....
M.&M. 85	Mechanics of Materials	.....	.....	3
Pet. 111, 112	Oil Field: Development, Production	3	3	.....
Pet. 131	Petroleum Refining	.....	.....	2
Pet. 138	Oil Field Mapping	.....	.....	2
Non-Technical Requirements*	Group III	3	3	.....
Technical Electives		.....	.....	3
	Total credits	18	17	16
	Summer Field Trip			
Geol. 150	Field Geology. Detailed systematic work conforming with standards of official surveys. Preparation of geologic maps, structure sections, reports; paragenesis of ores and their relation to geologic structure. Field: Black Hills, South Dakota			6 credits
	FIFTH YEAR			
Geol. 101	Sedimentation	3	.....	.....
Geol. 131, 132	Petrology	.....	4	4
Geol. 153	Subsurface Stratigraphy	3	.....	.....
Geophys. 108, 110	Introduction to Geophysics: General, Exploration	3	.....	3
Engl. 85, 86	Advanced Technical Communication	3	3	.....
G.E. 103	Professional Problems	.....	1	.....
Min. 141	Mineral Economics	3	.....	.....
Pet. 134	Natural Gas Engineering	.....	2	.....
Pet. 152, 153, 154	Petroleum Production Technology	3	3	3
Technical Electives		.....	.....	2
	Total credits	18	13	12

Credits beyond the curricula requirements may be taken with special permission. Recommended courses are the following:

I.T.: G.E. 101; I.E. 150; M.E. 14, 24, 50, 128, 132, 198; Met. 106, 107, 110, 111, 112, 156; Min. 121, 122, 126, 127; Pet. 135, 144, 145.

S.L.A.: Econ. 8, 9; B.A. 54, 55; Geol. 110, 111, 121, 140, 145, 161, 166; Phys. 50.

* See *Non-Technical Required Courses*, page 68.

Geophysics

A five-year curriculum is offered which leads to the degree of bachelor of geophysics, B.Geophys. A total of 241 credits, exclusive of field trips, is required for graduation.

Geophysics means physics of the earth, and is concerned with the application of the laws and techniques of physics to earth problems. In practice, a division is made between problems dealing with the entire earth or large portions of it and local problems which arise in exploration for minerals or petroleum. In the former category are topics such as the age, shape, and internal construction of the earth, gravitational and magnetic fields, isostasy, tides, and poles; particular emphasis is placed on earthquake study because of the valuable data supplied by it to the fields of physics and geology. Exploration geophysics makes use of differences in physical properties of rocks to provide information on materials buried hundreds or thousands of feet beneath the surface.

Both the geophysics curriculum and individual geophysics courses place primary emphasis on basic principles and fundamental techniques, in order to prepare students either for graduate work in geophysics and related fields or for responsible positions in geophysical companies or research institutions. The curriculum includes a thorough background in geology, physics, and mathematics; field work in geology is also required in order to help the geophysics student understand the nature of geologic problems. Courses in geophysics attempt to provide not only geophysical data but also the evidence on which such data are based.

FIRST AND SECOND YEARS

Curriculum for either School of Mines on page 20, or College of Engineering on page 19 is acceptable.

THIRD YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Geol. 1, 2—General Geology (Physical and Historical)	3	3	.....
Geol. 23, 24—Mineralogy	4	4	.....
Geol. 25—Rock Study	.....	.....	2
I.T.M. 80—Differential Equations	.....	.....	3
I.T.M. 90—Elementary Engineering Statistics	.....	3	.....
Econ. 8, 9—General Economics	3	.....	3
Phys. 107, 109, 111—Modern Physics	3	3	3
Electives	3	3	6
Total credits	16	16	17

FOURTH YEAR

Geophys. 108, 109—Introduction to General Geophysics; Elementary Seismology	3	3	.....
Geol. 112—Petroleum Geology	.....	.....	3
Geol. 125—Structural Geology	3	.....	.....
Geol. 144—Geologic Maps	.....	3	.....
Phys. 144—Electrical Measurements	4	.....	.....
E.E. 117, 119—Engineering Electronics	.....	3	3
E.E. 118, 120—Engineering Electronics Laboratory	.....	1	1
I.T.M. 150—Calculus III: Intermediate Calculus	3	.....	.....
I.T.M. 154—Vector Analysis	.....	3	.....
C.E. 17—Surveying	.....	.....	3
Non-Technical Requirements*—Group III	3	3	.....
Electives	.....	.....	6
Total credits	16	16	16

Summer Field Trip

Geol. 150—Field Geology. Detailed systematic work conforming with standards of official surveys. Preparation of geologic maps, structure sections, reports; paragenesis of ores and their relations to geologic structure. Field: Black Hills, South Dakota ..... 6 credits

FIFTH YEAR

Geophys. 125, 126, 127—Principles of Gravity and Magnetic Exploration; Principles of Seismic Exploration; Principles of Electrical Exploration	2	2	2
Geol. 110—Economic Geology	.....	3	.....
Geol. 153A—Subsurface Stratigraphy Laboratory	2	.....	.....
G.E. 103—Professional Problems	.....	1	.....
Phys. 101, 103, 105—Theoretical Physics	5	5	5
Engl. 85, 86—Advanced Technical Communication	3	3	.....
Electives	3	3	6
Total credits	15	17	13

Suggested electives: Geol. 70, 131, 137, 151; Phys. 136.

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* See *Non-Technical Required Courses*, page 68.

Industrial Engineering

A five-year curriculum is offered which leads to the degree of bachelor of industrial engineering, B.I.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation.

Through industrial engineering, the analytical viewpoint of the engineer is brought to bear on production and management problems. In connection with day-to-day plant operation, industrial engineers plan and schedule the flow of work, control quality, establish production standards, estimate costs of new operations, and administer wage incentive and cost reduction programs.

In setting up for the manufacture of new products and reducing costs, the industrial engineer studies product designs to adapt them for economical production, determines the necessary operations, develops work methods, and selects or develops production equipment and tooling. He is also concerned with the over-all planning and coordination of manufacturing processes, the determination of required production facilities, and the layout and planning of industrial plants. Industrial engineering surveys provide management with factual data on which to base decisions on new products, equipment installations, plant locations, and expansion programs.

Training and experience in industrial engineering also lead to responsibilities in production supervision and management and to higher administrative and staff positions. In addition to the direct production functions, industrial engineers are also engaged in plant and equipment maintenance, safety engineering, technical sales, purchasing, and other activities which require engineering background and a knowledge of manufacturing and management. Industrial engineering is applied not only in manufacturing, but in mining, construction, agriculture, and in stores, warehouses, offices, and service enterprises.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined course with business administration. Because of the close relationship between industrial engineering and general management functions, this combination is especially appropriate for students in industrial engineering.

A cooperative work-study program is also available under which periods of supervised industrial employment are substituted for a portion of the classroom instruction.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in industrial engineering elect the following courses in the second year:

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Phys. 14A	Physics Laboratory	1	.....	.....
Phys. 50A	Physics Laboratory	.....	1	.....
Org.Chem. 16	Carbon Compounds	.....	.....	4
I.E. 1	Industrial Engineering Orientation	.....	.....	1

Psychology 1, 2, and 155 are recommended for the Group I and Economics 8, 9, and 73 for the Group II non-technical requirements. Economics 8, 9, and 73 are prerequisites for later required courses in the industrial engineering curriculum.

THIRD YEAR

I.E. 150—Elements of Industrial Engineering and Management	.....	.....	3
I.T.M. 90—Elementary Engineering Statistics	.....	.....	3
M.&M. 127—Engineering Dynamics	5	.....	.....
M.&M. 128—Mechanics of Materials	.....	5	.....
M.&M. 141—Materials Testing Laboratory	.....	1	.....
Hydr. 101—Fluid Mechanics	.....	.....	3
M.E. 12, 13, 14—Casting Processes; Metal Processing; Metal Cutting (may be taken in any order)	2	2	2
M.E. 21, 20, 24—Kinematics and Mechanisms; Elementary Machine Design; Elements of Machine Design	3	2	3
M.E. 33, 34—Mechanical Engineering Laboratory I and II	2	2	.....
M.E. 131, 132—Thermodynamics	3	3	.....
Non-Technical Requirements**—Group II or I	3	3	3
Total credits	18	18	17

FOURTH YEAR

I.E. 153—Methods Engineering and Work Measurement	3	.....	.....
I.E. 163—Process Planning and Development	.....	3	.....
I.E. 165—Industrial Plants	.....	.....	3
M.E. 118—Advanced Processing Technology	3	.....	.....
M.E. 141—Heat Power Engineering M.E. 150—Internal Combustion Engines M.E. 160—Heating, Ventilation, and Air Conditioning M.E. 180—Refrigeration (Two courses to be taken. M.E. 141 and 160 recommended)	.....	3-4	3-4
E.E. 36, 37, 38—Electrical Engineering Survey	3	3	3
B.A. 54, 55, 66—Elementary Accounting; Managerial Costs	4	4	3
Non-Technical Requirements*—Group III	3	3	3
Total credits	16	16-17	15-16

FIFTH YEAR

I.E. 154—Advanced Methods Engineering and Work Measurement I.E. 170—Production Planning and Control I.E. 171—Quality Control I.E. 173—Engineering Economic Analysis I.E. 180—Elements of Supervision I.E. 194—Applied Industrial Engineering	6	6	6
I.E. 190, 191, 192—Industrial Engineering Seminar	1	1	1
I.E. 193—Inspection Trip	.....	1	.....
G.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	3	3	.....
B.A. 167—Introduction to Industrial Relations	.....	.....	3
Non-Technical Requirements* (toward 31-credit total)	3-4	.....	.....
Electives (to make 250-credit total)	3	6	6
Total credits	16-17	18	16

* See *Non-Technical Required Courses*, page 68.

** See additional information on "Non-Technical Requirements" for sequences which may be taken. Psychology 1, 2, and 155 are recommended for Group I and Economics 8, 9, and 73 for Group II. The latter three courses are prerequisites for other required courses in the industrial engineering curriculum.

Cooperative Work-Study Curriculum

A five-year work-study curriculum to provide practical work experience in conjunction with the regular class and laboratory work is available through cooperation with nearby industrial concerns. Students in the work-study program are on a twelve-month basis and spend alternate quarters in industry, starting with the summer or fall quarter following the second year.

Work-study students follow a modified program of study in which 42 credits are granted for the six quarters of supervised industrial assignments. A comprehensive report on each industrial period is required, and the work-study students take all of the basic work in the regular curriculum. Work-study students are registered at the University and are considered regular full-time students during the work assignments. While on the work assignments they are paid at regular rates by the companies.

Industrial engineering students who have completed their first two years of work with an honor point average of 1.0 or better are eligible for the work-study program at the end of the spring quarter of their second year. Applications should be filed by February 1 of the second year. Selection will be based on scholastic ability, aptitude for industrial work, and financial need. Further information is available at the industrial engineering office.

The regular bachelor of industrial engineering degree is awarded upon completion of 250 credits including the 42 credits for the six industrial quarters and all of the required courses in the work-study curriculum. Work-study students are eligible to receive the bachelor of science degree and enter the Graduate School on a basis similar to that of regular students. This requires completion of 200 regular course credits with an honor point average of 1.80 or better, and completion of all of the required courses in the first four years of the regular industrial engineering curriculum including 28 credits of the non-technical requirement. Application for the bachelor of science degree is made by petition to the Committee on Student Scholastic Standing and requires departmental approval.

FIRST YEAR

Same as the first year in the regular industrial engineering curriculum.

SECOND YEAR

Same as the second year in the regular industrial engineering curriculum.

THIRD, FOURTH, AND FIFTH YEARS

Curricula for the third, fourth, and fifth years are available in the industrial engineering office, or from the director of the work-study program.

Mechanical Engineering

A five-year curriculum is offered which leads to the degree of bachelor of mechanical engineering, B.M.E.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation.

The mechanical engineering department includes the following major divisions: heating, ventilating, and refrigeration; heat power; industrial; and machine design and instrumentation. Within these areas work may be taken in the fields of design of machinery and apparatus; industrial instrumentation and automatic controls; production and manufacturing methods; operation of industrial plants; steam power generation; internal-combustion engines; heating, ventilating and air conditioning; refrigeration; mechanical research and development; and the general field of management. A student may specialize in any of these by taking the appropriate senior design courses, senior laboratory courses, and electives.

Students with an honor point ratio of 1.50 or better may petition for admission to the combined curriculum of engineering and business administration.

Cooperative work-study curricula in mechanical engineering and in industrial engineering are available to qualified students.

The combined curricula in engineering and law are also available to qualified students in mechanical engineering.

FIRST YEAR

See curriculum for the first year on page 19.

SECOND YEAR

See curriculum for the second year on page 19.

The department recommends that students in mechanical engineering elect the following courses in the second year:

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Phys. 14A, 50A—Physics Laboratory	1	1	.....
Org.Chem. 16—Carbon Compounds	.....	.....	4
M.E. 1—Mechanical Engineering Orientation	.....	.....	1

THIRD YEAR

M.E. 12, 13, 14—Casting Processes; Metal Processing; Metal Cutting (may be taken in any order)	2	2	2
M.E. 21, 20, 22—Kinematics and Mechanisms; Elementary Machine Design; Mechanisms of Automatic Machinery	3	2	3
M.E. 33, 34, 35—Mechanical Engineering Laboratory I, II, and III	2	2	2
M.E. 131, 132—Thermodynamics	3	3	.....
M.&M. 127—Engineering Dynamics	5	.....	.....
M.&M. 128—Mechanics of Materials	.....	5	.....
M.&M. 141—Materials Testing Laboratory	.....	1	.....
Hydr. 103—Fluid Mechanics	.....	.....	5
Hydr. 104—Hydraulics Laboratory	.....	.....	1
Non-Technical Requirements*—Group II or I	3	3	3
Total credits	18	18	16

* See *Non-Technical Required Courses*, page 68.

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
M.E. 24—Elements of Machine Design	3	.....	.....
M.E. 121—Machine Design	.....	3	.....
M.E. 23—Dynamics of Machinery	.....	.....	3
M.E. 118—Advanced Processing Technology M.E. 141—Heat Power Engineering M.E. 150—Internal Combustion Engines M.E. 160—Heating, Ventilation and Air Conditioning M.E. 180—Refrigeration I.E. 150—Elements of Industrial Engineering and Management	6	7	6
E.E. 36, 37, 38—Electrical Engineering Survey	3	3	3
Met. 156—Metallography for Mechanical, Mining, and Petroleum Engineers	3	.....	.....
Technical Electives†	.....	.....	3
Non-Technical Requirements*—Group III	3	3	3
Total credits	18	16	18

FIFTH YEAR

M.E. 190—Seminar	1	.....	.....
M.E. 195—Inspection Trip	.....	1	.....
Engineering Design Group§ (a minimum of 6 credits)	3	3	.....
Laboratory Group¶ (a minimum of 3 courses)	2	2	2
G.E. 103—Professional Problems	.....	1	.....
Technical Electives†	3	3	5
Engl. 85, 86—Advanced Technical Communication	3	3	.....
Non-Technical Requirements*	.....	.....	3
Electives	3	3	3
Total credits	15	16	13

Cooperative Work-Study Curricula

A five-year work-study curriculum designed to provide both theoretical and practical training over a period of five years is offered in cooperation with industry leading to the degree of bachelor of mechanical engineering. The program is available to all qualified students registered in the mechanical engineering curriculum. Students registered in any division of mechanical engineering who have completed the first two years of the required program with an honor point average of 1.0 or better are eligible at the end of the spring quarter of their second year. Application should be filed by February 1 preceding the completion of the first two years' work.

The first industrial assignment is made during the summer or fall term following the completion of the freshman and sophomore work. The student is registered in the University during the work periods, and at all times is considered a regular full-time university student.

The awarding of the Bachelor's degree with departmental designation will require the satisfactory completion of all the basic required university work as designated in the regular five-year mechanical engineering curriculum including six alternate quarters of supervised industrial experience.

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* See *Non-Technical Required Courses*, page 68.

† Courses in the Institute of Technology, the physical sciences, and selected courses in ROTC.

§ A minimum of 6 credits of engineering design shall be selected from the following courses: M.E. 119, 122, 123, 147, 148, 154, 155, 161, 162, 170, 182 and I.E. 165.

¶ Three of the eight laboratory courses, M.E. 110, 125, 149, 159, 169, 189, 198, and I.E. 153 must be taken and not more than two in any one quarter.

In the event a program of graduate study leading to a graduate degree is to be pursued, students may petition the Committee on Student Scholastic Standing for the bachelor of science degree without designation during the third quarter of the fourth year of their curriculum. This will require an honor point average of 1.80 or better, completion of all of the required work, including the non-technical required courses, in the first four years of the regular mechanical engineering curriculum, a total of 200 credits and departmental approval.

Students in mechanical engineering should contact their departmental office for information on this program and the procedure for submitting applications. Candidates will be selected on the basis of scholastic ability, financial need, personal qualifications, and fitness for work.

FIRST YEAR

Same as the first year in the regular mechanical engineering curriculum.

SECOND YEAR

Same as the second year in the regular mechanical engineering curriculum.

THIRD, FOURTH, AND FIFTH YEARS

Curricula for the third, fourth, and fifth years are available in the mechanical engineering office, or from the director of the work-study program.

Combined Curricula of Mechanical Engineering and Law

These curricula enable the student to obtain two degrees, one in the Institute of Technology and one in the Law School, in a period of approximately seven years. To be eligible for admission to the Law School, the student must complete a modified four-year mechanical engineering program and qualify for the bachelor of science degree undesignated. Then the regular law program covering ten quarters of work will be followed. This leads to the degree of bachelor of laws.

FIRST YEAR

Same as the first year in the College of Engineering.

SECOND YEAR

Same as the second year in the College of Engineering except Psy. 1, 2, 3 to be taken as Group I.

THIRD YEAR

M.E. 12, 13, 14, 20, 21, 22, 23, 33, 34, 131, 132, 141; M.&M. 127, 128, 141; Hydr. 103, 104; Econ. 8, 9; Pol.Sci. A, B.

FOURTH YEAR

M.E. 24, 118, 121, 150, 160, 180, 190; two M.E. sr. labs.; I.E. 150; E.E. 36, 37, 38; Engl. 85, 86; G.E. 103; Hist. 70, 71, 72; Phil. 2A, 3A.

Metallurgical Engineering

A five-year curriculum is offered which leads to the degree of bachelor of metallurgical engineering, B.Met.E.

A total of 241 credits, exclusive of summer field trips, is required for graduation.

Courses in metallurgy are designed to prepare the student for responsible positions in metallurgical industries. The instruction deals with the production and uses of ferrous, nonferrous, and precious metals. Metallurgists are concerned with the preparation of raw materials for smelting, the design and operation of furnaces to convert ores into metals, and the structure and physical properties of metals and alloys.

Lectures cover the construction and operation of mineral dressing and concentrating machinery, together with typical combinations of mineral dressing machines. The sequence of physical and chemical changes occurring during smelting, furnace design, fuels, refractories, methods, and efficiency of heat application and control over quality of product are stressed in courses dealing with metallurgical processes.

Laboratories equipped with various types of furnaces are provided so that the students can become familiar with high temperature equipment and conduct experiments demonstrating important features of metallurgical processes.

Metallography is an important branch of metallurgy dealing with the application of metals and alloys. The work relates to internal structures as studied by the microscope, and to the physical and chemical properties of metals and alloys.

Laboratory courses accompany lecture work. The metallographic laboratory is equipped with the most up-to-date microscopes and apparatus for heat treating and physical and mechanical testing. Practice is obtained in taking photomicrographs.

Students taking the combined course with business administration may substitute business courses for non-technical required courses, group I, group II, group III (page 68), and electives.

FIRST AND SECOND YEARS

See curriculum for the first two years of the School of Mines and Metallurgy on page 20.

THIRD YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Met. 11, 12—Metallurgy of Pig Iron; Metallurgy of Steel	3	.....	3
Met. 106, 107, 108—Nonferrous Metallurgy	3	3	3
Anal.Chem. 9—Quantitative Analysis	.....	3	.....
Geol. 1, 2—General Geology (Physical and Historical)	3	3	.....
Geol. 23, 24—Mineralogy	4	4	.....
M.&M. 85—Mechanics of Materials	.....	.....	3
M.&M. 87—Materials Testing Laboratory	.....	.....	1
I.T.M. 90—Elementary Engineering Statistics	.....	3	.....
Non-Technical Requirements* (toward 31-credit total)	3	.....	5
Total credits	16	16	15

* See *Non-Technical Required Courses*, page 68.

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Met. 110, 111, 112—Mineral Dressing	4	4	4
Met. 133—Electrometallurgy	.....	3	.....
Met. 153, 154, 155—Metallography (General, Ferrous, Nonferrous)	4	4	4
Geol. 106—Petrography	3	.....	.....
M.E. 14—Metal Cutting	.....	.....	2
Phys.Chem. 101, 102, 103—Physical Chemistry	3	3	3
Non-Technical Requirements*—Group III	3	3	.....
Technical Electives	.....	.....	2
Total credits	17	17	15

Summer Field Trip

Met. 75—Study of Metallurgical Operations in Important Iron and Steel Centers ..... 2 credits

FIFTH YEAR

Met. 121, 122, 123†—Ore Testing; Advanced Mineral Dressing	2	3	3
Met. 134, 135, 136†—Advanced Metallurgy of Steel; Advanced Metallurgy of Pig Iron; Refractories	3	3	3
Met. 137, 139—Metallurgical Calculations; Metallurgical Laboratory	2	.....	1
Met. 163, 164, 165†—Advanced Metallography (Principles and Practice)	3	3	3
E.E. 41—Electrical Engineering Survey (Laboratory)	.....	1	.....
E.E. 42—Electrical Engineering Survey	.....	3	.....
G.E. 103—Professional Problems	.....	1	.....
Engl. 85, 86—Advanced Technical Communication	3	3	.....
Technical Electives	3	.....	3
Total credits	16	17	13

Credits beyond the curricula requirements may be taken with special permission. Recommended courses are the following:

I.T.: G.E. 101; Geophys. 108; I.E. 150; M.E. 12, 24, 50, 128, 131, 138, 198; I.T.M. 80; Met. 138; Chem.E. 119.

S.L.A.: Econ. 8, 9; B.A. 54, 55; Geol. 107, 121, 131, 161; Phys. 50, 107, 109, 111, 144.

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* See *Non-Technical Required Courses*, page 68.

† Three credits in I.T. may be substituted for one of the following three courses: Met. 123, Met. 136, Met. 165.

Mining Engineering

A five-year curriculum is offered which leads to the degree of bachelor of mining engineering, B.Min.E. There are two options: Mining and Petroleum.

A total of 241 credits, exclusive of summer field trips, is required for graduation.

The curriculum in mining is designed to prepare the student for responsible positions in the field of mining. In such positions a mining engineer, in addition to meeting the technical problems involved in the development and operation of a mine, must be able to pass upon proposals and specifications for structures and for mechanical and electrical equipment. In addition he must be familiar with the fundamental principles of mineral dressing and be able to determine whether separation of the minerals in the ore may be made at a profit. The basic training must, therefore, include thorough courses in mathematics, drafting, chemistry, physics, and geology including the identification of minerals and rocks. It must also include plane and mine surveying, mapping, mineral dressing, and ore testing.

The Department of Mining is well supplied with samples of the smaller mine equipment, models, drawings, photographs, lantern slides, and mine maps. The lectures treat of prospecting, development, support of excavations, mining methods, mine administration, mining law, safety and safety regulations, and the necessary allied subjects.

Additional geophysics courses are recommended to supplement this curriculum. Geophysics aids in geological interpretations, provides knowledge of the earth's crust, and is used in the discovery of mineral deposits and petroleum. Geophysics courses may be substituted for electives to be chosen from courses offered by the College of Science, Literature, and the Arts or, with approval, for prescribed credits.

Students taking the combined curriculum with business administration may substitute business courses for non-technical required courses, group I, group II, group III (page 68), and electives.

FIRST AND SECOND YEARS

See curriculum for the first two years of the School of Mines and Metallurgy on page 20.

THIRD YEAR

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Min. 11, 12, 13	Surveying	3	3	2
Min. 14	Surveying Field Work	.....	.....	5
Geol. 1, 2	General Geology (Physical and Historical)	3	3	.....
Geol. 23, 24	Mineralogy	4	4	.....
Geol. 25	Rock Study	.....	.....	2
Anal.Chem. 9	Quantitative Analysis	.....	3	.....
Hydr. 102	Fluid Mechanics	.....	.....	4
Hydr. 104	Hydraulics Laboratory	.....	.....	1
I.T.M. 90	Elementary Engineering Statistics	.....	3	.....
Non-Technical Requirements*	(toward 31-credit total)	6	.....	2
Total credits		16	16	16

* See *Non-Technical Required Courses*, page 68.

Mining Option in Mining Engineering

Summer Field Trips

Min. 15—Mine Surveying Field Work ..... 6 credits
Geol. 100—Field Work in Northern Minnesota ..... 3 credits

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Min. 106—Mine Mapping	.....	2	.....
Min. 111, 112, 113—Elements of Mining	3	3	3
Min. 121, 122—Mine Plant Design	.....	2	3
Geol. 125—Structural Geology	3	.....	.....
E.E. 41—Electrical Engineering Survey (Laboratory)	.....	1	.....
E.E. 42—Electrical Engineering Survey	.....	3	.....
M.E. 131—Thermodynamics	3	.....	.....
M.&M. 85—Mechanics of Materials	.....	.....	3
M.&M. 87—Materials Testing Laboratory	.....	.....	1
Met. 11—Metallurgy of Pig Iron	3	.....	.....
Met. 110, 111, 112—Mineral Dressing	4	4	4
Non-Technical Requirements*—Group III	3	3	.....
Total credits	19	18	14

Summer Field Trip

Min. 139—Mining Field Trip. Study of mining operations, mine plants, and metallurgical plants on iron ranges and in several other mining areas ..... 6 credits

FIFTH YEAR

Min. 123—Mine Air Conditioning	3	.....	.....
Min. 126, 127—Engineering Construction	2	3	.....
Min. 141—Mineral Economics	3	.....	.....
Min. 142—Surface Mining	.....	3	.....
Min. 144, 145—Advanced Mining	.....	2	4
Geol. 110, 111—Economic Geology	.....	3	3
Geophys. 110—Introduction to Exploration Geophysics	.....	.....	3
G.E. 103—Professional Problems	.....	1	.....
M.E. 138—General Laboratory	.....	2	.....
Met. 121—Ore Testing	2	.....	.....
Met. 156—Metallography	.....	.....	3
Engl. 85, 86—Advanced Technical Communication	3	3	.....
Total credits	13	17	13

Credits beyond the curricula requirements may be taken with special permission. Recommended courses are the following:

I.T.: C.E. 53, 147, 159; G.E. 101; Geophys. 108; I.E. 150; M.E. 14, 24, 50, 128, 132, 150, 198; Met. 106, 107; Min. 143, 160; I.T.M. 80.
S.L.A.: Econ. 8, 9; B.A. 54, 55; Geol. 101, 106, 112, 121, 144; Phys. 50.

* See *Non-Technical Required Courses*, page 68.

Petroleum Option in Mining Engineering

The petroleum option is designed to prepare the student for positions in the field of petroleum production. The petroleum engineer must be familiar with oil geology involving a knowledge of geological ages during which oil was formed, geological conditions under which the oil was collected in pools, and the methods of interpreting geological data to determine whether a given locality contains such pools. He must know the principles of pumping with gas lift and mechanical pumps, and the methods of gasoline recovery.

The basic training must, therefore, include thorough courses in mathematics, drafting, chemistry, physics, and geology, including in particular, a thorough knowledge of sedimentary deposits. It must also include surveying and mapping.

The department is well supplied with samples of smaller oil field equipment, well logs, drill cores, models, maps, photographs, lantern slides, and samples of petroleum products. The lectures treat of location, prospecting, development, production, refining methods, distribution, administration, leasing, mineral laws, safety work and safety regulations, and allied subjects affecting oil and gas production. Laboratory work includes special problems in oil and gas production.

THIRD YEAR

Summer Field Trip

Geol. 115†—Field Work in Southeastern Minnesota	3 credits
Min. 15†—Mine Surveying Field Work	6 credits

FOURTH YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Pet. 111, 112—Oil Field Development; Oil Field Production	3	3	.....
Pet. 131—Petroleum Refining	.....	.....	2
Pet. 138—Oil Field Mapping	.....	.....	2
Min. 122—Mine and Petroleum Plant Design	.....	.....	3
Geol. 101—Sedimentation	3	.....	.....
Geol. 112—Petroleum Geology	.....	.....	3
Geol. 125—Structural Geology	3	.....	.....
Geol. 144—Geologic Maps	.....	3	.....
Geol. 153A—Subsurface Stratigraphy Laboratory	2	.....	.....
E.E. 41—Electrical Engineering Survey (Laboratory)	.....	1	.....
E.E. 42—Electrical Engineering Survey	.....	3	.....
M.E. 150—Internal Combustion Engines	.....	4	.....
M.E. 131, 132—Thermodynamics	3	3	.....
M.&M. 85—Mechanics of Materials	.....	.....	3
M.&M. 87—Materials Testing Laboratory	.....	.....	1
Met. 156—Metallography for Mechanical, Mining, and Petroleum Engineers	.....	.....	3
Non-Technical Requirements*—Group III	3	3	.....
Total credits	17	20	17

* See *Non-Technical Required Courses*, page 68.

† Options: Either Geol. 150 or both Min. 15 and Geol. 115 (Geol. 100 if Geol. 115 not offered). Min. 15 must be followed by Min. 106, 1 credit, which may be used to satisfy Institute of Technology elective requirements.

Summer Field Trip

Pet. 135—Study of Oil Well Drilling and Production Methods and Refining Practice in One or More Oil Fields ..... 3 credits
Geol. 150†—Field Geology ..... 6 credits

FIFTH YEAR

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Pet. 134	Natural Gas Engineering	.....	2	.....
Pet. 144, 145	Advanced Petroleum Engineering	.....	2	4
Pet. 152, 153, 154	Petroleum Production Technology	3	3	3
Min. 126	Engineering Construction	2	.....	.....
Min. 141	Mineral Economics	3	.....	.....
Geophys. 110	Introduction to Exploration Geophysics	.....	.....	3
G.E. 103	Professional Problems	.....	1	.....
M.E. 24	Elements of Machine Design	3	.....	.....
M.E. 138	General Laboratory	.....	2	.....
Engl. 85, 86	Advanced Technical Communication	3	3	.....
Technical Electives		.....	3	.....
	Total credits	14	16	10

Credits beyond the curricula requirements may be taken with special permission. Recommended courses are the following:

I.T.: G.E. 101; Geophys. 108; I.E. 150; M.E. 14, 198; Min. 15, 121, 127; I.T.M. 80; Phys.Chem. 107, 108.
S.L.A.: Econ. 8, 9; B.A. 54, 55; Geol. 106, 107, 131, 151; Phys. 50, 107, 109, 111, 144.

† Options: Either Geol. 150 or both Min. 15 and Geol. 115 (Geol. 100 if Geol. 115 not offered). Min. 15 must be followed by Min. 106, 1 credit, which may be used to satisfy Institute of Technology elective requirements.

Physics

A five-year curriculum is offered which leads to the degree of bachelor of physics, B.Phys.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of 255 credits for graduation.

The sequences leading to the degree of bachelor of physics are intended to be sufficiently broad to provide for the needs of those who desire to prepare for the industrial research field or for graduate work in physics as a major. The outlines given below may be modified on petition.

It is clear that a student having the above objectives must attain an adequate background in mathematics and in chemistry. The work in physics is planned to give a greater or lesser contact with theoretical physics and experimental physics, depending upon the special aptitude of the applicant. Any special interest of the applicant may be met by a careful choice of elective courses which meets the approval of his adviser. The Department of Physics reserves the right to limit the registration in this course to those who have given evidence of being able to profit by it. Those who contemplate registering in this course should consult the chairman of the department.

Students intending to enter this course may take the curriculum outlined on page 20 for the first year in the School of Chemistry or the curriculum for the first two years in the College of Engineering, page 19. They may register for a major in physics if they have maintained a C average or better during their freshman year in the School of Chemistry or during their first two years in the College of Engineering. During the third and fourth years the sequence of courses given below will be somewhat modified for students beginning in the College of Engineering in order that they may satisfy the prerequisites for certain courses.

FIRST YEAR

See curriculum for the first year in the School of Chemistry on page 20 or the curriculum for the first two years in the College of Engineering on page 19.

SECOND YEAR

For students beginning in the School of Chemistry; others continue in the basic curriculum.

COURSE NO.	TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
Phys. 7, 8, 9	General Physics	5	5	5
I.T.M. 24, 25	Calculus I: Differential; Calculus II: Integral	5	5	.....
I.T.M. 80	Elementary Differential Equations	.....	.....	3
Org.Chem. 61, 62	Elementary Organic Chemistry	4	4	.....
Anal.Chem. 7	Quantitative Analysis	.....	.....	4
Non-Technical Requirements*	Group I or II	4	4	4
	Total credits	18	18	16

* See *Non-Technical Required Courses*, page 68.

THIRD YEAR

Phys. 107, 109, 111—Modern Physics	3	3	3
Phys. 144—Electrical Measurements	4	.....	.....
E.E. 117, 119—Engineering Electronics	.....	3	3
E.E. 118, 120—Engineering Electronics Laboratory	.....	1	1
I.T.M. 150, 152, 153—Calculus III: Intermediate Calculus; Calculus IV, V: Advanced Calculus	3	3	3
Phys.Chem. 101, 102, 103—Physical Chemistry	3	3	3
Non-Technical Requirements*—Group II or I	3	3	4
Total credits	16	16	17

FOURTH YEAR

Phys. 101, 103, 105—Theoretical Physics	5	5	5
Phys. 120—Atomic Physics	3	.....	.....
Phys. 121—Experimental Nuclear Physics I	.....	3	.....
Phys. 134—Experimental Optics	3	.....	.....
Phys. 136—Spectrum Analysis or Phys. 122—Experimental Nuclear Physics II	.....	.....	3
Non-Technical Requirements*—Group III	5	5	5
Total credits	16	13	13

FIFTH YEAR

Phys. 181, 183, 185—Atomistics and Elementary Quantum Mechanics or Phys. 191, 192, 193—Introduction to Mathematical Physics	3	3	3
Engl. 85, 86—Advanced Technical Communication	3	3	.....
G.E. 103—Professional Problems	.....	1	.....
Electives			

Students who take the basic curriculum for the first two years in the College of Engineering may take Inorg.Chem. 11 (Semimicro Qualitative Analysis) during the Summer Session between their second and third years, and Anal.Chem. 7 (Quantitative Analysis) during the fall quarter of their third year in order that they may satisfy the prerequisites for Phys.Chem. 101, 102, 103, which should then be taken during the fourth year. These students should also take Phys. 134 (Experimental Optics) during the winter or spring quarter of their third year instead of in their fourth year. Modification of the curriculum, such as the omission of Org.Chem. 61 and 63, may be made when approved by the chairman of the department.

Electives

Acceptable electives may be taken in astronomy, chemistry, economics, engineering, English, geology, history, humanities, languages, mathematics, philosophy, political science, psychology, or the biological sciences.

* See *Non-Technical Required Courses*, page 68.

Two-Year Technical Aid Curriculum

(Engineering Drafting)

A two-year technical aid program in engineering drafting is offered leading to a certificate of technical aid.

This program provides post–high school technological training for students who desire to prepare for positions in industry requiring more responsibility and preparation than normally required of skilled craftsmen but less than needed by graduate engineers.

High school graduation including two years of mathematics (elementary algebra and plane geometry or unified mathematics) are prerequisites for admission. Students who have been registered in the Institute of Technology or who have attended any accredited college or university may transfer into this program. Some advanced standing credit may be received for previous college work, but it will normally take two years to finish the balance of the requirements. Because of the sequence nature of the courses, admission may normally be obtained for the fall quarter only.

It may be possible to transfer into regular engineering curriculum from the technical aid program if a high scholastic average has been maintained. However, because of the lack of similarity between the two programs, normal progress toward an engineering degree cannot be made while registered in technical aid.

This course is planned to give a thorough training in engineering drafting, a grounding in practical mathematics, and shop operations. It also includes courses in English so that the student can make out reports, handle correspondence, and be able to read and understand technical literature. Enrolment may be limited due to facilities and staff available. (Not being offered for beginning students, 1953-54.)

FIRST YEAR

COURSE NO. TITLE	CREDITS 1st qtr.	2nd qtr.	3rd qtr.
T.A. 11, 12, 13—Engineering Drafting	5	5	5
T.A. 21, 22, 23—Applied Mathematics	6	6	6
T.A. 34, 35, 36—Technical Writing	3	3	3
T.A. 16—Lettering	1	.....	.....
T.A. 17—Slide Rule	1	.....	.....
T.A. 28—Basic Physical Science	.....	2	.....
T.A. 82—Foundry	.....	.....	2
Total credits	16	16	16

SECOND YEAR

T.A. 14, 41, 15—Engineering Drafting; Production Illustration	5	5	5
T.A. 24, 25, 26—Applied Mathematics	6	6	6
T.A. 37—Oral Composition	3	.....	.....
T.A. 83, 84—Forging, Welding, and Heat Treating; Machine Shop	2	2	.....
T.A. 85—Machine Design	.....	.....	2
T.A. 18—Charts and Graphs	.....	1	.....
T.A. 27—Engineering Problems	.....	.....	3
T.A. 42—Engineering Materials	.....	2	.....
Total credits	16	16	16

Non-Technical Required Courses

(Social-Humanistic Area)

To complete the requirements in this area the student should elect credits as indicated in each of the three groups outlined below, plus enough credits from the recommended elective subjects to total 31 credit hours. These credits, in addition to the 15 credits of engineering English, comprise the group of non-technical credits required for the Bachelor's degree in engineering.

GROUP I—Minimum of 6 credits from any one sequence

1. Natural Science 7-8-9
2. Botany 1-2-3
3. Psychology 1-2, 155
4. Zoology 1-2-3

GROUP II—Minimum of 6 credits from any one sequence

1. Economics 8-9 or 6-7 may be followed by Econ. 73, 164
2. Political Science 1-2, or 5 or A-B, which may be followed by Political Science 25
3. Sociology 1-2, 14 or 1-2, 104
4. Social Science 1-2-3

GROUP III—Minimum of 6 credits from any one sequence

1. Humanities 51, 52, 53 or 21, 22, 23 or 71, 72, 73
2. History 59, 60, 61 or 79, 80, 81
3. Philosophy
4. English 37, 38, 39
5. Religion†

Section A. If the total number of credits completed from the three groups above is less than 31, sufficient credits must be taken to make up the balance from the following departments:

Anthropology	Fine Arts	Languages	Speech
Astronomy	Geography	Music	Social Science
Botany	Geology	Philosophy	Sociology
Classics	History	Political Science	Zoology
English	Humanities	Psychology	

Students who complete the program in NROTC may substitute 25 credits in naval science for an equivalent number of credits in the required non-technical area. At least 6 credits must be taken within a sequence in one of the above three groups. The balance of NROTC credits may be used as electives.

Students who complete the program in Air ROTC or ROTC may substitute 15 credits in air or military science for an equivalent number of credits in the required non-technical area. At least 16 credits in the required non-technical area must be completed, including 6 credits or more within a sequence in two of the above three groups. The balance of the ROTC credits may be used as electives.

† A maximum of 4½ transfer credits in religion may be applied to Group III. Additional courses to meet the minimum of 6 credits may be selected in this case from any of the other listed Group III courses.

Additional Course Information

General Engineering Elective

G.E. 105, Engineering Library Techniques, offered fall quarter; 1 credit; no prerequisite; one hour per week. See page 96 for course description.

Credit for Summer Employment

Consult your departmental or college office concerning information regarding credit for summer employment.

Substitutions

The courses listed in the right-hand column may be substituted for the corresponding courses in the left-hand column. The excess credits may be applied as elective credits.

COURSE	SUBSTITUTE COURSE
Aero.E. 115 (3 cred.)	M.&M. 180 (3 cred.)
Anal.Chem. 132 (3 cred.)	Anal.Chem. 105 (3 cred.)
Arch. 104 (3 cred.)	Arch. 106 (3 cred.)
Draw. 7 (3 cred.)	Draw. 4 (3 cred.)
Draw. 8 (3 cred.)	Draw. 5 (3 cred.)
Draw. 21 (2 cred.)	Draw. 28 (2 cred.)
M.&M. 84 (5 cred.)	M.&M. 26 and 127 (10 cred.)
M.&M. 85 (3 cred.)	M.&M. 128 (5 cred.)
Hydr. 101 (3 cred.)	Hydr. 102 (4 cred.)
Hydr. 101 (3 cred.)	Hydr. 103 (5 cred.)
M.&M. 87 (1 cred.)	M.&M. 141 (1 cred.)
I.T.M. 91 (4 cred.)	I.T.M. 24 and 25 (10 cred.)
M.&M. 92 (4 cred.)	M.&M. 26 (5 cred.)
M.&M. 92 (4 cred.)	M.&M. 84 (5 cred.)
M.&M. 93 (4 cred.)	M.&M. 85 (3 cred.)
M.&M. 93 (4 cred.)	M.&M. 128 (5 cred.)
Hydr. 102 (4 cred.)	Hydr. 103 (5 cred.)

Extension Courses

Credits will be accepted from the General Extension Division toward a degree in the Institute of Technology for the following types of courses:

1. Elective courses approved by the Committee on Student Scholastic Standing and such other courses as have been approved by the department concerned and by the dean.
2. Correspondence Study Courses:
   C.E. 1c, 2c, 5c, 46c, 49c; Draw. 1, 2, 4; General Eng. 70; I.T.M. 9, 11, 12, 24, 25; M.&M. 26, 127, 128.
3. Evening Courses:
   Inorg.Chem. 6, 7, 12; Anal.Chem. 1, 2, 7, 123; C.E. 12, 31, 32, 141, 142; Draw. 1, 2, 3, 10, 38; E.E. 11-12, 13-14; I.T.M. 9, 11, 12, 13, 24, 25, 80; M.&M. 26, 127, 128; Hydr. 102.

Description of Courses

Aeronautical Engineering

Aeronautical Engineering laboratory fee (required of second, third, fourth, and fifth year students in aeronautical engineering). $3.00 per quarter.

1—AERONAUTICS. History. Nomenclature. Resistance of simple bodies. Theory of flight. The airplane and its parts. Constructional details. Performance. 3 cred.; prereq. I.T.M. 24; 3 lect. hrs. per week. Hermann.

4—LABORATORY. Systems of measuring units and their interrelations. 1 cred.; no prereq.

5—LABORATORY. Familiarization with physical properties of materials. 1 cred.; no prereq.

6—LABORATORY. Inspection and demonstration of aeronautical facilities. 1 cred.; no prereq.

20-21-22—FLYING: THEORY AND PRACTICE. Consists of 12 hours of ground instruction and 10 hours of flying each. 1 lect. hr. and average flying hrs. 1 per week. Laboratory fee by arrangement. 2 cred.; no prereq. Magnus.

46—ORIENTATION COURSE. Indoctrination course on Link instrument flying. 2 cred.; prereq. 4th, 5th yr. or graduate in Aeronautical Engineering or special permission of Aeronautical Engineering Department. Twelve 2-hr. periods, lect. and practice. Magnus.

83—STRESSES IN SIMPLE STRUCTURES. Statically determinate trusses and beams. Graphic statics. Combined stresses. Short and long struts. Airplane structures. 4 cred.; prereq. M.&M. 128; 3 lect. and 2 lab. hrs. per week. Staff.

100-101-102—AERODYNAMICS. Fluid mechanics; Prandtl's wing theory. Performance stability, propeller theory. Motion of body in fluids in three dimensions. 3 cred. per qtr.; prereq. 1 and I.T.M. 25, 3 lect. hrs. per week. Stolarik, Cronk.

103-104-105*—ADVANCED AERODYNAMICS. Dynamic stability, advanced theoretical aerodynamics, flutter analysis. 3 cred. per qtr.; prereq. 102; 3 lect. hrs. per week. Stolarik, Cronk.

106—ADVANCED AERODYNAMICS. Compressible flow. Comparison of compressible and incompressible flow influences on aircraft. Airfoil analysis and design. Spanwise lift distribution. 3 cred.; prereq. 102; 3 lect. hrs. per week. Upson, Stolarik.

107—AERODYNAMICS OF VISCOUS FLUIDS. Viscosity effects in fluid flows, Navier-Stokes equation, laminar boundary layer theory. Application of boundary layer theory to aerodynamic design problems. 3 cred.; prereq. 102; 3 lect. hrs. per week. Cronk.

110—VIBRATION AND FLUTTER. Free harmonic and forced vibrations. Spring constants. Critical frequency. Vibrating systems with several degrees of freedom. Vibration and flutter of aircraft. 3 cred.; prereq. 115 and I.T.M. 80; 3 lect. hrs. per week. Werner.

115—AIRPLANE STRESSES. Deflection of structures. Theory of statically indeterminate structures. Analysis of fuselage trusses, landing gear, wing beams. Structural details and connections. 3 cred.; prereq. 83; 2 lect. and 2 lab. hrs. per week. Cronk.

116—ADVANCED AIRPLANE STRESSES. Frames, space frameworks, secondary stresses, beams, columns, curved beams, rings, multispar and unit wing construction, monocoque fuselages. 3 cred.; prereq. 115 or M.&M. 180; 3 lect. hrs. per week. Wise.

117—ADVANCED AIRPLANE STRESSES. Analysis of thin-shelled plates and membranes used in aircraft wings and fuselages. Local, initial, thermal and combined stresses. Theories of failure. 3 cred.; prereq. 115; 3 lect. hrs. per week. Wise.

* May be taken out of sequence.

118—STRESSES ON AIRCRAFT STRUCTURES. Theory of flexure of flat plates. Bucklings of plates. Combined bendings and axial stress in plates. Application and design of seaplane floats and hulls. 3 cred.; prereq. 115; 3 lect. hrs. per week. Wise.

119—TESTING OF AIRCRAFT STRUCTURES AND MODELS. Theory of model studies. Mohr's circles of stress and circles of strain. Measurement of deflection. 3 cred.; prereq. 115; 2 lect. and 3 lab. hrs. per week. Wise.

120-121-122—AIRPLANE DESIGN. Design and stress analysis of aircraft structures involving beam-columns, thin-web beams, multi-cell wings, closed frames. Shell structures. 2 cred. per qtr.; prereq. 83, 102; 2 lect. hrs. per week. Upson.

123-124-125—ADVANCED AIRPLANE DESIGN. Problems in airplane design or development. 2 to 5 cred. per qtr.; prereq. 121. Staff.

126—AIRSCREW PROPULSION. Study of the theory common to the propulsive and lifting airscrews. Theory of the helicopter performance. 3 cred.; prereq. 120. Stolarik.

127-128—ADVANCED PROBLEMS IN AIRSCREW DESIGN. 2 to 5 cred. per qtr.; prereq. 126. Stolarik.

130—AERODYNAMIC DESIGN LABORATORY. Preliminary airplane design. 2 cred.; prereq. reg. in 120; 6 lab. hrs. per week. Stolarik and staff.

131-132—AIRPLANE DESIGN LABORATORY. Air loading analysis. Load factors. Structural design and analysis. 131 to be taken concurrently with 121. 132 to be taken concurrently with 122. 2 cred. per qtr.; 6 lab. hrs. per week. Stolarik and staff.

135—AIRPLANE STATIC TESTING. Theory and use of electrical strain gauges as applied to aircraft structures. Tests of wing structures and aircraft components. 2 cred.; prereq. 142; 1 lect. and 3 lab. hrs. per week. Staff.

140—AERONAUTICAL LABORATORY. Study of airplane parts and construction. Fittings. Rigging. Inspection and maintenance. 4 cred.; prereq. 142; 3 lect. and 3 lab. hrs. per week. Staff.

141—AERODYNAMICS LABORATORY. Wind tunnel test procedure. Calibration of wind tunnels. Wind tunnel testing of wings, propellers, and airplane models. 2 cred.; prereq. 101; 6 lab. hrs. per week. Cronk.

142—AIRCRAFT INSTALLATION I. Installation and function of airplane components and accessories. 2 cred.; prereq. 1; 1 lect. and 3 lab. hrs. per week. Staff.

143—AIRCRAFT INSTALLATION II. 3 cred.; prereq. reg. in 130; 1 lect. and 6 lab. hrs. per week. Staff.

155—AERONAUTICAL CALCULATIONS. Special methods in practice. 2 cred.; prereq. 5th yr.; 2 lect. hrs. per week. Cronk.

158—PHYSICS OF THE ATMOSPHERE. Physical properties of the air. Atmosphere, troposphere, and stratosphere. Basic effects on functioning of the human body, performance of aircraft. 2 cred.; prereq. 3rd yr.; 2 lect. and 1 rec. hr. per week. Staff.

164—PROBLEMS RELATING TO THE STRATOSPHERE. 3 cred.; prereq. 102; 3 lect. hrs. per week. Upson.

165-166-167*—ADVANCED AERONAUTICAL LABORATORY. Research problems in aeronautical engineering requiring laboratory of field research facilities. 2-4 cred.; prereq. 141 and permission of instructor; 1 lect. and 3 lab. hrs. per week. Akerman.

173—INTRODUCTORY METEOROLOGY. Survey of meteorological phenomena and physical principles; atmospheric statics, thermodynamics; equations for simple atmospheric motions. The laboratory work on principles involved. 3 cred.; prereq. 3rd or 4th yr.; 2 lect. and 3 lab. hrs. per week. Mantis.

174—APPLIED METEOROLOGY. Meteorological observation; the collection and dissemination of meteorological data. Elementary weather analysis and the interpretation of weather charts. 4 cred.; prereq. 173; 1 lect. and 6 lab. hrs. per week. Mantis.

175—ADVANCED METEOROLOGY. Physical meteorology. Atmospheric stability; heat balance; the equations of atmosphere hydrodynamics, cyclones and anticyclones. 4 cred.; prereq. 173; 3 lect. and 3 lab. hrs. per week. Mantis.

180—INSTRUMENTATION AND TECHNIQUES FOR SUPERSONIC FLOW. Principles of Mach cones and wedges, shadowgraph, Schlieren, interferometer, hot wire anemometer; problems. 2 cred.; prereq. 106 or M.E. 134; 1 lect. and 2 lab. hrs. per week. Bradfield.

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* May be taken out of sequence.

190-191-192*—SEMINAR. Readings, reports, conferences, and discussions. 1 cred. per qtr.; prereq. 101 or permission of instructor; 1 rec. hr. per week. Staff.

193-194-195—ADVANCED PROBLEMS IN AERONAUTICAL ENGINEERING. 2 to 6 cred. per qtr.; prereq. 5th yr. or grad. in aeronautical engineering. Staff.

201-202-203—AERODYNAMICS OF COMPRESSIBLE FLUID. Equations of motion. Thermodynamics; isentropic channel flow. Method of characteristics. The small perturbation method. The Busemann first and higher order approximations to pressure coefficient on aerodynamic surfaces. Aerodynamic characteristics of two-dimensional supersonic profiles. Extension of foregoing techniques to three dimensions. Finite wing theory. Conical flow. Applications to supersonic aircraft design. 3 cred. per qtr.; prereq. 106 or special permission; 3 lect. hrs. per week. Bradfield.

204—SUPERSONIC AERODYNAMICS LABORATORY. A laboratory course in supersonic wind tunnel operations, technique, and instrumentation. Flow study and model testing for static and dynamic characteristics in three supersonic wind tunnels at Rosemount Research Laboratory. 3 cred.; prereq. registration in 201 or M.E. 134; 2 lect. and 3 lab. hrs. per week. Staff.

208—AERODYNAMICS OF VISCOUS FLUIDS. Turbulent boundary layers, free turbulence and laminar stability in incompressible flow. Laminar and turbulent boundary layers in compressible flow with applications. 3 cred.; prereq. 107; 3 lect. hrs. per week. Leadon.

220—HIGH SPEED PERFORMANCE AND DESIGN. General principles of designing for performance. Compressibility corrections at subsonic speeds. Transonic effect. Supersonic possibilities and requirements. 3 cred.; prereq. 202 or special permission; 3 lect. hrs. per week. Upson.

230—AERODYNAMICS OF SUPERSONIC INLET DIFFUSERS. Diffuser types and pressure recovery. The one-dimensional normal shock diffuser. Various definitions of diffuser efficiency. Compression by one, two, or more oblique shocks. Two-dimensional diffuser for ramjets. Spike diffusers and pulsations. 3 cred.; prereq. 201 or M.E. 134; 3 lect. hrs. per week. Hermann.

231—AERODYNAMICS AND FLIGHT PERFORMANCE OF SUPERSONIC MISSILES. 3 cred.; prereq. 230; 3 lect. hrs. per week. Hermann.

232—AERODYNAMICS AND FLIGHT PERFORMANCE OF SUPERSONIC MISSILES. 3 to 5 cred.; prereq. 231 or special permission. Hermann.

238—JOINT SEMINAR (Aero.E., I.T.M.) Topics covered will vary from year to year and will be announced each time the course is given. 3 cred.; prereq. permission of instructors. Graduate staff Aeronautical Engineering and Mathematics.

240—DYNAMICS OF AIRCRAFT STRUCTURES. Fundamental principles of vibrations of spring supported masses, beams, trusses, and other structural forms; response of structures to suddenly applied forces and impulses; strength of structures under impactive and repeated forces; application to vibration and flutter of aircraft structures and components, and their response to blast or explosion, jet reaction, gust loads, landing loads, and similar dynamic forces. 3 to 5 cred. Wise.

241—DYNAMICS OF AIRCRAFT STRUCTURES. 3 cred.; prereq. 240. Wise.

272-273-274—RESEARCH IN AERONAUTICAL ENGINEERING. 3 to 6 cred. per qtr.; prereq. permission of instructor. Graduate staff.

280—THESIS. Cred. ar.; prereq. special permission of adviser.

For description of additional courses available to aeronautical engineers in the fields of:

Internal Combustion Engines, see M.E. 150A, 151A, 152, 153, 154, 156, 157, 158, 159, 250, 252, 253, 255, 257.

Electrical Engineering Survey and Aeronautical Radio, see E.E. 46-47.

Advanced Strength of Materials, see M.&M. 180, 181, 182, 183, 294, 295, 296.

Agricultural Biochemistry

(College of Agriculture, Forestry, and Home Economics)

119—COLLOIDS. Lectures and assigned readings dealing with the colloidal state of matter, the preparation and properties of colloidal systems, and the relation of these to biochemical processes. 3 cred.; prereq. 3, or 8 cred. in organic chemistry, Phys. 9 advised. Briggs.

* May be taken out of sequence.

129—COLLOIDS LABORATORY. Methods for the preparation, purification, and study of the physico-chemical properties of inorganic and biocolloid systems. 2 cred.; jr., sr., grad.; prereq. 2 or equiv., parallel 119. Briggs.

Agricultural Economics

(College of Agriculture, Forestry, and Home Economics)

25—PRINCIPLES OF ACCOUNTING. 4 cred.; soph., jr., sr. in this college only.

102—FARM ORGANIZATION. Characteristics of farming as a business; factors determining type of farming; tenure and selection; layout and improvements; factors affecting the selection of crops and livestock for a particular farm. 3 cred.; jr., sr., grad.; prereq. 2 or Econ. 8, 9. Pond.

107—FARM WORK SIMPLIFICATION. A study of principles and methods of accomplishing farm work in less time and with less effort. Methods of analyzing jobs, principles of motion economy, efficient working methods for different farm enterprises. Practice in planning improved working methods. 3 cred.; jr., sr., grad.; prereq. 2.

144—COOPERATIVE ORGANIZATION. Development of cooperation in agriculture in the United States and foreign countries. Analysis of economic problems peculiar to cooperative organization, especially of marketing agencies. 3 cred.; jr., sr., grad.; prereq. 40. Jesness.

Agricultural Engineering

(College of Agriculture, Forestry, and Home Economics)

8—LABORATORY. Engineering units and measurements. 1 cred.; no prereq.; 2 lab. hrs. per week.

9—LABORATORY. Engineering materials, their characteristics and use. 1 cred.; no prereq.; 2 lab. hrs. per week.

10—LABORATORY. Introduction to agricultural engineering applications. 1 cred.; no prereq.; 3 lab. hrs. per week.

18—AGRICULTURAL AUTOMOTIVES. Internal combustion engines and tractors including ignition, lubrication, carburetion, cooling, real gas cycles, transmission systems, and drive members. 3 cred.; prereq. M.E. 131; 2 lect. and 3 lab. hrs. per week. Strait, Keppel.

21—ELEMENTS OF SURVEYING. Use of tape, level, transit, traverse board in differential and profile leveling, cross sectioning, circular curves, topographic and agricultural surveys. Mapping, calculation of earthwork, and adjustments of instruments. 5 cred.; prereq. Draw. 6, I.T.M. 12; 1 lect. and 12 lab. hrs. per week. Manson.

36—RURAL SANITATION AND WATER SUPPLY. Wells, pumps, and water supply. Methods of securing sanitary water systems for farmsteads and rural institutions. Sanitary sewage disposal methods for homes, creameries, etc. 3 cred.; prereq. Hydr. 102; 3 lect. hrs. per week. Allred.

51—SOIL AND WATER CONSERVATION. Principles and practices of land drainage, soil erosion control, and water conservation in relation to plant growth, farm operation, land development, and community interest. 3 cred.; prereq. 21, Soil. 4, Hydr. 102 or reg. in Hydr. 102; 3 lect. hrs. per week. Manson.

52—ELEMENTS OF FARM MACHINERY. Principles of design, and economics of agricultural machines. Drawbar power. 3 cred.; prereq. M.E. 24; 1 lect., 1 rec., and 3 lab. hrs. per week. Schwantes.

53—FARM STRUCTURES. Planning and economics of farm buildings. Functional and structural requirements. 3 cred.; prereq. C.E. 32 and Econ. 9; 1 lect., 1 rec., and 3 lab. hrs. per week. Otis.

61—IRRIGATION. Principles and practices of irrigation in arid and humid regions in relation to plant growth. Design, cost, and construction of irrigation systems of all types. 3 cred.; prereq. 51; 3 lect. hrs. per week. Allred.

63—FARM STRUCTURES LABORATORY. Materials and construction methods used in farm buildings. Tests of materials and assemblies. 3 cred.; prereq. 53, M.&M. 141; 6 lab. hrs. per week. Otis.

73—STEAM BOILERS AND HEAT ENGINES. Steam boilers and heat engines in their applications to agriculture. A study of steam equipment, internal combustion engines, and refrigeration including properties of vapors, thermodynamics of theoretical and real cycles, heat transfer, operating principles, and performance characteristics. 3 cred.; prereq. 18 and M.E. 131; 2 lect. and 4 lab. hrs. per week. Strait.

106—AGRICULTURAL HYDROLOGY. Study of the hydrologic cycle and its component parts—precipitation, transpiration, evaporation, infiltration, and runoff. Measurement and estimation of runoff. Ground water hydrology. 3 cred.; prereq. 51 or registration in 51; 3 lect. hrs. per week. Manson, Larson. (Offered winter quarter in alternate years only, 1954, 1956.)

107—DRAINAGE, IRRIGATION, AND SOIL EROSION CONTROL DESIGN. Design and field layout of drainage, erosion control, and irrigation systems for the control and conservation of soil and water in agriculture. 4 cred.; prereq. 61 or registration in 61 and 106; 2 lect. and 6 lab. hrs. per week. Allred, Larson. (Offered spring quarter in alternate years only, 1954, 1956.)

111-112-113*—PROBLEMS IN AGRICULTURAL ENGINEERING. Special problems in soil moisture, farm buildings, farm power machinery, or rural electrification. 2 to 6 cred. per qtr.; prereq. permission of instructor. Staff.

125—TOPICS IN AGRICULTURAL PHYSICS. An advanced study of the essential physical principles involved in the utilization of electricity in agriculture. 3 cred.; prereq. 172, or integral calculus and 25 or equiv.; open to sr. or grad. Hustrulid.

126—MANAGEMENT OF AGRICULTURAL MACHINERY. Principles of power and machinery management. 3 cred.; prereq. 171, Ag.Econ. 102; 2 lect. and 3 lab. hrs. per week. Schwantes.

150—INSPECTION TRIP. During spring vacation of the senior year an inspection trip is made to observe activities, in agriculture and industry, that have agricultural engineering significance. Required of seniors in agricultural engineering. 1 cred.

167—ADVANCED FARM STRUCTURES. Design of structural members and assemblies for farm structures. Insulation and ventilation of animal shelters. Building equipment. 3 cred.; prereq. 63; 1 lect., 1 rec., and 3 lab. hrs. per week. Otis.

171—DESIGN OF AGRICULTURAL MACHINERY. Operating principles and problems in design of agricultural machines. 3 cred.; prereq. 52, and M.E. 121; 1 lect. and 6 lab. hrs. per week. Strait.

172—APPLIED ELECTRICITY. A study of topics important in the application of electric power to agriculture, including instruments, farmstead wiring, lighting, motors and controls, control circuits, and storage batteries. 3 cred.; prereq. E.E. 37; 2 lect. and 4 lab. hrs. per week. Hustrulid.

211-212-213*—ADVANCED PROBLEMS AND RESEARCH. Research problems in agricultural engineering. 2 to 6 cred.; prereq. 111, 112, 113. Staff.

Agronomy and Plant Genetics

(College of Agriculture, Forestry, and Home Economics)

1—GENERAL FARM CROPS. Adaptation, distribution, production, and uses of the important field crops of the United States. 3 cred.; no prereq.

21—GRAIN CROPS. Production, improvement, and uses of corn, small grains, and oilseed crops. Lect. and lab. work. 4 cred.; soph., jr., sr.; prereq. 1.

23—FORAGE CROPS. Distribution, characteristics, production, preservation, and uses of forage crops. Lect. and lab. work. 4 cred.; soph., jr., sr.; prereq. 1.

135—WEED CONTROL. Cultural and chemical methods of weed control; weed and seed laws pertaining to dissemination and control. Lect., lab., and field work. 3 cred.; jr., sr., grad.; prereq. 1 and Pl.Path. 3. Same as Pl.Path. 135.

Air Science and Tactics (Air ROTC)

The Department of the Air Force will offer a four- (4-) year program consisting of Air Science I, II, III, IV, leading to a commission in the Air Force Reserve. The program is offered as a university elective enabling students to qualify for an Air Force Reserve Commission concurrently with enrolment in any of the undergraduate courses offered by the University. Students accepted for the Air ROTC program must be enrolled in a four-year

* May be taken out of sequence.

or longer college course and meet the physical and age requirements established by the Air Force.

The four years encompass a course designed to give the student a well-rounded background in Air Force activities and operations which he will encounter as an officer. These courses are Introduction to Aviation, Applied Air Science, Aerial Warfare, Global and Political Geography, Communications and Effective Writing, Military Law, Principles of Leadership, and various short courses in officer orientation. During the student's summer encampment between his third and fourth years, he will learn Air Force organization and the functions of an Air Force base with familiarization training in weapons and flying.

Air Science and Tactics courses carry college credits of 1 credit per quarter for AS I and AS II; and, 3 credits per quarter for AS III and AS IV.

During the last two years, students are paid approximately $27 per month. During the summer encampment period, they are paid at the rate of $78 per month plus travel, food, shelter, and clothing.

Students enrolling in the program may be deferred from service under Selective Service and U.M.T. until the completion of their undergraduate college program within quotas established by the Air Force. Subsequent service, if directed by the President of the United States, would be performed in a commissioned officer grade.

Students, upon completion of the course, are encouraged to apply for flight training in a commissioned officer grade if they meet the age and physical requirements.

Further information may be obtained from the professor of Air Science and Tactics, Room 1, Armory.

Animal Husbandry

(College of Agriculture, Forestry, and Home Economics)

1—LIVESTOCK PRODUCTION. Opportunities and problems in livestock production. Survey of practices followed in the production of beef cattle, sheep, swine, and horses. Lectures and laboratory practice in classifying and appraising livestock. 4 cred.; jr., sr.; no prereq.; 3 lect. and 2 lab. hrs. per week. Harvey.

56—LIVESTOCK FEEDING I. A study of the nutritional requirements of farm animals and the composition and characteristics of livestock feeds. Differences in the utilization of feeds by ruminants and non-ruminants. 3 cred.; jr., sr.; prereq. 1. L. E. Hanson.

57—LIVESTOCK FEEDING II. The values of individual feeds and of combinations of feeds for beef cattle, sheep, swine, and horses. The feeding of farm livestock for the most economical production of livestock products. 3 cred.; jr., sr.; prereq. 56. L. E. Hanson, R. M. Anderson.

Architecture

HISTORY AND THEORY

1—INTRODUCTION TO ARCHITECTURE. Discussions and problems to inform prospective students of the nature of architecture as an art and a profession. 1 cred.; prereq. permission of instructor; 1 rec. hr. per week. McClure.

51-52-53—HISTORY OF ARCHITECTURE. Significant architecture of the past, with particular reference to the geographic, social, and technical influences which produced it. 4 cred. per qtr.; prereq. 3rd yr.; 4 lect. and conf. hrs. per week. Koeper.

57-58-59—BUILDING MATERIALS AND METHODS. Principles, methods, and materials involved in the standard types of building construction. 4 cred. per qtr.; prereq. 3rd yr.; 4 lect. hrs. per week.

71-72-73—BUILDING EQUIPMENT. Mechanical, electrical, acoustical, and sanitary equipment of buildings. 3 cred. per qtr.; prereq. 3rd yr.; 4 lect. and conf. hrs. per week. Close and associates.

101-102-103—TUTORIAL WORK IN HISTORY OF ARCHITECTURE. 2 cred. per qtr.; prereq. 53 and 4th yr. standing or above; 1 conf. and 5 research hrs. per week. Koeper.

104—CITY PLANNING. Same as Econ. 111, Pol.Sci. 123, Soc. 106. Social, economic, political, and technical phases of modern city planning. 3 cred.; prereq. 4th yr. standing or above; 3 lect. hrs. per week. Anderson, Chapin, Filipetti, Vaile, and associates.

105—PROFESSIONAL RELATIONS. Relations of the architect to clients, contractors, and fellow practitioners; procedures of architectural practice. 3 cred.; prereq. 4th yr. standing; 2 two-hr. seminars per week. Cavin.

106—CITY PLANNING. Technical phases of modern city planning, with special reference to the architect's functions therein. 3 cred.; prereq. 104 and 4th yr. standing or above; 3 conf. hrs. per week.

For courses required of architectural students in applied mathematics, structural design, drawing and painting see: I.T.M. 91, M.&M. 92-93, Calculus, Mechanics, and Mechanics of Materials, in Departments of Applied Mathematics and Mechanics and Materials; C.E. 38-39-41, Structural Design for Architects, in Department of Civil Engineering; Art 23A, 24A, 25A, 60A-61A-62A in Department of Art in College of Science, Literature, and the Arts.

DESIGN

Completion of these courses is dependent upon achievement rather than time. Students will continue their registration until the course is completed and a mark is reported. An acceptable quality of work normally allows a rate of progress as indicated for each course.

The objective of the courses in architectural design is to develop the individual student's skill in creative effort as applied to the production of architecture. They provide opportunity for the student to exercise himself in all necessary phases of that creative effort, including especially research, composition, construction, and representation as four essential and interrelated parts of one unified process.

The courses consist of a series of problems, classified into several stages of advancement called grades, and culminating in a thesis whose satisfactory completion is a prerequisite for the degree in architecture. Most problems are done under criticism in which critics representing the several phases involved will collaborate. Certain problems are done entirely without criticism, in order to develop and test more fully the student's own power of independent achievement.

A certain amount of specialization in various phases of architectural design and practice may be accomplished by means of optional problems or course substitutions in AD-IV, and by the choice of a thesis subject in AD-V.

Grade I normally may be entered only at the beginning of the fall quarter. Work in all other grades is carried on simultaneously and continuously. A student may enter or leave them at any time he is judged ready to do so. They are administered by a design committee consisting of the major and consulting critics of which the head of the school is chairman. See also *Statement Concerning Courses in Architectural Design* issued by the School of Architecture.

In addition to the prerequisites indicated below, enrolment in these courses is subject to specific approval by the School of Architecture and to limitation by the work space and instructional facilities available.

Major critics: Cerny, McClure, Vivrett, Bliss, Cavin, Graffunder, and associates. Consulting critics: ———— (City Planning), ———— (Construction), Heath (Graphics and Construction), Graves (Structural Design), Close (Building Equipment), Koeper (Architectural History), Tovish (Painting and Sculpture), and associates.

AD-I—ARCHITECTURAL DESIGN, GRADE I. 18 cred. (normally 6 cred. per qtr.); prereq. 2nd yr. standing for Institute of Technology students, 3rd yr. standing for Science, Literature, and the Arts students; 18 lab. hrs. per week.

AD-II—ARCHITECTURAL DESIGN, GRADE II. 18 cred. (normally 6 cred. per qtr.); prereq. AD-I; 18 lab. hrs. per week.

AD-III—ARCHITECTURAL DESIGN, GRADE III. 24 cred. (normally 8 cred. per qtr.); prereq. AD-II; 24 lab. hrs. per week.

AD-IV—ARCHITECTURAL DESIGN, GRADE IV. 18 cred. (normally 9 cred. per qtr.); prereq. AD-III; 27 lab. hrs. per week.

AD-V—ARCHITECTURAL THESIS. 12 cred.; prereq. AD-IV; 36 lab. hrs. per week.

Astronomy

(College of Science, Literature, and the Arts)

20—ASTRONOMY FOR CELESTIAL NAVIGATION. Deals with the principles and the practice of navigation of planes and ships by using the stars in the sky. Includes some dead reckoning. 5 cred.; no prereq.; 4 lect. and 1 three-hr. lab. per week.

51—GENERAL ASTRONOMY. Fundamental facts and principles of astronomy. 3 cred.; prereq. I.T.M. 12; 3 rec. hrs. per week. Luyten.

101*—CELESTIAL MECHANICS. A course dealing with Newton's law of gravitation and its application to astronomy, especially planetary motions. 3 cred.; prereq. I.T.M. 25; 3 rec. hrs. per week. Luyten.

140*—METHODS OF LEAST SQUARES. Combination and adjustment of observations and the discussion of their precision as applied to engineering, physics, astronomy, and psychology. 3 cred.; prereq. 51 or 11 and I.T.M. 24. Luyten.

Bacteriology and Immunology

(Medical School)

53—GENERAL BACTERIOLOGY. Lectures, demonstrations, and laboratory exercises are employed for instruction in the morphology, physiology, taxonomy, and ecology of bacteria. The practical applications of these fundamental principles in other phases of science and industry are emphasized. 5 cred.; soph. with a C average in the prerequisite courses, jr., sr.; prereq. 10 cred. in chemistry and 4 cred. in biological sciences or permission of instructor. Staff.

121—PHYSIOLOGY OF BACTERIA. A detailed study covering the following topics: chemical and physical structure; staining; growth; influence of environment on growth; nutrition; enzymes; metabolism. 3 cred.; prereq. 53 (min. grade C), 8 cred. in organic chemistry or biochemistry; required of all graduate students in bacteriology and open to others by permission of instructor. Lichstein.

122—PHYSIOLOGY OF BACTERIA LABORATORY. Special techniques employed in the study of bacterial physiology and metabolism. 3 cred.; prereq. 121; required of all graduate students in bacteriology and open to others by permission of instructor. Lichstein.

123—BACTERIAL METABOLISM. An advanced treatment of several broad aspects of metabolism including: enzymes; biological energy; fermentation; respiration; nitrogen metabolism; photosynthesis. 3 cred.; prereq. 121-122 or equiv., introductory biochemistry; required of all graduate students in bacteriology and open to others by permission of instructor. Lichstein. (Offered 1953-54 and alternate years.)

Botany

(College of Science, Literature, and the Arts)

1-2-3—GENERAL BOTANY. A survey lecture and laboratory course on the form, structure, and functions of plants; reproduction in plants and the principle of inheritance and variation; relation of plants to environment; the principal groups of plants; organic evolution. 10 cred.; no prereq.; 2 lect. and 4 lab. hrs. per week.

Chemical Engineering

80—CHEMICAL ENGINEERING MATERIALS. The application of general chemical principles, physical and chemical properties of materials, and economic considerations in the selection of materials of construction for chemical engineering equipment and plants. Metals and alloys, woods, cement, ceramics, plastic materials, textiles, rubber, protective materials, etc. 2 cred.; prereq. Inorg.Chem. 12; 2 lect. hrs. per week. Preckshot.

100—CHEMICAL ENGINEERING STOICHIOMETRY. 3 cred.; prereq. Anal.Chem. 1, 2; 3 lect. and rec. hrs. per week. Ceaglske.

* Courses 101 and 140 are usually offered in alternate years, and only one will be given in each year, depending on the demand. No student should register for this course without first consulting the instructor.

101—UNIT OPERATIONS. Fundamental principles of unit operations, materials of construction, performance and uses of equipment, fluid flow, and filtration. 3 cred.; prereq. 3rd yr.; 2 lect. and 2 rec. hrs. per week. Stoppel, Amundson, Earle.

102—UNIT OPERATIONS. Continuation of 101 on heat transfer, evaporation, solid-liquid and liquid-liquid extraction. Their applications and the solution of problems. 5 cred.; prereq. 101; 3 lect. and 3 rec. hrs. per week. Stoppel, Amundson, Earle.

103—UNIT OPERATIONS. Continuation of 101 and 102 on drying, distillation, absorption, and humidification, with problems. 5 cred.; prereq. 102; 3 lect. and 2 rec. hrs. per week. Stoppel, Amundson, Earle.

104—UNIT OPERATIONS. An elective course primarily for undergraduates to include topics sparsely covered or not considered in 101-102-103. 3 cred.; prereq. 103; 3 lect. and rec. hrs. per week. Preckshot.

111—UNIT OPERATIONS LABORATORY. 2 cred.; prereq. 101; 4 lab. hrs. per week. Preckshot, Madden, Earle.

112—UNIT OPERATIONS LABORATORY. 2 cred.; prereq. 102; 4 lab. hrs. per week. Preckshot, Madden, Earle.

113—UNIT OPERATIONS LABORATORY. 2 cred.; prereq. 103; 4 lab. hrs. per week. Preckshot, Madden, Earle.

117-118—CHEMICAL ENGINEERING PROCESS AND PLANT DESIGN. Several phases of chemical engineering training including unit operations, reaction kinetics, economic balance and market survey are combined to develop from laboratory and literature data an economic and technically sound industrial process for a projected chemical product. Equipment and plant layout prepared. Cost analyses. 3 cred. per qtr.; prereq. 103; 6 lab. hrs. per week. Piret.

119-120—CHEMICAL ENGINEERING THERMODYNAMICS. A study of the principles of the three fundamental laws of energy as applied to chemical engineering problems. 3 cred.; prereq. 103; 2 lect. and 2 rec. hrs. per week. Isbin, Preckshot.

121—CHEMICAL ENGINEERING ECONOMICS. Economic factors affecting plant location, layout, and design. Unit operation costs. Principles of management, operation, and control. 3 cred.; prereq. 131; 3 lect. hrs. per week.

131-132—INDUSTRIAL TECHNOLOGY. Introduction to the principles of reactor design for homogeneous and heterogeneous reactions. The analysis of several chemical process industries from both the organic and inorganic fields, including such factors as raw materials employed, unit operations and reactor design principles involved, materials of construction of equipment used, by-products produced, other economic factors, safety considerations. 3 cred. per qtr.; prereq. 103; 3 lect. hrs. per week. Madden.

151†—CHEMICAL MANUFACTURE (INORGANIC). Manufacture of technical products on a scale large enough to afford data for the determination of operating conditions and costs of manufacture. Use of semi-plant scale equipment. Technical trade journals used. Laboratory. 3 cred.; prereq. 103, 131. Staff. (Offered 1954 and alternate years.)

152†—CHEMICAL MANUFACTURE (ORGANIC). Similar to 151 but covering the unit organic processes. Laboratory. 3 cred.; prereq. 103, 132. Staff. (Offered 1954 and alternate years.)

153-154-155-156*—SPECIAL PROBLEMS. Investigations in chemical engineering. Library or laboratory research. 3 or more cred. per qtr.; 1 conf. hr. per week, lab. hrs. ar. Staff.

171-172—PROCESS CONTROL. Theory and application of instrumentation and control with particular emphasis on application to the chemical industry, including analytical methods. 3 cred. per qtr.; prereq. 4th or 5th yr. or permission; 3 lect. and rec. hrs. per week (171), 2 lect. and 3 lab. hrs. per week (172). Ceaglske.

176—APPLIED ELECTROCHEMISTRY. Laws and phenomena of electrochemistry including batteries, electroplating, electric furnace operation, and electrochemical products. 3 or 4 cred. per qtr.; prereq. Phys.Chem. 103, or by permission; 3 lect., or 3 lect. and 4 lab. hrs. per week. Madden.

181-182-183*—SENIOR THESIS. Independent laboratory work combined with library research and presentation of oral and written reports on a comprehensive problem. 3 cred. per qtr.; prereq. 5th yr., honor point average greater than 1.5; 9 lab. and 1 rec. hrs. per week. Staff.

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* May be taken out of sequence.

† Undergraduate chemical engineers are required to enroll during the Summer Session of either the fourth or fifth years since the course is offered in alternate years. Open only to graduate students in fall and winter.

187—INSPECTION TRIP. Various industrial plants in the Middle West are visited by the class on a trip, which lasts about six days, during the spring vacation period. A written report covering the plants visited must be submitted. 2 cred.; prereq. 131 and 132; required of 4th yr. chemical engineers. Staff.

201-202-203*—SEMINAR. Presentation and discussion of papers concerning the newer developments in chemical engineering. 1 cred. per qtr. Staff.

205-206-207*—ADVANCED UNIT OPERATIONS. A study of basic principles and of new developments in the unit operations. Theory and applications to equipment and process design including economic balance problems. 3 cred. per qtr.; prereq. 103 and permission. Piret. (Offered 1954-55; alternates with 208-209-210.)

208-209-210*—ADVANCED UNIT OPERATIONS. An extended study of the principles of chemical engineering and their applications to industrial problems. Survey of the literature. 3 cred. per qtr.; prereq. 103 and permission. Piret, Madden. (Offered 1953-54; alternates with 205-206-207.)

211-212-213—ADVANCED PROCESS AND PLANT DESIGN. A technically and economically feasible plant for the projected chemical product is designed from data from the literature and laboratory and the considerations of the interdependent and controlling unit operations, reaction kinetics, materials of construction, economics of plant location, raw materials and process operations and market surveys. 3 cred. per qtr.; prereq. 103 or permission; 6 lab. hrs. per week.

214-215-216—ADVANCED MATHEMATICS FOR CHEMICAL ENGINEERS AND CHEMISTS. Numerical analyses; ordinary and partial differential equations; Fourier series and special functions; finite difference equations; partial differentiation. Theory of heat conduction and diffusional operations. 3 cred. per qtr.; prereq. differential equations; 3 lect. and rec. hrs. per week. Amundson. (Offered 1954-55; alternates with 225-226-227.)

217—ANALYSIS OF CHEMICAL ENGINEERING PROBLEMS. A critical analysis of current chemical engineering literature. 3 cred.; prereq. concurrent registration in 216; 3 lect. hrs. per week. Amundson.

218-219*—ADVANCED TOPICS IN CHEMICAL ENGINEERING. 3 cred. per qtr.; 3 lect. hrs. per week.

220—ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS. An advanced course covering chemical engineering applications. 3 cred.; prereq. 120 or permission; 3 lect. and rec. hrs. per week. Preckshot.

221-222*—REACTION KINETICS IN CHEMICAL ENGINEERING. Applications of the principles of reaction kinetics to chemical engineering process development. 3 cred. per qtr.; prereq. permission of instructor; 3 lect. and rec. hrs. per week. Piret. (Offered 1953-54 and alternate years.)

225-226-227—FLUID FLOW AND RELATED TOPICS. A fundamental course covering advanced topics in viscous and turbulent fluid flow, eddy diffusion, and heat transfer. 3 cred. per qtr.; prereq. permission; 3 lect. and rec. hrs. per week. Amundson. (Offered 1953-54; alternates with 214-215-216.)

231-232-233—NUCLEAR REACTOR DESIGN. An engineering approach to the development and application of nuclear reactor theory including designs of homogeneous and heterogeneous reactors, with special emphasis on heat transfer and fluid flow problems. 3 cred. per qtr.; prereq. permission; 3 lect. and rec. hrs. per week. Isbin.

264—GENERAL SURVEY OF CHEMICAL ENGINEERING. A course of independent reading under the guidance of the staff. This course is a prerequisite to candidacy for the Ph.D. degree with major or minor in chemical engineering and an examination must be taken by the end of the fall quarter of the second year in residence. 1 cred.; prereq. permission of instructor. Staff.

301-302-303*—RESEARCH IN CHEMICAL ENGINEERING. Unit operations, applied unit processes, electrochemistry and electric furnace work, and chemical manufacture. Cred. ar. Amundson, Ceaglske, Piret, Stoppel, Isbin, Madden, Preckshot.

Chemistry

ANALYTICAL CHEMISTRY

1-2†—QUANTITATIVE ANALYSIS. Introductory courses covering the general principles and methods of quantitative analysis. Typical problems are assigned and attention given to proper laboratory practice. Course 1, Gravimetric Analysis. Course 2, Volu-

* May be taken out of sequence.

† Course 2 may precede 1 if necessary.

metric Analysis. 5 cred. per qtr.; prereq. Inorg.Chem. 13 (for chemists), Inorg.Chem. 12 (for chem. eng.); 1 lect., 1 rec., 1 quiz, and 9 lab. hrs. per week. Meehan, Herr.

7—QUANTITATIVE ANALYSIS. (Premed.) Introductory course covering the general principles and methods of quantitative analysis, both gravimetric and volumetric. Typical problems are assigned and attention is given to proper laboratory practice. 4 cred.; prereq. Inorg.Chem. 11 or 12; 1 lect., 1 rec., 1 quiz, and 9 lab. hrs. per week. Meehan and ar.

9—QUANTITATIVE ANALYSIS. (Dentists, engineers, miners.) Short introductory course covering general principles of quantitative analysis, both gravimetric and volumetric. Typical problems are assigned and attention given to proper laboratory practice. 3 cred.; prereq. Inorg.Chem. 11 or 12; 1 lect., 1 rec., and 6 lab. hrs. per week. Ar.

96-97-98*—SENIOR THESIS. 5 cred. per qtr.; 5th yr. Kolthoff, Sandell, Meehan.

101-102*—QUANTITATIVE ANALYSIS. General principles, methods, and procedure of quantitative analysis, both gravimetric and volumetric. Typical problems are assigned and attention given to proper laboratory practice. 5 cred. per qtr.; prereq. Inorg.Chem. 13; 1 lect., 1 rec., 1 quiz, and 9 lab. hrs. per week. Meehan.

103—QUANTITATIVE INORGANIC MICROANALYSIS. Representative methods of micro- and semi-microgravimetric, volumetric, and colorimetric analysis. 3 cred.; prereq. 1, 2; 1 lect. and 6 lab. hrs. per week; class limited to 16 students. Sandell.

104—QUALITATIVE INORGANIC MICROANALYSIS. Use of microscope. Technique of handling small amounts of materials, inorganic qualitative analysis by means of crystal reactions and modern spot reactions. 3 cred.; prereq. 1, 2; 1 lect. and 6 lab. hrs. per week. Sandell.

105—POLARIZING MICROSCOPE. Its use and application to chemistry. Identification of substances. 3 cred.; prereq. Phys.Chem. 101; 1 lect. and lab. hr. ar. per week. Sandell.

106-107-108*—GENERAL TECHNICAL ANALYSIS. Analysis of commercially important materials such as iron, steel, nonferrous alloys, ores, and glass; use of microscope in technical problems; quantitative analysis of heterogeneous mixtures, particle size determinations. 2 or 3 cred. per qtr.; prereq. 1, 2; 1 lect. and lab. hrs. ar. per week. Sandell.

109—ROCK ANALYSIS. Laboratory course covering the technique of rock analysis. 3 cred.; prereq. 1, 2 and permission of instructor. Goldich.

122—ADVANCED ANALYTICAL CHEMISTRY. Condensed review of modern fundamentals of gravimetric and volumetric analysis. 2 cred.; prereq. 1, 2; 2 lect. hrs. per week. Meehan.

123—ADVANCED ANALYTICAL CHEMISTRY. Analysis of complex materials by modern methods. 3 cred.; prereq. 1, 2, or by permission; 1 lect. and 6 lab hrs. per week. Meehan.

127—OPTICAL METHODS IN ANALYTICAL CHEMISTRY. 2 cred.; prereq. Phys. Chem. 103; 2 lect. hrs. per week. Meehan.

131—APPLICATIONS OF INDICATORS IN NEUTRALIZATION REACTIONS AND pH DETERMINATIONS. 2 cred. without lab., 3 cred. with lab.; prereq 1, 2, and Phys.Chem. 103; 2 lect. and 3 lab. hrs. per week. Kolthoff.

132§—ELECTROMETRIC MEASUREMENTS AND TITRATIONS. Application of potentiometric and conductometric methods in analytical work. 2 cred. without lab., 3 cred. with lab.; prereq. 1, 2, and Phys.Chem. 103; 2 lect. and 3 lab. hrs. per week. Kolthoff.

133—VOLTAMMETRY AND AMPEROMETRIC TITRATIONS. A lecture course. A discussion of the use of the dropping mercury electrode (polarograph) and the platinum microelectrode in pure and applied chemistry. 2 cred.; prereq. 1, 2 and Phys.Chem. 103; 2 lect. hrs. per week. Kolthoff.

134—VOLTAMMETRY AND AMPEROMETRIC TITRATIONS. A laboratory course. 2 cred.; prereq. cred. in, or registration in 133; 6 lab. hrs. per week. Kolthoff.

135-136-137*—SEMINAR: MODERN PROBLEMS IN ANALYTICAL CHEMISTRY. 1 cred. per qtr.; prereq. 1, 2, and Phys.Chem. 103; 1 lect. hr. per week. Kolthoff.

138—ADVANCED VOLUMETRIC ANALYSIS. 3 cred.; prereq. 131; 2 lect. and lab. hrs. ar. per week. Kolthoff.

140—WATER ANALYSIS. Analysis of potable water with interpretation of results. 2 cred.; prereq. 1, 2. Sandell.

201-202-203*—SELECTED TOPICS IN ANALYTICAL CHEMISTRY. 3 cred. per qtr.; prereq. 1, 2, and 123. Kolthoff.

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* May be taken out of sequence.

§ Anal.Chem. 105 may be substituted for Anal.Chem. 132.

262—GENERAL SURVEY OF ANALYTICAL CHEMISTRY. A course of independent reading under the guidance of the staff. This course is a prerequisite to candidacy for the Ph.D. degree in any field of chemistry and an examination must be taken by the end of the fall quarter of the second year in residence. 1 cred.; prereq. permission of instructor.

301-302-303*—RESEARCH IN QUANTITATIVE ANALYSIS. Cred. ar. Kolthoff, Meehan, Sandell.

INORGANIC CHEMISTRY

1-2—GENERAL INORGANIC CHEMISTRY. (Agr., S.L.A., predent., premed., eng., and mines without high school chem.) Study of the general laws of chemistry and of the nonmetals and metals and their compounds. 4 cred. per qtr.; no prereq.; 3 lect., 1 quiz, and 4 lab. hrs. per week. Pervier, Pray.

4-5—GENERAL INORGANIC CHEMISTRY. Study of the general laws of chemistry and of the nonmetals and their compounds. More intensive than Course 1-2. 4 cred. per qtr.; prereq. high school chemistry; 3 lect., 1 quiz, and 4 lab. hrs. per week. (Students doing unsatisfactory work in this course will be required to take two additional hours per week.) Brasted, Johnson, Maynard.

6-7—GENERAL INORGANIC CHEMISTRY. Study of the general laws of chemistry and of nonmetals, metals, and their compounds. 5 cred. per qtr.; no prereq.; 3 lect., 1 quiz, and 5 lab. hrs. per week. Johnson, O'Brien.

9§-10—GENERAL INORGANIC CHEMISTRY. Study of general laws of chemistry and of nonmetals, metals, and their compounds. 5 cred. per qtr.; prereq. one year of high school chemistry; 3 lect., 1 quiz, and 5 lab. hrs. per week. Sneed.

11—SEMIMICRO QUALITATIVE ANALYSIS. Laboratory work in systematic qualitative analysis of cations with lectures on solutions, ionization, chemical and physical equilibria, oxidation and reduction, etc. 4 cred.; prereq. 2, 5, 7, or 10; 3 lect. and 4 lab. hrs. per week. Brasted, Heisig, Hugus, Maynard, Pervier.

12-13—SEMIMICRO QUALITATIVE ANALYSIS. Laboratory work in systematic qualitative analysis of the cations in 12 and of the anions in 13 with lectures on solutions, ionization, chemical and physical equilibria, oxidation and reduction, etc. 5 cred. per qtr.; prereq. 2, 5, 7, or 10; 3 lect. and 6 lab. hrs. per week for Course 12; 2 lect., 1 quiz, and 8 lab. hrs. per week for Course 13. Sneed, Brasted, Heisig, O'Brien.

14-15—INORGANIC CHEMISTRY. This course is designed for and limited to students enrolled in the College of Engineering (other than chemical engineering and mining engineering). Fundamental principles and survey of inorganic chemistry. 4 cred.; prereq. Phys. 11, 12, or permission by head of Division of Inorganic Chemistry; 3 lect., 1 rec., 1 quiz, and 3 lab. hrs. per week. Heisig, Hugus.

52-53-54*—SEMINAR: MODERN PROBLEMS IN INORGANIC CHEMISTRY. 1 cred. per qtr.; prereq. 5th yr. Staff.

96-97-98*—SENIOR THESIS. 5 cred. per qtr. Staff.

102—SEMIMICRO QUALITATIVE ANALYSIS. A course designed to acquaint the student with the universally applicable method and underlying principles in the identification of the more common cations by use of drop reactions on spot plate and filter paper, and separation by use of the centrifuge. 3 cred.; prereq. Anal.Chem. 1, 2. Heisig.

103-104-105*—ADVANCED INORGANIC CHEMISTRY. (Fall) Atomic structure and the properties of elements based thereon. (Winter) Chemistry of the more representative elements. (Spring) Coordination compounds. 3 cred. per qtr. (104, 4 cred. for grad. students); prereq. Anal.Chem. 1, 2, Org.Chem. 62; 3 lect. hrs. per week. O'Brien, Brasted, Maynard.

106-107*—CHEMISTRY OF THE LESS FAMILIAR ELEMENTS. 3 cred. per qtr.; prereq. Anal.Chem. 1, 2, Org.Chem. 62; 3 lect. hrs. per week. O'Brien, Hugus. (106 offered alternate years; not offered 1953-54.)

108—NONAQUEOUS SYSTEMS. A study of the principal nonaqueous systems, both protonic and aprotonic systems. The theories of Bronsted, Lewis, and Usanovich are considered in detail. 3 cred.; prereq. Anal.Chem. 1, 2, Org.Chem. 62; 3 lect. hrs. per week. Pray.

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* May be taken out of sequence.

§ Students who have failed in 1, 4, 6, or 9 may register for this course without further prerequisite.

109—SYNTHETIC INORGANIC CHEMISTRY. Methods of preparation and purification of inorganic compounds of special interest. Current literature. 3 to 5 cred.; prereq. Org.Chem. 63; 2 lect. hrs. with lab. Heisig.

111—SILICON AND RELATED ELEMENTS. Review of current studies on boron, silicon, germanium, tin, and lead, with emphasis on recent silicon chemistry. 3 cred.; prereq. Anal.Chem. 1, 2, Org.Chem. 62; 3 lect. hrs. per week. Johnson.

134-135-136*—SEMINAR: MODERN PROBLEMS IN INORGANIC CHEMISTRY. 1 cred. per qtr.; prereq. grad. Staff.

161—NUCLEAR CHEMISTRY AND RADIOACTIVITY. The properties of nuclei, disintegration, properties of radiations; natural and artificial radioactivity; modern views of nuclear structure. 3 cred.; prereq. Phys.Chem. 103; 3 lect. hrs. per week. O'Connor.

231—RADIOACTIVITY LABORATORY. Use and standardization of electroscopes and Geiger-Muller tubes; radioactive measurements; chemistry of trace quantities. 1 or 2 cred.; must be preceded or accompanied by 161. O'Connor.

260—GENERAL SURVEY OF INORGANIC CHEMISTRY. A course of independent reading under the guidance of the staff. This course is a prerequisite to candidacy for the Ph.D. degree in any field of chemistry and an examination must be taken by the end of the fall quarter of the second year in residence. 1 cred.; prereq. permission of instructor. Staff.

262—RADIOACTIVITY SEMINAR. 3 cred. O'Connor.

301-302-303*—RESEARCH IN INORGANIC CHEMISTRY. Cred. ar. Staff.

ORGANIC CHEMISTRY

16—CARBON COMPOUNDS. (Engineers, except Chemical Engineers and Mining Engineers.) A brief discussion of the carbon compounds, with special emphasis upon those useful as engineering materials, together with the processes by which such compounds are made. 4 cred.; prereq. Inorg.Chem. 15; 4 lect. hrs. per week. (This course cannot be substituted for Org.Chem. 61 or 62.) Arnold.

61-62†—ELEMENTARY ORGANIC CHEMISTRY. (Chem., Chem.E., premed., predent., pharm.) Discussion of important classes of organic compounds, both aliphatic and aromatic together with some heterocyclic compounds. Laboratory work includes the preparation of typical substances. 4 cred. per qtr.; prereq. 12-15 cred. in chem.; 3 lect., 1 lab. conference, 1 quiz, and 4 lab. hrs. per week. Koelsch, Fenton, Noland.

63—ELEMENTARY ORGANIC CHEMISTRY. Lecture course. Continuation of 61-62. This course is prerequisite to all other advanced courses in organic chemistry. 3 cred.; prereq. 62; 3 lect. and 1 quiz hr. per week. Parham.

64—ELEMENTARY ORGANIC CHEMISTRY LABORATORY. To accompany or follow Course 63. This course is prerequisite to all advanced courses in organic chemistry. 3 cred.; prereq. cred. or reg. in 63; 6 lab. hrs. and 1 conf. hr. per week. Parham.

96-97-98*—SENIOR THESIS. 5 cred. per qtr.; sr.; prereq. 63 and 64. May be taken with any member of the staff of the Division of Organic Chemistry.

101—INTERMEDIATE ORGANIC CHEMISTRY. A survey course in which are considered important modern topics such as unusual types of aliphatic, aromatic, and heterocyclic compounds, natural products, and industrial processes. 3 cred.; prereq. 14 cred. in organic chemistry; 3 lect. hrs. per week. Lauer.

102—CHARACTERIZATION OF ORGANIC COMPOUNDS. (Elementary course.) An introduction to the methods of organic qualitative analysis. 4 cred.; prereq. one year of organic chemistry; 1 lect. and 6 lab. hrs. per week. Fenton.

105-106-107—ADVANCED ORGANIC CHEMISTRY. Advanced descriptive course covering the field of organic chemistry, together with an introduction to the literature of organic chemistry. Lectures and outside reading. Ability to read German is assumed. 3 cred. per qtr.; prereq. 63 and 64; 3 lect. hrs. per week. Smith.

108—PHYSICAL TECHNIQUES IN ORGANIC CHEMISTRY. Discussion of physical methods as applied to the identification and structural analysis of organic compounds. 3 cred.; prereq. 63 or permission of instructor; 5 lect. hrs. per week. Fenton. (Offered in Summer Session only.)

110—ADVANCED ORGANIC QUALITATIVE ANALYSIS. For graduate students. 4 cred.; prereq. 102 and permission of instructor; 9 lab. hrs. per week. Koelsch.

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* May be taken out of sequence.

† To receive credit for any part of this course a student must complete the parts preceding the dagger.

116—HETEROCYCLIC COMPOUNDS. Discussion of typical classes of heterocyclic compounds, their chemical and physical properties and uses, and the ring closures leading to heterocycles. 3 cred.; prereq. 63 and 64. Parham. (Offered alternate years; not offered 1954-55.)

130—ORGANIC QUANTITATIVE ANALYSIS. Methods of proximate and ultimate analysis of organic compounds, with special attention to semimicro methods. 3 cred.; prereq. permission of instructor, 63 and 64 and Anal.Chem. 1 and 2; 1 lect. and 6 lab. hrs. per week. Lauer.

139—ADVANCED ORGANIC CHEMISTRY LABORATORY WORK. Selected laboratory problems of an advanced nature, including some original work. Ability to read German is assumed. Students are advised to take this course during the winter quarter. Permission of instructor is required to take it at any other time. 2 to 5 cred.; prereq. 63 and 64. Noland.

140—AROMATIC COMPOUNDS. Discussion of the chemistry of typical aromatic compounds, including derivatives of benzene, naphthalene, anthracene, phenanthrene, and other polynuclear hydrocarbons, together with a consideration of certain heterocyclic compounds which show aromatic character. The properties of these compounds will be illustrated by examples chosen from the sterols and the alkaloids. 3 cred.; prereq. 63 and 64; 3 lect. hrs. per week. Koelsch, Parham.

141—REAGENTS IN ORGANIC CHEMISTRY. Discussion of typical reagents used in organic reactions; their limits of applicability, methods of use, and types of substances with which they react. 3 cred.; prereq. 63 and 64; 3 lect. hrs. per week. Koelsch. (Offered alternate years; not offered 1953-54.)

142—THE CHEMISTRY OF NATURAL PRODUCTS. Discussion of the organic chemistry of important classes of natural products. 3 cred.; prereq. 63 and 64; 3 lect. hrs. per week. Fenton. (Offered alternate years; not offered 1954-55.)

151-152-153*—ORGANIC CHEMISTRY SEMINAR. (For seniors.) 1 cred. per qtr.; 1 hr. per week. Staff.

201-202-203*—ORGANIC CHEMISTRY SEMINAR. Required of all graduate students taking major work in organic chemistry. 1 cred. per qtr.; 1 hr. per week. Staff.

205-206*—THEORETICAL ORGANIC CHEMISTRY. Structure, reaction mechanisms, relation of physical properties to constitution, and other topics of a theoretical nature. Course 205 will center around a discussion of stereochemistry and stereochemical problems; Course 206 will center around a discussion of polymerization and high polymers. 3 cred. per qtr.; prereq. 107.

212—PHYSICO-ORGANIC CHEMISTRY. Contributions made to organic chemistry by kinetic and equilibrium studies of organic reactions, including mechanisms of catalytic and ionotropic reactions; and an introduction to the current electronic formulations of organic reactions. Lectures, outside reading, and a term paper are required. 4 cred.; prereq. 107, Phys.Chem. 103, and calculus, or permission of instructor. Arnold, Fenton.

261—GENERAL SURVEY OF ORGANIC CHEMISTRY. A course of independent reading under the guidance of the staff. This course is a prerequisite to candidacy for the Ph.D. degree in any field of chemistry and an examination must be taken by the end of the fall quarter of the second year in residence. 1 cred.; prereq. permission of instructor.

301-302-303*—RESEARCH IN ORGANIC CHEMISTRY. Cred. ar.; prereq. Org.Chem. 102 or 110 and permission of division.

PHYSICAL CHEMISTRY

Candidates for an advanced degree in the Graduate School, who are not majoring in chemistry, may offer Physical Chemistry 101-102-103, 104-105-106, or 107-108 in partial or complete fulfillment of the course requirements for a minor in physical chemistry.

96-97-98*—SENIOR THESIS. 5 cred. per qtr.

101-102-103—PHYSICAL CHEMISTRY. General survey of the subject. 3 cred. per qtr.; prereq. Anal.Chem. 1, 2 (or Anal.Chem. 7 for physicists), Phys. 7, 8, 9, differential and integral calculus; 3 lect. and 1 rec. hrs. per week. Prager (1953-54), Crawford (1954-55).

104-105-106—PHYSICAL CHEMISTRY LABORATORY. 1 or 2 cred. per qtr.; prereq. 101 for 104, 102 for 105, 103 for 106, or concur. reg.; 1 rec. and 5 lab. hrs. per week. Lumry.

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* May be taken out of sequence.

107-108—ELEMENTARY PHYSICAL CHEMISTRY. (Premed.) 3 cred. per qtr.; prereq. two years of college chemistry, one year of college physics, Math. 15-16 or 6-7; 2 lect., 1 rec., and 3 lab. hrs. per week. Lipscomb (1953-54), Wertz (1954-55).

110—EXPERIMENTAL RESEARCH TECHNIQUES, I. Physical manipulations, including the use of tools and machines as well as a course in glass blowing with demonstrations and practice by the student. 2 or 3 cred.; prereq. 103 and permission of instructor. Wertz. (Offered alternate years; not offered 1954-55.)

111—EXPERIMENTAL RESEARCH TECHNIQUES, II. Materials of research, high vacuum techniques, characteristics of thermionic tubes, rectifiers, amplifiers, oscillators, photocells. 2 or 3 cred.; prereq. 110. Wertz. (Offered alternate years; not offered 1954-55.)

112—ADVANCED PHYSICOCHEMICAL EXPERIMENTS. Precise measurements in various fields such as thermochemistry, conductance, surface tension, magnetic susceptibility, dielectric constant, characteristics of the photographic plate and ionization potentials of a gas. 2 or 3 cred.; prereq. 111. Wertz. (Offered alternate years; not offered 1954-55.)

116—THERMODYNAMICS AND CHEMISTRY. A detailed study of the principles of thermodynamics and their application to physical and chemical phenomena. 4 cred.; prereq. 103 and calculus; 3 lect. hrs. per week. Wertz (1953-54), Lumry (1954-55).

117—FUNDAMENTALS OF REACTION KINETICS. Empirical analysis of rate measurements, collision theory, transition state theory, chain reactions. 3 cred.; prereq. 103; 3 lect. hrs. per week. Livingston. (Offered spring quarter 1953-54 and winter quarter 1954-55.)

118—ADVANCED PHYSICAL CHEMISTRY. Methods of determining molecular structure with simple applications. Chemical and physical properties in terms of the nature of chemical bonds. 3 cred.; prereq. 103; 3 lect. hrs. per week. Crawford (1953-54), Ar. (1954-55). (Offered winter quarter 1953-54 and spring quarter 1954-55.)

119—KINETICS OF REACTIONS. SELECTED TOPICS. Effect of solvents and electrolytes on reaction velocity, diffusion processes; induced reactions; homogeneous and heterogeneous catalysis. 3 cred.; prereq. 117; 3 lect. hrs. per week. Livingston. (Not offered 1953-54 or 1954-55.)

120—PHOTOCHEMISTRY. General survey, including a discussion of spectroscopy, with particular reference to the visible and ultraviolet absorption spectra of molecular gases. 3 cred.; prereq. 103 and Phys. 9; 3 lect. hrs. per week. Livingston. (Offered alternate years; not offered 1953-54.)

128—COLLOID CHEMISTRY. The fundamental principles of colloid chemistry, surface chemistry, electrokinetic phenomena, lyophobic and lyophilic colloids. 3 cred.; prereq. 103; 3 lect. hrs. per week. Reyerson.

129—ADSORPTION AND CATALYSIS. The fundamental principles of adsorption at the different interfaces and the application of these principles to heterogeneous catalysis. 3 cred.; prereq. 128; 3 lect. hrs. per week. Reyerson.

130—COLLOIDS IN INDUSTRY. The important applications of colloid chemistry to many of the fields of chemical industry. 3 cred.; prereq. 128; 3 lect. hrs. per week. Reyerson. (Offered alternate years; not offered 1953-54.)

131—COLLOIDAL PROCESSES. A survey of the important colloidal processes; coagulation, sol-gel transformation, thixotropy and dilatancy. 3 cred.; prereq. 128. Reyerson. (Offered alternate years; not offered 1954-55.)

132-133-134*—COLLOID CHEMISTRY LABORATORY. 1 or 2 cred. per qtr.; prereq. 128 or concurrent registration; hrs. ar. Reyerson.

150-151-152*—PHYSICAL CHEMISTRY SEMINAR FOR SENIORS. 1 cred. per qtr. Livingston.

180-181—EXPERIMENTAL TECHNIQUES IN PHYSICAL CHEMISTRY. This course is primarily designed for physical chemistry minors and others interested in properties of molecules related to optical and infrared spectra, refractive index, polarimetry, diffraction analysis, and other related experimental techniques. 1 cred. per qtr.; prereq. permission of instructor. Livingston. (Not offered 1953-54.)

204-205-206—ATOMISTICS. Kinetic theory of gases, statistical mechanics and quantum mechanics, and their application to the interpretation of the properties of matter in terms of its microscopic structure. 4 cred. per qtr.; prereq. 103 and calculus; 3 lect. hrs. per week. Crawford (1953-54), Prager (1954-55).

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* May be taken out of sequence.

217-218—THERMODYNAMICS AND CHEMISTRY. A detailed study of the principles of thermodynamics and their application to physical and chemical phenomena. 4 cred. per qtr.; prereq. 116; 3 lect. hrs. per week. Wertz (1953-54), Ar. (1954-55).

223-224—CRYSTAL ANALYSIS. Theory and practice of X-ray crystallography. Methods and examples of structure determinations. 3 cred. per qtr.; prereq. 103; 3 lect. hrs. per week. Lipscomb.

250-251-252*—PHYSICAL CHEMISTRY SEMINAR. 1 cred. per qtr.; required of all graduate students majoring in physical chemistry. Livingston and staff.

253-254—MOLECULAR VIBRATIONS. The dynamics of molecular vibrations will be discussed with the aid of group theory and the result applied to the interpretation of vibrational spectra. 3 cred. per qtr. Crawford. (Offered alternate years; not offered 1953-54.)

263—GENERAL SURVEY OF PHYSICAL CHEMISTRY. A course of independent reading under the guidance of the staff. This course is a prerequisite to candidacy for the Ph.D. degree in any field of chemistry and an examination must be taken by the end of the fall quarter of the second year in residence. 1 cred.; prereq. permisison of instructor.

290-291-292*—SELECTED TOPICS IN PHYSICAL CHEMISTRY. From time to time, when the demand exists, advanced seminars are held in subjects such as quantitative theory of valence, advanced thermodynamics, polymers, transport processes, magnetochemistry, and structural and related properties of solids. Cred. ar. Crawford, Lipscomb, Livingston, Prager, Reyerson, Wertz.

301-302-303*—RESEARCH IN PHYSICAL CHEMISTRY. Thermodynamics, electrochemistry, photochemistry, reaction kinetics, tracer techniques, molecular structure, colloids, adsorption, crystal structure. Cred. ar. Crawford, Kolthoff, Lipscomb, Livingston, O'Connor, Prager, Reyerson, Wertz.

Civil Engineering

Surveying: C.E. 17, 18, 19, 20, 23, 24, 109, 110, 111, 112.

Structural Engineering: C.E. 31, 32, 33, 34, 37, 38, 39, 41, 130, 131, 132, 136, 137, 140, 141, 142, 143, 147, 232, 233, 234-235, 236, 237-238-239, 240-241-242, 243-244, 245, 247-248-249.

Highway Engineering and Soil Mechanics: C.E. 51-52, 53, 146, 148-149-150, 151, 152, 153, 156, 157, 158, 159, 251-252.

Sanitary Engineering: C.E. 170, 171, 172, 173, 174, 175, 176-177-178, 179, 261-262, 264, 276, 277.

General: C.E. 1, 2, 3, 124, 167, 169, 280-281-282.

Hydraulic Engineering: C.E. 160, 161, 164, 166, 168, 263.

1, 2, 3—CIVIL ENGINEERING LABORATORY. Fundamentals of civil engineering practice in the laboratory and field presented by lectures, laboratory tests, demonstrations, and inspection trips. Problems and reports. 1 cred. per qtr.; no prereq.; 3 lab. hrs. per week; recommended in second year.

17—SURVEYING. Short course including problems in chaining, transit and tape surveys; differential leveling, stadia mapping with transit and plane table, computations and platting of notes, etc. Open to students other than civil engineers. 3 cred.; prereq. I.T.M. 12; 8 lab. hrs. per week.

18—SURVEYING. Taping practice; transit adjustments and use; level adjustments and use. Field problems in traverses, obstructed lines, and stadia theory. Adjustment of traverses and plotting methods. 3 cred.; prereq. I.T.M. 12, Draw. 4; 2 lect. and 4 lab. hrs. per week.

19—SURVEYING. Land surveying; simple, compound, and spiral horizontal curves; vertical curves; elements of route surveying, grades, curvature, rise and fall, mass diagram, and earth work volume calculations. 3 cred.; prereq. 18; 2 lect. and 4 lab. hrs. per week.

20—SURVEYING. Differential and profile leveling, adjustments of level circuits; field problems in cross-sectioning, slope staking, grade staking, and curve staking. Azimuth by solar observation. 3 cred.; prereq. 19; 2 lect. and 4 lab. hrs. per week.

* May be taken out of sequence.

23—SURVEYING CAMP. Applied problems and lectures in mapping, route surveying, hydrographic surveying, control surveys, traverses, triangulation, leveling, and engineering astronomy. 9 cred.; prereq. 20; first term of Summer Session in the field at summer camp.

24—RAILWAY ENGINEERING. Study of the construction and maintenance of railway roadbed, track, and structures. Study of design of turnouts, crossovers, frogs, and track parts. 3 cred.; prereq. 20; 2 lect. and 3 lab. hrs. per week.

31—STRESSES IN STRUCTURES. Algebraic and graphical analysis of structural framework, influence lines. Equivalent loads. 3 cred.; prereq. Draw. 4, M.&M. 26; 3 lect. and 3 lab. hrs. per week. Graves.

32—DESIGN IN STEEL. Design principles and methods of selecting members and connections. 3 cred.; prereq. 31, M.&M. 128; 3 lect. and 3 lab. hrs. per week. Graves.

33—DESIGN IN TIMBER. Design of timber members and connections. 3 cred.; prereq. 32; 3 lect. and 3 lab. hrs. per week. Graves.

34—DRAFTING ROOM PRACTICE. Detailing, drafting, and estimating of structural steel and timber. 3 cred.; prereq. reg. in 33; 1 lect. and 4 lab. hrs. per week.

37—ELEMENTARY STRUCTURAL ENGINEERING. (Ag.En., M.E., E.E.) Elementary structural analysis and design in wood, steel, and reinforced concrete. 3 cred.; prereq. M.&M. 128; 2 lect. and 2 lab. hrs. per week. Graves.

38—ELEMENTARY STRUCTURAL DESIGN (STEEL). (Arch.) Elementary structural analysis and design of frame buildings. 3 cred.; prereq. M.&M. 93; 3 lect. hrs. per week. Graves.

39—ELEMENTARY STRUCTURAL DESIGN (STEEL AND TIMBER). (Arch.) Elementary structural analysis and design of timber frame buildings. 3 cred.; prereq. 38; 3 lect. hrs. per week. Graves.

41—ELEMENTARY STRUCTURAL DESIGN (CONCRETE). (Arch.) Elementary structural analysis and design of reinforced concrete for buildings and foundations. 3 cred.; prereq. 39; 3 lect. hrs. per week. Graves.

51-52—HIGHWAYS AND PAVEMENTS. Elementary course with field inspection, relating to the economics, location, design, construction, and maintenance of highways and pavements. 3 cred. per qtr.; prereq. reg. in M.&M. 128; 2 lect. and 3 lab. hrs. per week for 51; 2 lect. and 4 lab. hrs. per week for 52. Thomas and staff.

53—ELEMENTS OF SOIL MECHANICS. General characteristics of soils; soil classification; stresses in earth masses. Identification tests and shear tests. 3 cred.; prereq. 52; 2 lect. and 3 lab. hrs. per week. Kersten and staff.

109—GEODETIC SURVEYING. Location of boundaries by geodetic methods. State-wide coordinate system. Establish and compute state-wide coordinates for monuments on the campus to first and second order accuracies. 3 cred.; prereq. 23 or permission; 2 lect. and 3 lab. hrs. per week.

110—ADJUSTMENT OF SURVEYS. Least squares adjustments; theory and computation as applied to triangulation nets, traverse nets, and level circuits. 2 cred.; prereq. 23 or permission; 2 lect. hrs. per week.

111—LAND SURVEYING. Study of Minnesota Public Land Survey. Field survey of a city block. Field survey and subdivision of a section of land. Preparation of standard plats and descriptions. 3 cred.; prereq. 23 or permission; 1 lect. and 6 lab. hrs. per week.

112—AERIAL SURVEYING AND PHOTOGRAMMETRY. Theory and methods of making planimetric and topographic maps from aerial and terrestrial photographs. 3 cred.; prereq. 23 or permission; 1 lect. and 6 lab. hrs. per week.

124—TRANSPORTATION. History of transportation in the U.S. from the establishment of the Interstate Commerce Commission. Operating statistics for railroad, air, highway, waterway, and pipeline transportation. Operating characteristics of steam and Diesel-electric locomotives. 3 cred.; prereq. 24; 2 lect. and 3 lab. hrs. per week.

130—STATICALLY INDETERMINATE STRUCTURES. Method of moment area. Williot diagram. Slope-deflection method. 3 cred.; prereq. 33; 2 lect. and 2 lab. hrs. per week. Andersen.

131—STRUCTURAL ANALYSIS. Moment distribution method. 2 cred.; prereq. 130; 1 lect. and 3 lab. hrs. per week. Andersen.

132—STRUCTURAL DESIGN. Continuous structures of steel and concrete. 2 cred.; prereq. 131; 1 lect. and 3 lab. hrs. per week. Andersen.

136—ADVANCED STRUCTURAL ANALYSIS. Wind bracing for buildings. Space structures. Secondary stresses. 3 cred.; prereq. 132; 3 lect. hrs. per week.

137—STRUCTURAL LABORATORY. Theoretical and experimental study of structural members, structural models, and strain gauges. Lectures and demonstrations on photo-elasticity and dynamic strain measurements. 3 cred.; prereq. 141 and reg. in 131; 2 lect. and 3 lab. hrs. per week. Graves.

140—ADVANCED STRUCTURAL LABORATORY. Continuation of 137. Calculated and experimental influence lines for framed structures including gabled bents. Secondary stresses in trusses. 3 cred.; prereq. 137; 2 lect. and 3 lab. hrs. per week. Wise.

141—REINFORCED CONCRETE. Principles of reinforced concrete. Theory of beams, slabs, and columns, and the application to simple structures. 3 cred.; prereq. 33; 2 lect. and 3 lab. hrs. per week. Wise.

142—REINFORCED CONCRETE DESIGN. Continuation of 141 with special emphasis on the practical features of the design of buildings, bridges, retaining walls, footings, etc. 3 cred.; prereq. 130, 141; 2 lect. and 2 lab. hrs. per week. Wise.

143—ARCH ANALYSIS AND DESIGN. Analysis and design of reinforced concrete and steel arches and rigid frame bridges. 3 cred.; prereq. 131 and 142; 3 lect. hrs. per week. Andersen.

146—CONCRETE AND CONCRETE MATERIALS. Design and control of concrete mixtures, air-entrained concrete, properties of concrete, and constitution of cement. 3 cred.; prereq. M.&M. 141; 2 lect. and 4 lab. hrs. per week. Thomas and staff.

147—FOUNDATIONS. Design and construction of footings, cofferdams, and caissons for bridges and buildings. Piers, abutments, and sheet piling. Exploration and testing of foundation sites. Excavation and removal of materials from foundation site. 3 cred.; prereq. 32; 3 lect. hrs. per week. Andersen.

148-149-150—ADVANCED CONCRETE. Short research problems in concrete. 2 cred. per qtr.; prereq. 146. Thomas.

151—ADVANCED HIGHWAY LABORATORY. Special experimental studies of highway materials. 3 cred.; prereq. 52. Thomas.

152—HIGHWAY DESIGN. Study of the basis for design, design of intersections, street grades, pavement design, plans, and specifications. 3 cred.; prereq. 52; 2 lect. and 3 lab. hrs. per week. Thomas.

153—SOILS IN HIGHWAY ENGINEERING. Classification, soil maps, surveys, physical tests, compaction, design of graded mixes, and soil stabilization. 3 cred.; prereq. 53. Kersten.

156—HIGHWAY TRAFFIC ENGINEERING. Traffic surveys, traffic control, highway safety, highway commercial transportation as related to other forms of transportation. 3 cred.; prereq. 52; 2 lect. and 3 lab. hrs. per week. Thomas.

157—HIGHWAY ECONOMICS. Annual highway costs, effect of highway location and design on motor vehicle operating costs. Economical significance of highway accidents. Allocation of highway costs to motor vehicle owners and general public. Economics of highway administration, finance, and taxation. 2 cred.; prereq. 4th or 5th yr.

158—AIRPORT DESIGN. Field layout, capacity, drainage, lighting, and studies of sub-bases, bases, and surfaces for aprons, runways, and taxiways. 3 cred.; prereq. 52. Kersten.

159—SOIL MECHANICS. Seepage, consolidation, strength theory. Settlement analysis; stability of slopes; bearing capacity. 3 cred.; prereq. 53; 3 lect. hrs. per week.

160—APPLIED HYDRAULICS. Pipe flow, compound pipe systems, network analysis. Centrifugal pumps, analysis, and problems. Characteristic curves, pump constants, selection and economic factors. Open channel flow design, hydraulic elements, non-uniform flow computations, losses, irrigation, and drainage problems. 3 cred.; prereq. Hydr. 102, 104; 2 lect. and 4 lab. hrs. per week. Cornell.

161—HYDROLOGY. A study of the fundamental aspects of hydrology as the basis for hydraulic engineering work. Sources of basic data, common curves. Precipitation, types, variations, rainfall depth computations, storm rainfall, intensity-duration-frequency. Losses. Groundwater and infiltration. Run-off, characteristics, components, variations, estimating supply, storage. Flood flows, Unit Graph analysis, flood control. Erosion, transportation, silting. Water used and rights. 3 cred.; prereq. Hydr. 101 or 102 or 103; 2 lect. and 4 lab. hrs. per week. Cornell, L. A. Johnson.

164—WATER CONSERVATION. Weather variations and cycles, variable stream flow and water levels with respect to control in problems of public water supply, sewage disposal, water power, navigation, floods, and low water. National and state water conservation policies with discussion of typical problems. 3 cred.; prereq. 161, or by permission.

166—WATER POWER. Stream flow and water power estimates. Storage problems. Analysis, design, and selection of water power structures and equipment. Types and purposes of dams. Turbine analysis. Transmission lines. Cost and value of water power. Typical problems, inspection trips. 3 cred.; prereq. 161; 2 lect. and 4 lab. hrs. per week; recommended for seniors in sanitary engineering.

167—CITY PLANNING. Physical elements of the city: topography, drainage, geology. Public works and structures. Internal and external transportation. Zoning. Subsurface structures. Esthetic features of the city. 3 to 5 cred.; prereq. 52.

168—IRRIGATION AND DRAINAGE. Applications of hydrology to the irrigation of arid and semi-arid regions. Water duty, diversion, storage, controlling, and transmission works. Cost estimates. Hydrology of drainage. Legal rights. Surface and ground water, survey problems in interception and diversion, storage, channels, ditches, miscellaneous structures. Pumping. Relations to public health and water conservation. Typical problems. 3 cred.; prereq. 161, or by permission.

169—PUBLIC WORKS ENGINEERING. An introduction to the engineering phases and relationships of public works. Historical survey. Federal, state, and local administration problems. Present trends and practices. The need for adequate public planning design and construction. Responsibilities of the engineer. Typical problems. 3 cred.; prereq. 52.

170—WATER SUPPLY. Sources of water supply; characteristics of water; quantities and rates; quality of water, collection, distribution, and water purification; test methods; selection of equipment. Laboratory problems in analysis and design. Inspection trips. 3 cred.; prereq. 160; 2 lect. and 4 lab. hrs. per week. Schroepfer, Johnson, and Ziemke.

171—SEWERAGE AND SEWAGE TREATMENT. Sources and quantities of sewage; sanitary, storm, and combined sewer systems; materials and methods of construction; sewer appurtenances; pumping equipment, physical, chemical, and biological characteristics of sewage. Disposal by dilution, domestic and industrial waste treatment. Laboratory problems in analysis and design. Inspection trips. 3 cred.; prereq. 161, 170; 2 lect. and 4 lab. hrs. per week. Schroepfer, Johnson, and Ziemke.

172—SANITARY LABORATORY. The biological, bacteriological, physical, and chemical analyses of water, sewage, air, coagulant chemicals, disinfectants, sewage sludge, etc. 3 cred.; prereq. 5th yr.; 8 lab. hrs. per week. Ziemke, Schroepfer.

173—SANITARY ENGINEERING PROBLEMS (WATER). Investigations of problems in water supply to supplement C.E. 170. Collection, distribution, and purification. Economic studies. 3 cred.; prereq. 170; 3 lect. hrs. per week. Schroepfer.

174—SANITARY ENGINEERING PROBLEMS (SEWAGE AND INDUSTRIAL WASTES). Investigations of problems in sewage treatment and industrial waste disposal to supplement C.E. 171. Stream pollution, stream standards, economic studies of various types and degrees of treatment. 3 cred.; prereq. 171; 3 lect. hrs. per week. Schroepfer.

175—INDUSTRIAL WASTE DISPOSAL. Investigation of quality of various types of industrial wastes and of methods of disposal. Economic studies. 3 cred.; prereq. 171; 3 lect. hrs. per week. Schroepfer.

176-177-178*—SANITARY ENGINEERING SEMINAR. Required of graduate and 5th year students in sanitary option. Reports and discussion on assigned topics in the field of sanitary engineering with occasional talks by practicing sanitary engineers on subjects of interest. 1 cred. per qtr.; prereq. 5th year.; 1 rec. hr. per week. Schroepfer.

179—PUBLIC HEALTH ENGINEERING. Sanitary problems associated with the location, construction, and operation of water supplies, purification works, and distribution systems, with the treatment and disposal of sewage, excreta, and waste, and with the production, pasteurization, and distribution of milk. Public health engineering methods as applied to sanitary problems in urban and rural communities including schools, institutions, camps, bathing places, dwellings, etc. Lectures, field and laboratory demonstrations. 3 cred.; no prereq.

232—ADVANCED STRUCTURAL PROBLEMS IN SANITARY ENGINEERING. Theory of domes, tanks, dams, culverts, and elliptical sewer sections. 3 cred.; prereq. 132.

233—ADVANCED FOUNDATIONS. Advanced problems in earth pressure, pile foundations, cofferdams, and caissons. 3 cred.; prereq. 132 and 147. Andersen.

234-235*—ADVANCED THEORY OF STRUCTURES. Application of the theory of indeterminate stresses to the more complex problems of structural analysis. Continuous and swing bridges, simple and multiple arch and suspension systems, wind stresses in tall building frames, secondary stresses. 3 to 5 cred. per qtr.; prereq. 132, 142. Andersen, Wise.

* May be taken out of sequence.

236—ADVANCED STRUCTURAL DESIGN. Effect of shrinkage and plastic flow. Eccentrically loaded concrete sections. Nonsymmetrical bending. Lateral earth pressure theories. 3 to 5 cred.; prereq. 131, 147. Andersen.

237-238-239—STRUCTURAL MODEL ANALYSIS. Analysis of indeterminate structures by use of models; methods of mechanical analysis; principles of similitude. 3 cred. per qtr.; prereq. 137. Staff.

240-241-242—ADVANCED STRUCTURAL LABORATORY. Experimental determination of principal strains by use of three or four intersecting gauge lines; plastic flow and shrinkage; prestressed reinforced concrete; moment redistribution; theory of limit design; theory of similitude; statistical data. Vierendell trusses. 3 to 5 cred. per qtr.; prereq. 140. Staff.

243—DYNAMICS OF STRUCTURES. Vibrations of beams, trusses, and frameworks. Impact and effect of suddenly applied forces. Forces on structures due to earthquakes, shocks, and explosions. Fatigue of materials. 3 cred.; prereq. 132. Wise.

244—DYNAMICS OF STRUCTURES LABORATORY. Laboratory work in vibrations of beams and trusses. 3 cred.; prereq. 243. Wise.

245—ADVANCED PROBLEMS IN BRIDGE DESIGN. Selection of type and span. Secondary stresses and problems associated with rigidity of joints. 3 cred.; prereq. 132.

247-248-249—SEMINAR. Special topics in the theory of structures. 3 to 6 cred. per qtr.; prereq. 131 and 142. Staff.

251-252—ADVANCED SOIL MECHANICS LABORATORY. Consolidation; permeability; direct shear; triaxial compression; California bearing ratio; and other special laboratory problems in soil mechanics. 3 cred. per qtr.; prereq. 159 or reg. in 159.

261-262*—WATER AND SEWAGE PLANT DESIGN. Design of water purification and sewage treatment works. 3 to 5 cred per qtr; prereq. 173 or 174. Schroepfer.

263—ADVANCED HYDRAULIC ENGINEERING PROBLEMS. Special hydraulic problems in laboratory, drafting room, and field. 3 to 5 cred.; prereq. Hydr. 183, 190, 192.

264—SANITARY ENGINEERING UNIT OPERATIONS. Lectures, laboratory studies, and plant-scale studies on screening, sedimentation, chemical coagulation, aeration, filtration, disinfection of water with chlorine, disinfection of air, heat transfer, handling of material, drying, incineration, and digestion. 3 cred.; prereq. grad.; 1 lect. and 6 lab. hrs. per week. Schroepfer.

276—ADVANCED SANITARY ENGINEERING (WATER). Principles of water collection, distribution, and purification. Inspections and investigations of water works systems. Advanced study of certain phases of purification. 3 to 5 cred.; prereq. 173. Schroepfer.

277—ADVANCED SANITARY ENGINEERING (SEWAGE AND INDUSTRIAL WASTE). Principles of sewage collection and treatment, and of industrial waste disposal. Inspection and investigation of sewage works. Advanced study of certain phases of sewage treatment. 3 to 5 cred.; prereq. 174. Schroepfer.

280-281-282—CIVIL ENGINEERING RESEARCH. Original work in concrete, structural steel, hydraulics, municipal, sanitary, or transportation problems. Investigations, reports, tests, designs. 5 cred. per qtr.; prereq. by permission. Staff.

Dairy Husbandry

(College of Agriculture, Forestry, and Home Economics)

1—ELEMENTS OF DAIRYING. Lectures and demonstrations with opportunity for laboratory practice. The history and development of the dairy industry. Origin, classification, and characteristics of dairy breeds of cattle. Milk, its composition, food value, chemical and physical properties with relation to handling, sanitary milk production, and the manufacture of milk products. Dairy arithmetic. 3 cred.; prereq. entrance cred. in chemistry or Inorg.Chem. 1 or 4; 3 lect. hrs. per week. Combs.

101—MILK PRODUCTION. Problems of the dairy farmer, such as characteristics and adaptation of dairy breeds; selection and management of dairy herd with sires; calf raising, dairy barns. 3 cred.; prereq. 1; jr., sr., grad.

Drawing and Descriptive Geometry

4—ENGINEERING DRAWING. Engineering graphics including shape and size description and graphical presentation of data. Sketching, lettering, applied geometry, and drafting techniques. 3 cred.; no prereq.; 8 lect. and lab. hrs. per week. Bullen and others.

* May be taken out of sequence.

5—ENGINEERING DRAWING. Descriptive geometry. Graphic solutions of space problems. Auxiliary views, revolution, intersections, developments, practical applications. 3 cred.; prereq. 4; 8 lect. and lab. hrs. per week. Palmer and others.

6—ENGINEERING DRAWING. Applied graphics: (a) application of theory and standard practices to working drawings; (b) graphical approach to engineering problems. Charts, diagrams, nomographs, and graphic scales. 3 cred.; prereq. 5; 8 lect. and lab. hrs. per week. Schuck and others.

7—ENGINEERING DRAWING. (Chem. and Chem.E.) An abbreviated course in methods of graphical representation including lettering, freehand sketching, theory of orthogonal projection, dimensioning, sectional views, and pictorial drawings. 3 cred.; no prereq.; 8 lect. and lab. hrs. per week. Schuck and others.

8—ENGINEERING DRAWING. (Chem. and Chem.E.) A continuation of Course 7 with particular emphasis on space problems, fastening devices, piping, and working drawings. 3 cred.; prereq. 7; 8 lect. and lab. hrs. per week. Schuck and others.

10—SOLID GEOMETRY. Lines and planes in space, dihedral and polyhedral angles, polyhedrons, surfaces, cylinders, cones, and spheres. Numerical exercises in areas, volumes, weights. No cred.; prereq. plane geometry; 3 lect., rec., and quiz hrs. per week. Eggers and others.

21—DRAFTING. (C.E.) Application of descriptive geometry to drafting room problems including working drawings. 2 cred.; prereq. 6; 6 lab. hrs. per week. Myers and others.

22—STRUCTURAL DETAILING (C.E.) Detail, assembly, and construction drawing of steel members and simple structures. Standards and conventions. 2 cred.; prereq. 21; 6 lab. hrs. per week. Myers and others.

23—STRUCTURAL DETAILING. (C.E.) Drafting problems in general construction work including earthwork, wood, steel, and concrete. 2 cred.; prereq. 22; 6 lab. hrs. per week. Myers and others.

28—DRAFTING. (Aero.E.) Applications of descriptive geometry to drafting room problems. Working drawings. 2 cred.; prereq. 6; 6 lect. and lab. hrs. per week. Myers and others.

34—LETTERING. Study and analysis of single stroke lettering with particular emphasis on the application to engineering drawing. 1 cred.; prereq. 4; 1 lect. and rec. hr. per week. Potter and others.

37—LETTERING FOR ENGINEERS. Analysis of the alphabets. Exercises in roman and gothic lettering. Design and composition of the paragraph and title. 2 cred.; prereq. 4; 2 lect. and rec. hrs. per week. Potter and others.

38—READING DRAWINGS. Calculations and estimates of areas, volumes, and weights. Tabulation of quantities from working drawings. Problems concerned with fabrication, manufacture, and construction. 2 cred.; prereq. 5; 2 lect. and rec. hrs. per week. Potter and others.

44—LETTERING. Practical course in plain lettering. Not an engineering or architecture elective. 1 cred.; no prereq.; 1 lect. and rec. hr. per week. Potter and others.

45—ALPHABETS. Construction and analysis of classic and modern roman, italic, script, and gothic styles, including Old English. Exercises in composition. Reference work. Not an engineering or architecture elective. 2 cred.; 2nd, 3rd, or 4th year; prereq. 44; 2 lect. and rec. hrs. per week. Potter.

50—DIAGRAMS AND CHARTS. Elementary course dealing with the construction of simple diagrams and charts. 2 cred.; prereq. 4; 2 lect. and rec. hrs. per week. Potter and others.

51—GRAPHIC REPRESENTATION AND COMPUTATION. Types of charts and applications to the solution of problems and equations. 3 cred.; prereq. 5, I.T.M. 11; 3 lect. and rec. hrs. per week. Potter and others.

52—ALIGNMENT CHARTS. Functional scales. Application of geometry to the development of straight line alignment charts for equations of three or more variables. 3 cred.; prereq. 5, I.T.M. 12; 3 lect. and rec. hrs. per week. Potter and others.

55—PRODUCTION ILLUSTRATION. Detail and assembly drawing by use of isometric, oblique, axonometric freehand, and mechanical perspective. Shaded drawings suitable for reproduction. 2 cred.; prereq. 6; 6 lect. and lab. hrs. per week. Potter and others.

111-112-113—ADVANCED DESCRIPTIVE GEOMETRY. Parallel and central projections. Curves and surfaces. Intersections and tangencies. Shades and shadows. Warped surfaces. The figured plan. 3 cred. per qtr.; prereq. 6, I.T.M. 25; 3 lect. and rec. hrs. per week. Eggers and others.

115-116-117—CURVE FITTING. Finite differences and their application to curve fitting; graduation of experimental data; interpolation; fitting of data to type form of curves. 3 cred. per qtr.; prereq. 6, I.T.M. 25; 3 lect. and rec. hrs. per week. Eggers and others.

118—SHORT COURSE IN CURVE FITTING. Derivation of formulas to fit experimental data. Combination of graphic and algebraic methods. 3 cred.; prereq. 6, I.T.M. 25, or permission of instructor; 3 lect. and rec. hrs. per week. Eggers and others.

152-153-154—NOMOGRAPHY. Application of geometry to the development of alignment charts involving curved and straight line scales. Networks, combination of networks, and alignment charts. Line coordinates. Use of determinants for the construction of alignment charts. Special rules. 3 cred. per qtr.; prereq. 52, I.T.M. 25 or permission of instructor; 3 lect. and rec. hrs. per week. Eggers and others.

157-158-159—GRAPHICAL MATHEMATICS. Graphical calculus. Polar diagram method of stress analysis. 2 cred. per qtr.; prereq. 6, M.&M. 26; 2 lect. and rec. hrs. per week. Eggers and others.

Economics and Business Administration

(School of Business Administration)

ECONOMICS

3—ELEMENTS OF MONEY AND BANKING. Basic principles of money and a description of the various types of financial institutions, their functions and relations to the whole economic organization. 5 cred.; no prereq.; 2 lect. and 3 rec. hrs. per week. Stehman and others.

5¶—ELEMENTS OF STATISTICS. Elementary concepts in statistical method; averages, ratios, errors, sampling, index numbers, graphic representation, collection of material. 5 cred.; no prereq.; 1 lect. and 4 rec. hrs. per week. Kozelka and others.

6-7†—PRINCIPLES OF ECONOMICS. A course in the fundamental principles of economics intended to serve as a foundation for advanced courses in business administration and economics. 5 cred. per qtr.; soph., jr., sr.; Econ. 6, no prereq.; Econ. 7, prereq. 3 or 6; 2 lect. and 3 rec. hrs. per week. Smith and others.

8-9—GENERAL ECONOMICS. (Engrs., arch., chem.) Principles of economics with special emphasis upon their application to current problems such as money, banking, conservation, insurance, international commerce, monopolies, transportation, labor, socialism, public ownership, and finance. 3 cred. per qtr.; prereq. soph., jr., sr.; 3 rec. hrs. per week. Filipetti and others.

28§—BUSINESS LAW. A practical course on the law of contracts, agency, partnership, corporations, negotiable instruments, real estate, deeds, mortgages, fixtures, leases, mechanics' liens, workmen's compensation. 3 cred.; prereq. soph. or jr. with 6 cred. in economics or seniors without economics cred.; 3 rec. hrs. per week. Palmer.

73§—MANPOWER ECONOMICS AND LABOR PROBLEMS. This course deals with: (1) the marketing of manpower resources; (2) the institutional structure of labor markets; (3) economic and social problems arising out of labor marketing processes; (4) methods, procedures, and proposals for solving these problems. 3 cred.; jr., sr.; prereq. 7 or equiv.

161§—GENERAL MANPOWER ECONOMICS. This course deals with: (1) the marketing of manpower resources; (2) the institutional structure of labor markets; (3) economic and social problems arising out of labor marketing processes; (4) methods, procedures and proposals for solving these problems. This course includes the basic materials of Econ. 73 plus advanced discussion and special assignments. 3 cred.; jr. and sr. with permission, grad.; prereq. 7 or equiv.

164—LABOR LEGISLATION: COLLECTIVE BARGAINING. This course is designed to provide an analysis of: (1) the inter-relationships between the development of labor organizations and the techniques utilized by them in furthering their interests, and the actions and decisions of the executive, legislative, and judicial branches of the government; and (2) the economic and social implications of issues arising in this area. 3 cred.; jr., sr., grad.; prereq. 73 or 161.

BUSINESS ADMINISTRATION

54-55—ELEMENTARY ACCOUNTING—COMBINED COURSE. A combination of Econ. 24, 25, 26 for engineering students in the combined engineering business curricula. 4 cred. per qtr.; no prereq.; 4 rec. hrs. per week. Heilman and others.

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† The entire course must be completed before credit is received for any quarter.

§ Credit may not be received for both Econ. 28 and B.A. 51, or for 73 and 161.

¶ Not open to students who have received credit in Soc. 45 or B.A. 70.

57—MONEY AND BANKING. Designed for students in the School of Business Administration who have not had an elementary course in this field. Principles of money and banking. Types and functions of financial institutions. 3 cred.; jr., sr.; no prereq.

66†—MANAGERIAL COSTS. A general survey of cost accounting from the point of view of the executive who must use cost information in the conduct of his business. 3 cred.; jr., sr., grad.; prereq. Econ. 26 or equiv.; 3 rec. hrs. per week.

70§—STATISTICS SURVEY. A survey of elementary statistical tools used in business administration and economic analysis, including averages, variation, sampling, graphics, correlation, and index numbers. Emphasis is placed on the logical interpretation and limitations of statistical data. 3 cred.; jr., sr.; prereq. Econ. 6-7 or equiv.; 3 rec. hrs. per week.

77—SURVEY IN MARKETING. Descriptive analysis of (1) marketing institutions and their control; (2) market areas; (3) marketing costs; (4) the operation of supply and demand in marketing. 3 cred.; jr., sr.; prereq. Econ. 7 or equiv.

167—INTRODUCTION TO INDUSTRIAL RELATIONS. A survey of policy and practice in manpower management. The course provides a professional viewpoint toward major functions, including policy formulation, determination of labor needs, job analysis, recruitment, selection, training and safety, service rating, employment stabilization, collective bargaining, and wage and salary administration. 3 cred.; jr., sr., grad.; prereq. Econ. 73 or 161.

Electrical Engineering

Electrical Engineering, Basic Required Courses:
Year 2—E.E. 12, 14, 16.
Year 3—E.E. 109, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120.
Year 4—E.E. 121, 122, 123, 124, 125, 126, 161, 162, 163.
Year 5—E.E. 127, 128, 129.

Communication Engineering: E.E. 161, 162, 163, 164, 165, 166, 167, 168, 169, 181, 187, 188, 189, 211, 212, 213, 261, 262, 263, 264, 265, 266, 267, 268, 269, 272, 273, 274, 287, 288, 289.

Electronics: E.E. 117, 118, 119, 120, 131, 133, 135, 157, 158, 159, 201, 202, 203, 287, 288, 289, 291, 292, 293.

Illumination: E.E. 151.

Inspection Trip: E.E. 100.

Measurement: E.E. 81.

Power and Central Station Engineering: E.E. 121, 122, 123, 124, 125, 126, 132, 134, 136, 138, 139, 140, 141, 142, 173, 174, 175, 183, 184, 185, 191, 192, 193, 197, 198, 199, 227, 228, 229, 255, 256, 257, 275, 276, 277.

Research: E.E. 171, 172.

Seminar: E.E. 98, 187, 188, 189, 191, 192, 193, 262, 264, 266, 291, 292, 293.

Survey of Electrical Engineering: (for nonelectrical engineering students) E.E. 36, 37, 38, 41, 42, 46, 47, 48.

12-14-16—ELEMENTS OF ELECTRICAL ENGINEERING LABORATORY. Principles, materials, safety, and laboratory techniques of electrical engineering. 1 cred. per qtr.; prereq. I.T.M. 11, 12, 13; 2 lab. hrs. per week. Cartwright.

36-37-38—ELECTRICAL ENGINEERING SURVEY. Elementary study of the principles of electrical engineering with applications. 3 cred. per qtr.; for M.E. and Chem.E.; prereq. M.&M. 26 or 84 for 36, 36 for 37 and 38; 2 lect. and 2 lab. hrs. per week. Kuhlmann and others.

41—ELECTRICAL ENGINEERING SURVEY. Laboratory. 1 cred.; prereq. concur. reg. in 42; 2 lab. hrs. per week.

42—ELECTRICAL ENGINEERING SURVEY. 3 cred.; for C.E. and Mines; prereq. M.&M. 26; 3 rec. hrs. per week. Larson and others.

46-47—ELECTRICAL ENGINEERING SURVEY AND AERONAUTICAL RADIO. Fundamentals of direct current and alternating current circuits, principles, vacuum tube applications. 3 cred. per qtr.; for Aero.E.; prereq. M.&M. 26; 2 rec. and 2 lab. hrs. per week. Staff.

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† Credit may not be received for both B.A. 66 and B.A. 152.

§ Not open to students who have received credit in Econ. 5.

48—AERONAUTIC RADIO DEVELOPMENTS. Study of radio aids for the operation of aircraft. Direction finding, instrument landing systems; ultra-high-frequency applications, television, and radiosonde equipment. 2 cred.; prereq. 47 or permission; 2 rec. hrs. per week.

81—ELECTRICAL ENGINEERING MEASUREMENTS. Principles of electrical measuring instruments, construction, limitations, sources of error, methods of calibration. Methods of measuring voltage, current, watts, watt hours, resistance, inductance, mutual inductance, capacitance. 3 cred.; prereq. 111; 2 lect. and 2 lab. hrs. per week.

98—SEMINAR. Weekly discussion of current engineering periodicals and reports on assigned topics. 1 cred.; 3rd year.

100—INSPECTION TRIP. Inspection of selected industrial plants. 2 cred.; required 5th year E.E.

109—ELECTRIC AND MAGNETIC FIELDS. Static and quasi-static electric and magnetic field theory, the dynamics of charged particles in fields. 3 cred.; prereq. 16 and M.&M. 26 or permission.

111-113-115—ELECTRICAL ENGINEERING. Electric circuit analysis. 5 cred. for 111, 3 cred. per qtr. for 113 and 115; prereq. M.&M. 26 and Phys. 50 for 111, 111 and 112 for 113, and 113 for 115. Anderson and others.

112-114-116—ELECTRICAL ENGINEERING LABORATORY. Experimental study of electric circuits. 2 cred. for 112, 1 cred. per qtr. for 114 and 116; prereq. reg. in 111-113-115. Barnes.

117-119—ENGINEERING ELECTRONICS. Fundamental theory of electronic devices. 3 cred. per qtr.; prereq. 109 and 111 for 117, 117 for 119; 3 rec. hrs. per week. Muckenhirn and others.

118-120—ENGINEERING ELECTRONICS LABORATORY. 1 cred. per qtr.; prereq. reg. in 117 for 118, reg. in 119 for 120; 2 lab. hrs. per week. Muckenhirn and others.

121-123-125—ELECTRICAL ENGINEERING. Principles and construction of electric machinery. 3 cred. per qtr.; prereq. 115, 116. Kuhlmann, Caverley, and others.

122-124-126—ELECTRICAL ENGINEERING LABORATORY. Laboratory study of electric machinery. 2 cred. per qtr.; prereq. reg. in 121-123-125; 3 lab. hrs. per week. Kuhlmann, Caverley, and others.

127-128-129—TRANSIENT ELECTRICAL PHENOMENA. Study of electric circuits during sudden changes of conditions. Classical and Laplace transform methods of analysis applied to electric circuits and machines, and use of the oscillograph in the analysis of these problems. 3 cred. per qtr.; prereq. 123, 162, and I.T.M. 80; 2 lect. and 2 lab. hrs. per week. Barnes.

131-133-135—ELECTRONIC CIRCUIT DESIGN. Study of practical circuits and components for design of industrial electronic applications, amplifiers, oscillators, etc. 3 cred. per qtr.; prereq. 163; 2 rec. and 2 lab. hrs. per week. Anderson and others.

132-134-136—TYPE STUDY OF ELECTRIC MACHINES. Uniformly applicable principles, prediction of performance, steady and transient behavior, direct current generators and motors, alternating current transformers, generators, and synchronous motors. 3 cred. per qtr.; prereq. 125. Caverley and others.

138-139-140—POWER SYSTEMS. Short-circuit currents in power networks; unbalanced loads in polyphase circuits, transformers, and motors; harmonics; stability of power systems under steady state conditions. Application of relay, oil circuit breakers, and lightning arresters to power systems for protection of apparatus and service. 3 cred. per qtr.; prereq. 125. Caverley, Cartwright.

141—CENTRAL STATIONS. Electric power generating stations and distributions systems. Economic considerations. Cost, load curves, plant location, selection of prime movers, station equipment. 3 cred.; prereq. 125; 3 rec. hrs. per week.

142—ELECTRICAL TRANSMISSION. Designing and building of transmission lines. Mechanical, electrical, and economic considerations. Lightning protection, underground lines, high voltage direct current transmission. 3 cred.; prereq. 125; 3 rec. hrs. per week.

143-144-145—ELECTROMECHANICAL VIBRATING SYSTEMS. Study of the steady state response of electromechanical systems. Electromechanical analogies. Transducers. Vibration damping, filters, and noise control. Introduction to mechanical wave motion. 3 cred. per qtr.; prereq. I.T.M. 80 and M.&M. 127 or Phys. 101 for 143, 143 for 144, 144 for 145. Lambert.

151—ILLUMINATING ENGINEERING. Light and vision. Principles of illumination. Photometry. Sources of light and their characteristics. Lighting equipment. Illumination requirements and calculation for various fields of use. 3 cred. per qtr.; prereq. reg. in 121. Johnson.

157-158-159—INDUSTRIAL ELECTRONICS. Theoretical and laboratory study; applications to X ray, dielectric heating, precipitation, servo-mechanisms, etc. 3 cred. per qtr.; prereq. 163; 2 rec. and 2 lab. hrs. per week. Murphy.

161-162-163—ELECTRIC COMMUNICATION. Theoretical and laboratory study of communication circuits and apparatus. 4 cred. per qtr.; prereq. 119; 3 rec. and 2 lab. hrs. per week. Shepherd, Harris.

164-165-166—COMMUNICATION CIRCUITS. Theoretical and laboratory study of circuits having distributed constants. Use of hyperbolic functions. Wave filters, balancing networks, equilizers, repeaters. 3 cred. per qtr.; prereq. 163; 2 rec. and 2 lab. hrs. per week. Harris.

167-168-169—RADIO COMMUNICATION. Maxwell's equations. U.H. frequency transmission and reception, micro-waves, wave guides, velocity modulation, klystrons and magnetrons. 3 cred. per qtr.; prereq. 163; 2 rec. and 2 lab. hrs. per week. Shepherd, van der Ziel.

171-172—UNDERGRADUATE THESIS. Investigation of some approved problems in electrical engineering. 3 to 6 cred. per qtr.; prereq. 121.

173-174-175—HIGH VOLTAGE ENGINEERING. Study of insulation and generating equipment for high voltage; measurements of electrical quantities at high voltage; surges and surge proof equipment. Lecture and laboratory. 2 or 3 cred.; prereq. 5th year.

176—ANALOG COMPUTER, ENGINEERING PROBLEMS. Theory, operation, and application of differential analyzers; servo-mechanisms, auto pilots, nonlinear elements, transient response, stability. 3 cred.; prereq. 127; hrs. ar. Hess.

177—COMPUTING LABORATORY. 1 to 3 cred.; prereq. 127, I.T.M. 80, or permission of instructor. Hess.

180—ELECTRICAL PULSES AND TRANSIENTS. Application of Fourier integral and transform methods, network response, distortion of wave form, response of multi-stage amplifiers. 3 cred.; prereq. 127, 163. Barnes.

181—COMMUNICATION FREQUENCY MEASUREMENTS. Bridge circuits for measuring of resistance, inductance, and capacity at audio and radio frequencies. 2 cred.; prereq. 163.

183-184-185—SPECIAL ELECTRICAL LABORATORY. Efficiency tests and special problems. 1 to 3 cred. per qtr.; prereq. 3rd year or permission.

187-188-189—COMMUNICATION SEMINAR. Study and discussion of current articles on communication or allied topics. 1 cred. per qtr.; prereq. permission of instructor. Hartig.

190—THEORY AND APPLICATION OF NONSINUSOIDAL WAVE FORMS. Transmission of pulses through linear networks, design of pulse amplifiers, generation of nonsinusoidal wave forms, time basis, cathode ray oscilloscopes. 3 cred.; prereq. 127, 163. Anderson.

191-192-193—GRADUATE SEMINAR. Discussions of problems in power circuits and machinery. 1 cred. per qtr.; prereq. permission of instructor. Caverley.

194-195-196—SERVO-MECHANISMS. Transient and sinusoidal response of servo-mechanisms, stability analysis, synthesis of servo-systems, nonlinearity, power requirements. 3 cred. per qtr.; prereq. 115, I.T.M. 80; 3 lect. hrs. per week in 194, 2 lect. and 2 lab. hrs. per week in 195 and 196. Murphy.

197-198-199—ADVANCED ELECTRICAL DESIGN. A study of the methods and procedures for the design of standard equipment for specific performance characteristics and for the design of special apparatus. Special problems in rotating machinery design including study of harmonics in air gap flux wave and their effect upon performance; study of starting of synchronous motors. Transformers for control and electronic applications including audio-transformers. 3 cred. per qtr.; prereq. 132-134-136. Kuhlmann.

201-202-203—ADVANCED INDUSTRIAL ELECTRONICS. Continuation of course 157-158-159. 3 cred. per qtr. Staff.

211-212-213—ADVANCED NETWORK ANALYSIS. The study of networks by advanced methods. Particular emphasis is placed on active networks, feedback, stability, and physical realizability, topics in design of impedance functions. Applications of general theorems to design of equalizers, input and output circuits, and interstage networks, applications to servo-mechanisms. 3 cred. per qtr.; prereq. by permission. Hartig.

227-228-229—STABILITY OF A.C. POWER SYSTEMS. A study of A.C. power systems, including the system design factors which affect the problem of stability. The relation of both steady state and transient conditions to stable operation of power distribution systems. 3 cred. per qtr.; prereq. 138-139-140. Caverley.

230-231-232—SOLID STATE DEVICES. Applications of solid state theory to engineering problems. Introduction to solid state theory, conduction, dielectric breakdown, piezoelectricity, ferromagnetism, thermionic emission, secondary emission, thermistors, resistors, crystal rectifiers, transistors. 3 cred. per qtr.; 3 lect. hrs. per week. Grad. only. Dekker, van der Ziel.

233-234-235—FLUCTUATION PHENOMENA. Application of the theory of fluctuating quantities to engineering problems such as thermionic tube noise, circuit noise. 2 cred. per qtr.; grad. only. van der Ziel.

255-256-257—ANALYSIS OF A.C. POWER-SYSTEMS CIRCUITS. Application of specialized network theorems and equivalent circuits to the study of A.C. generators, motors, transformers, and transmission lines. The study of the behavior of A.C. equipment under unbalanced conditions by the use of symmetrical components. Transients in machines and associated circuits. 3 cred. per qtr.; prereq. 138-139-140. Caverley.

261-263-265—ADVANCED COMMUNICATION. Applications of basic electro-magnetic theory to problems in electrical engineering. Studies of antennas, free space transmission including refraction and diffraction phenomena, wave guides, and circuits. Static electric and magnetic fields with applications to the motions of charged particles. Interaction of electromagnetic fields with electron streams. 3 cred. per qtr.; prereq. Phys. 101-103-105 or equiv. Shepherd.

262-264-266—COMMUNICATION SEMINAR. Study and discussion of current literature. 1 to 3 cred. per qtr.; prereq. permission of instructor. Shepherd.

267-268-269—THEORY OF COMMUNICATION. Theory of communication with special reference to amplitude, frequency, phase, time division, pulse code modulation. Conservation of frequency space. Advanced study of communication networks and their synthesis, filters, phase and amplitude corrective networks. 3 cred. per qtr.; prereq. permission of instructor. (Offered whenever demand warrants.)

272-273-274—ELECTROMECHANICAL VIBRATING SYSTEMS AND ENGINEERING ACOUSTICS. Theoretical discussion of the production of sound by electrically driven vibrating systems, sound transmission, reflection, absorption. Laboratory study of vibrating systems, pipes, horns, absorbing materials, sound pressure, articulation, reverberation, resonance, sound filters. 3 cred. per qtr.; prereq. grad. by permission. Hartig, Lambert.

275-276-277—ADVANCED ELECTRIC DESIGN. Study of the metadyne. Special problems. 3 cred. per qtr.; prereq. 132-134-136. Kuhlmann, Pestarini.

287-288-289—ADVANCED VACUUM TUBE ANALYSIS. Theoretical and laboratory investigations of vacuum tubes used for communication purposes with particular emphasis on high frequency applications. Space charge control tubes, deflection control, electron multipliers, klystrons, magnetrons and traveling wave amplifiers, transit time effects and noise. 3 cred. per qtr.; prereq. permission of instructor. Shepherd.

291-292-293—ELECTRONICS SEMINAR. Study and discussion of current literature. 1 to 3 cred. per qtr.; prereq. permission of instructor. van der Ziel.

English (Engineering)

4-5-6—WRITTEN AND SPOKEN COMMUNICATION. Elementary technical writing and speaking integrated with analytic reading in class and pleasure reading outside of class. 3 cred. per qtr.; prereq. placement test; 3 rec. hrs. per week. Guthrie, Haga, and others.

37-38-39—TWENTIETH-CENTURY LITERATURE. Introduction to intelligent reading of literature, intended for students in all colleges, and not particularly for English majors. 37: Nonfiction and short story; 38: Poetry and drama; 39: The novel since Thomas Hardy. 3 cred. per qtr.; prereq. 6; 3 rec. hrs. per week.

85-86—ADVANCED TECHNICAL COMMUNICATION. Theory and practice in professional uses of language. 85: Reports and talks; 86: Letters, articles, conferences, interviews. 3 cred. per qtr.; prereq. 6; 3 rec. hrs. per week. Guthrie, Haga.

General Engineering

21—ORIENTATION. Series of lectures designed to orient the student who has just begun his university course. 1 cred.; no prereq.; required of all 1st year students. 1 lect. hr. per week.

70—THE SLIDE RULE. Computation practice and theory. Design of special scales. 1 cred.; prereq. I.T.M. 11 or reg. in I.T.M. 11; 1 rec. hr. per week.

101—CONTRACTS AND SPECIFICATIONS. Engineering contracts. Specification essentials; approved methods of handling construction projects; trade practices, workman compensation acts. Powers and duties of engineer executive. 3 cred.; prereq. 5th yr., grad.; 3 rec. hrs. per week. Fixen.

103—PROFESSIONAL PROBLEMS. Lectures covering some of the problems the engineer will meet upon entering his professional career. 1 cred.; required of all 5th yr. students in the Institute of Technology; 1 lect. hr. per week.

105—ENGINEERING LIBRARY TECHNIQUES. Lectures designed to instruct the student in the use of libraries and bibliographic tools in technical fields. Offered fall quarter. 1 cred.; no prereq.; 1 hr. per week.

Geology and Mineralogy

(College of Science, Literature, and the Arts)

1-2—GENERAL GEOLOGY (PHYSICAL AND HISTORICAL). A study of geologic processes and of the materials on which they operate. A résumé of the history of the earth and its inhabitants as recorded in the rocks. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week.

A-B—GENERAL GEOLOGY LABORATORY (PHYSICAL AND HISTORICAL). The physical properties of common minerals and rocks; interpretation of topographic maps. Identification of fossils; interpretation of geologic maps. 2 cred. per qtr.; with or after 1-2; 4 lab. hrs. per week.

5-6—ENGINEERING GEOLOGY. Materials of the earth and geologic processes. Applications of geology to engineering problems. Brief survey of occurrence, properties, production, and use of building stones, cements, clays, fuels, and road material. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week. Schwartz.

8—EARTH FEATURES AND THEIR MEANING—An Introductory Course. A general education elective. An explanation of the natural landscape as produced by such agents as the atmosphere, water, glaciers, volcanoes, and mountain building forces acting on the materials of the earth. 5 cred.; no prereq.; 5 lect. hrs. per week. Thiel.

23-24—MINERALOGY. The crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. 4 cred. per qtr.; prereq. one term of college chemistry; 3 lect., 1 rec., and 4 lab. hrs. per week. Gruner.

25—ROCK STUDY. The occurrence and origin of rocks; their mineral and chemical composition and classification. 2 cred.; prereq. 24; 1 lect., 1 rec., and 2 lab. hrs. per week. Goldich.

70—GEOLOGIC FIELD METHODS. Application of the plane table, altimeter, hand level, and Brunton compass to problems in the field. 2 cred.; prereq. 25 and trigonometry. Ar.

100—FIELD WORK IN NORTHERN MINNESOTA. July 15 to 30, approximately. Selected areas in the iron district of Minnesota. 3 cred.; prereq. 25.

101—SEDIMENTATION. Environments of sedimentation. The origin of sedimentary rocks and their primary structures; lithologic associations. 3 cred.; prereq. 24; 3 lect. hrs. per week. Thiel.

102—METHODS OF STUDY OF SEDIMENTS. Methods used in the study of sediments and sedimentary rocks. Textural and mineralogical analyses of clastic and nonclastic materials. 3 cred.; prereq. 101, 106; 1 lect. and 4 lab. hrs. per week. Thiel.

103-104—MICROPALEONTOLOGY. The study and classification of Foraminifera, Ostracoda, and other small fossils, and their use in stratigraphy. 3 cred. per qtr.; prereq. 107; hrs. ar. Swain.

106—PETROGRAPHY. Optical methods for identification of minerals in thin sections and immersion media; introduction to microscopic work on rocks. 3 cred.; prereq. 25; 1 lect., 1 rec., and 4 lab. hrs. per week. Goldich.

107—INVERTEBRATE PALEONTOLOGY. Morphology and classification of important fossil groups other than Foraminifera and Ostracoda. 3 cred.; prereq. 25 or permission of instructor; 1 lect. and 4 lab. hrs. per week.

108-109—ADVANCED INVERTEBRATE PALEONTOLOGY. Procedures in taxonomy; international rules of zoological nomenclature; techniques and elements involved in preparation of a paleontologic report. 3 cred. per qtr.; prereq. 107; 6 lab. hrs. per week.

110-111—ECONOMIC GEOLOGY. The nature, genesis, and distribution of mineral deposits; relation of mineral deposits to structure and surficial alteration. 3 cred. per qtr.; prereq. 25; 3 lect. hrs. per week. Schwartz.

112—PETROLEUM GEOLOGY. The composition and origin of petroleum, methods of exploration and the geology of the important oil producing regions. 3 cred.; prereq. 125 and 151; 3 lect. hrs. per week. Swain.

114—GEOLOGY OF MINNESOTA AND ADJOINING AREAS. The structure, stratigraphy, and lithology of the rocks and their associated mineral resources, with emphasis on the Precambrian. 3 cred.; prereq. 25; 3 lect. hrs. per week. Thiel. (Offered 1953-54.)

115—FIELD WORK IN SOUTHEASTERN MINNESOTA. July 15 to 30, approximately. Stratigraphic methods and principles as illustrated by study of Cambrian and Ordovician rocks. 3 cred.; prereq. 25.

118—GEOMORPHOLOGY. Origin and evolution of landforms in temperate, arctic, desert, and tropical regions in different geologic settings. Effects of structural history and climatic change on landform development. Relations of geomorphic processes to soil formation and engineering problems. Field trips; term paper or field project. 3 cred.; prereq. A and 2; 3 lect. hrs. per week. Wright.

119a—GEOMORPHOLOGY OF EASTERN UNITED STATES. General geology of the physiographic provinces east of the Great Plains, with emphasis on the landforms and the Cenozoic history. Map study. 3 cred.; prereq. 118 or 125; 2 lect. hrs. per week, lab. ar. Wright. (Offered 1953-54.)

119b—GEOMORPHOLOGY OF WESTERN UNITED STATES. General geology of the physiographic provinces from the Great Plains westward, with emphasis on the landforms and the Cenozoic history. Complementary to Geol. 119a. Map study. 3 cred.; prereq. 118 or 125. (Offered 1954-55.)

120—GLACIAL GEOLOGY. Physics of modern glaciers. Glacial erosion and deposition. Stratigraphy and chronology of the Pleistocene in glaciated and nonglaciated areas. Causes of Pleistocene climatic changes. 3 cred.; prereq. A and 2; 3 lect. hrs. per week. Wright.

121—CRYSTALLOGRAPHY. The symmetry relations in the thirty-two crystal classes. Crystal drawings and measurements. Projections and mathematical calculations. 3 cred.; prereq. trigonometry and one year of college chemistry. Gruner.

124—METAMORPHIC GEOLOGY. Conditions, processes, and results of metamorphism. 3 cred.; prereq. 131; 3 lect. hrs. per week. Schwartz. (Not offered 1953-55.)

125—STRUCTURAL GEOLOGY. Primary and secondary structures of sedimentary, igneous, and metamorphic rocks; mechanics of rock deformation; use in field mapping and interpretation of geologic history. 3 cred.; prereq. 25; 3 lect. hrs. per week. Wright.

131-132—PETROLOGY. Petrographic description of igneous, metamorphic, and sedimentary rocks; their mineral and chemical composition, classification, origin, and alteration. Laboratory methods; preparation of samples. 4 cred. per qtr.; prereq. 106; 2 lect., 1 rec., and 4 lab. hrs. per week. Goldich.

137—PRINCIPLES OF CHEMICAL GEOLOGY. A study of geochemical literature. Methods in geochemical research and application of chemical and physical chemical principles to geologic problems. 3 cred.; prereq. 25; hrs. ar. Gruner.

140-141—APPLIED PETROGRAPHY. Application of petrographic techniques to problems in mining and petroleum geology. 3 cred. per qtr.; prereq. 131.

144—GEOLOGIC MAPS. Laboratory problems on construction and interpretation of geologic maps, cross-sections, structure contour maps, and mine maps. Fault problems and other three-dimensional analyses of geologic structures. 3 cred.; prereq. 125; 6 lab. hrs. per week. Wright.

145—AERIAL PHOTOGRAPHS. Elements of photogrammetry, construction of mosaics and of planimetric and topographic maps, stereovision, geologic and geomorphic interpretation, field use. 3 cred.; prereq. A and 2; 6 lab. hrs. per week. Wright.

146-147—SOIL MINERALOGY. The crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. For students in soil science and agriculture and civil engineering. 3 cred. per qtr.; prereq. one term of college chemistry; Gruner.

150—FIELD GEOLOGY. June 15 to July 15. Detailed systematic field work. Preparation of geologic maps, structure sections, reports; genesis of ores and their relations to geologic structures. Field, Black Hills, South Dakota. 6 cred.; prereq. 125.

151-152—STRATIGRAPHY. Principles and methods illustrated by selected stratigraphic reports; stratigraphic history of United States; index fossils of each geologic period; term paper in 152. 3 cred. per qtr.; prereq. 107; 3 lect. hrs. per week.

153—SUBSURFACE STRATIGRAPHY. The application of sample logs, electrical logs, and other methods to the detailed stratigraphy of the subsurface in selected areas. 3 cred.; prereq. 151; 1 lect. and 4 lab. hrs. per week. Swain.

153A—SUBSURFACE STRATIGRAPHY LABORATORY. Laboratory study of sample logs, electrical logs, and other techniques in subsurface stratigraphy. 2 cred.; prereq. 2 and 125; 4 lab. hrs. per week. Swain.

161—ADVANCED MINERALOGY. Systematic study of mineral groups including some of the less common ones. Laboratory study of select specimens. Special physical and chemical tests including blowpipe analysis. 3 cred.; prereq. 24. Gruner.

166-167—MINERALOGRAPHY. Methods of studying opaque minerals and applications to problems in ore genesis and history. 3 cred. per qtr.; prereq. 111, 131. Schwartz.

170—GEOLOGIC PROBLEMS. Individual research in laboratory, or field problems at Senior College and graduate levels. 1-3 cred. per qtr. ar.; prereq. permission of major adviser. Staff.

175—FIELD WORK IN GLACIAL GEOLOGY AND GEOMORPHOLOGY. Mapping of surficial deposits and landforms of a selected area in Minnesota. One day of field work each week. 3 cred.; prereq. 118, 120. Wright.

Geophysics

108—INTRODUCTION TO GENERAL GEOPHYSICS. Physics of the earth; evidence and data on age, shape, internal constitution, gravity and magnetic fields, etc. 3 cred.; prereq. Phys. 9 or 14, Geol. 2; Geol. 125 recommended. Mooney.

109—ELEMENTARY SEISMOLOGY. Physics and geology of earthquakes; causes, effects, distribution. Theory of seismic waves. 3 cred.; prereq. Phys. 9 or 14, Geol. 125. Mooney.

110—INTRODUCTION TO EXPLORATION GEOPHYSICS. Principles of exploration by gravity, magnetic, seismic, and electrical measurements. 3 cred.; prereq. Phys. 9 or 14, Geol. 2; Geol. 125 recommended. Mooney.

125—PRINCIPLES OF GRAVITY AND MAGNETIC EXPLORATION. Techniques of interpretation; use in geologic and mining problems. 2 cred.; prereq. Phys. 9 or 14, Geol. 125, I.T.M. 25. Mooney.

126—PRINCIPLES OF SEISMIC EXPLORATION. Reflection and refraction seismology; interpretation of data. 2 cred.; prereq. Phys. 9 or 14, Geol. 125, I.T.M. 25. Mooney.

127—PRINCIPLES OF ELECTRICAL EXPLORATION. Resistivity method and others; theory, interpretation, and instruments. 2 cred.; prereq. Phys. 9, Geol. 125, I.T.M. 25. Mooney.

130—SPECIAL PROBLEMS IN GEOPHYSICS. Cred. ar.; prereq. permission of instructor. Mooney.

German

(College of Science, Literature, and the Arts)

24-25-26—CHEMICAL GERMAN. Grammatical fundamentals, vocabulary, sentence analysis, and translation. 3 cred. per qtr.; for students who have had no German previously; 3 rec. hrs. per week.

27-28-29—CHEMICAL PROSE. Representative chemical prose. 3 cred. per qtr.; prereq. two years of high school German or one year of college German; 3 rec. hrs. per week.

41-42-43—READINGS FROM GERMAN CHEMICAL PERIODICALS. 2 cred. per qtr.; prereq. 26 or equiv.; 2 rec. hrs. per week.

History

(College of Science, Literature, and the Arts)

Except where otherwise stated, there are no prerequisites for the courses numbered 50 to 169. Most of these courses are announced for f-w-s or w-s, but students may enter any quarter.

59-60-61—AMERICAN HISTORY. 9 cred.; not open to those who have credit in 20-21-22.

70-71-72—ENGLISH CONSTITUTIONAL HISTORY. 70: The medieval period. 71: Early modern times. 72: In the last two centuries. 3 cred. per qtr.; open to prelegal soph. with at least a C average in Courses 4-5-6, 1-2-3, or in all their college work, and to all jrs. and srs. Thompson, Willson.

79-80-81—AMERICAN HISTORY SINCE 1900. 9 cred.

106-107-108—CONTINENTAL EUROPE. 106: 1559-1661, the era of the Thirty Years' War. 107: 1661-1774, the age of Louis XIV, the "Age of Reason," and the "Enlightened Despots." 108: 1774-1815, the French Revolution and the Napoleonic Empire. 9 cred.

109-110-111—EUROPE IN THE TWENTIETH CENTURY. 9 cred.

134-135-136—WORLD WAR II. 9 cred.; jr., sr., grad.

Humanities

(College of Science, Literature, and the Arts)

21—AMERICAN LIFE I. (Formerly Hum. 22) The growth of individualism and democracy (with particular attention to minorities) as recorded in American history, social thought, literature, and the arts. 3 cred.; no prereq.

22—AMERICAN LIFE II. (Formerly Hum. 23) The place in American civilization of the land, the city, and the good life; their implications and interrelations. 3 cred.; no prereq.

23—AMERICAN LIFE III. (Formerly Hum. 21) The growth and interrelation of nationalism, regionalism, and internationalism in American culture and thought. 3 cred.; no prereq.

51-52-53†—HUMANITIES IN THE MODERN WORLD. This course is similar to 1-2-3 except that it is confined to juniors and seniors. A student may not receive credit for any quarter of this course if he has completed the corresponding quarter of 1-2-3. 5 cred. per qtr.; no prereq.; students may enter any quarter.

1: The old regime, the revolution, neo-classicism and romanticism. Period: from about 1740 to about 1820. Authors: Voltaire, Rousseau, Burke, Paine, Goethe, and the poets. One historical novel, Tolstoy's *War and Peace*.

2: The industrial revolution; liberalism and socialism; the psychology of the individual. Period: from about 1776 to 1890. Authors: Carlyle, Mill, Marx, Smith, Malthus, Ibsen, Flaubert, Dostoievsky, and the poets.

3: The impact of science and evolution; religion and morals in a changing world. Period: from about 1840 to about 1914. Authors: Huxley, Arnold, Turgeneff, Nietzsche, Shaw, Mann, and the poets.

61-62-63—THE EUROPEAN HERITAGE. This course is similar to 11-12-13 except that it is confined to juniors and seniors. A student may not receive credit for any quarter of this course if he has completed the corresponding quarter of 11-12-13. 5 cred. per qtr.; no prereq.; students may enter any quarter.

71-72-73—HUMANITIES IN THE UNITED STATES. This course is conducted on a more advanced level than Hum. 21-22-23. A student may receive credit for both this course and 21-22-23, but not to exceed 9 credits altogether. 3 cred. per qtr.; no prereq.; students may enter any quarter.

Hydromechanics*

101—FLUID MECHANICS. (Aero.E. and E.E.) Hydrostatics, Bernoulli's theorem, pressure-momentum relationships, compressible and incompressible flow through pipes. 3 cred.; prereq. M.&M. 26 or 84; 3 rec. hrs. per week. Straub and staff.

102—FLUID MECHANICS. Physical properties of fluids, hydrostatics, flow of ideal and real fluids, elementary principles of turbines and pumps. 4 cred.; prereq. M.&M. 26; 4 rec. hrs. per week. Straub and staff.

103—FLUID MECHANICS. Physical fluid properties, fluid statics, energy principle for compressible and incompressible fluids, pressure-momentum principle, elementary principles of turbines and pumps, dimensional analysis, introduction to advanced principles of flow phenomena. 5 cred.; prereq. M.&M. 26 or 84; 5 rec. hrs. per week. Straub and staff.

104—HYDRAULICS LABORATORY. Introduction to laboratory techniques, calibration principles, and fluid measurements. Open channel, pipe line; and hydraulic machinery experiments. 1 cred.; prereq. cred. or reg. in 101 or 102 or 103 or Chem.E. 101. Straub, L. A. Johnson, and staff.

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* Courses in hydromechanics are administered by the Civil Engineering Department.

† Students in Hum. 1, 2, 3, 51, 52, and 53 will attend, in addition to the regular class sessions, concerts and exhibitions with hours to be arranged.

183—OPEN CHANNEL FLOW. Theory of uniform and varied flow in open channels, with practical applications to the design of hydraulic structures, computations of drawdown curves, backwater curves, hydraulic jump, measuring flumes, submerged weirs, etc. 3 cred.; prereq. 101 or 102 or 103 and 104; 3 rec. hrs. per week. Straub, Anderson.

184-185-186—ADVANCED HYDRAULIC PROBLEMS. Special problems in hydraulic design. 2 cred. per qtr.; prereq. 183 or reg. in 183; 6 lab. hrs. per week. Straub and staff. (Offered by individual arrangement.)

187—INTERMEDIATE FLUID MECHANICS. One- and two-dimensional flow of an ideal fluid, energy and momentum relations, fluid forces, boundary layer theory, separation and cavitation, hydrofoils. 3 cred.; prereq. 101 or 102 or 103 and 104.

190—MECHANICS OF SIMILITUDE AND DIMENSIONAL ANALYSIS. Theory of the use of models in design; conditions for similarity in the case of hydraulic structures, elastic structures, aircraft, ships, waves, etc. 3 cred.; prereq. 101 or 102 or 103 and M.&M. 127, 128, or permission of instructor; 3 rec. hrs. per week. Straub, Anderson.

191—HYDRAULIC MOTORS AND PUMPS. Study of the mechanics of turbo-machines, including impulse, reaction, and propeller turbines and radial, mixed, and axial flow pumps. Hydraulic transmissions. Torque converters. Miscellaneous pumping devices. 3 cred.; prereq. 187 or permission of instructor; 3 rec. hrs. per week. Ripken.

192—NATURAL AND ARTIFICIAL WATERWAYS. Wave motion, tides, ship resistance, transportation of sediment. Control and regulation of rivers, design of ship canals, locks, dry docks, movable dams, harbors. 3 cred.; prereq. 183 or permission; 3 rec. hrs. per week. Straub, Anderson.

193—HYDRAULIC MEASUREMENTS. Detailed study of laboratory and field, methods and instruments for measurement of hydraulic pressure, velocity and discharge. 3 cred.; prereq. 187 or permission of instructor; 3 rec. hrs. per week. Ripken.

194-195-196—ADVANCED HYDRAULICS LABORATORY. Special experimental studies concerning the characteristics of turbines, pumps, etc. Hydraulic models. 2 cred. per qtr.; prereq. 103 and 104; 6 lab. hrs. per week. Straub and staff. (Offered by individual arrangement.)

287—FLUID TURBULENCE. Description of turbulence; momentum and vorticity transfer theories; statistical theory of turbulence. Phenomena of turbulence, diffusion, energy dissipation. Turbulence in wind-tunnels, rivers, and the atmosphere. 3 cred.; prereq. basic training in fluid mechanics and permission of instructor.

290-291-292—ADVANCED FLUID MECHANICS. 3 cred. per qtr.; prereq. 187, 190; 3 rec. hrs. per week.

293-294-295—HYDRODYNAMICS. Equations of motion, irrotational flow, potential theory, two-dimensional motion, conformal mapping, three-dimensional motion, bodies in motion in a fluid, vortex motion, waves, compressibility, viscous flow. 3 cred. per qtr.; prereq. 187 and differential equations or advanced calculus, or permission of instructor; 3 rec. hrs. per week. Silberman.

296-297-298—ADVANCED HYDRODYNAMICS. 3 cred. per qtr.; prereq. 295; 3 rec. hrs. per week. Silberman.

Industrial Engineering

1—INDUSTRIAL ENGINEERING ORIENTATION. Lectures and inspection trips to acquaint the student with manufacturing technology and industrial engineering. 1 cred.; no prereq.; 3 lab. hrs. per week. Staff.

90-91-92-93-94-95†—INDUSTRIAL ASSIGNMENT. Industrial work assignments for students in the cooperative work-study program in industrial engineering. Grades are based on written reports covering the student's work experience. 3 cred. per qtr.; prereq. reg. in work-study program. Block.

150—ELEMENTS OF INDUSTRIAL ENGINEERING AND MANAGEMENT. A survey of industrial plant operation, production management, and industrial engineering functions. 3 cred.; prereq. M.E. 14; 3 rec. hrs. per week. Staff.

153—METHODS ENGINEERING AND WORK MEASUREMENT. Development of methods and processes for economical production; motion study, time study, incentives. 3 cred.; prereq. 150; 2 rec. and 3 lab. hrs. per week. MacKenzie.

154—ADVANCED METHODS ENGINEERING AND WORK MEASUREMENT. Multiple operation analysis, advanced work measurement techniques and incentives. 3 cred.; prereq. 153; 2 rec. and 3 lab. hrs. per week. Block.

† The entire sequence must be completed before credit is given.

163—PROCESS PLANNING AND DEVELOPMENT. Planning of manufacturing operations to meet quantity, quality, and cost requirements of the product. 3 cred.; prereq. 150; 2 rec. and 3 lab. hrs. per week. MacKenzie.

165—INDUSTRIAL PLANTS. Analysis of materials flow; layout of production and service departments; plant buildings, service facilities, and handling equipment. 3 cred.; prereq. 153; 2 rec. and 3 lab. hrs. per week.

167—MATERIALS HANDLING AND PACKAGING. Development of materials handling systems and selection of equipment; industrial packaging techniques. 3 cred.; prereq. 165; 3 rec. hrs. per week. MacKenzie.

170—PRODUCTION PLANNING AND CONTROL. Planning of production requirements; routing, scheduling, and coordination of production; inventory policies and control. 3 cred.; prereq. 153; 3 rec. hrs. per week. Block.

171—QUALITY CONTROL. Quality standards, application of statistical methods and sampling theory; interpretation of results and corrective action. 3 cred.; prereq. 150 and I.T.M. 90 or permission of instructor; 3 rec. hrs. per week. McElrath.

173—ENGINEERING ECONOMIC ANALYSIS. Analysis of capital expenditures and annual operating costs as the basis for management policies and decisions. 3 cred.; prereq. 165, B.A. 66; 3 rec. hrs. per week. MacKenzie.

180—ELEMENTS OF SUPERVISION. Supervisory functions and relations with employees, other supervisors, staff departments, and management. 3 cred.; prereq. 150; 3 rec. hrs. per week. Block.

181—INDUSTRIAL RELATIONS. Labor-management relations and their effect on plant operations. Collective bargaining, employee selection and training, job evaluation, wage surveys, incentives. 3 cred.; prereq. 150; 3 rec. hrs. per week. Block.

182—INDUSTRIAL SAFETY AND HYGIENE. Safety requirements for production processes, equipment, and plants; organization and administration of safety and hygiene programs. 3 cred.; prereq. 150; 3 rec. hrs. per week. Block.

190-191-192*—INDUSTRIAL ENGINEERING SEMINAR. Current developments in industrial engineering and management; assigned articles and classroom discussion. 1 cred. per qtr.; prereq. 5th yr.; 1 rec. hrs. per week. Staff.

193—INSPECTION TRIP. Visits to selected industrial plants during spring vacation period. Studies of production methods and processes, equipment, and plants. 1 cred.; prereq. required of 5th yr. Staff.

194-195-196—APPLIED INDUSTRIAL ENGINEERING. Industrial engineering surveys and programs; case problems; studies in local plants. 3 cred. per qtr.; prereq. 15 cred. in industrial engineering; 2 rec. and 3 lab. hrs. per week. Staff.

251-252-253*—ADVANCED INDUSTRIAL ENGINEERING. Advanced studies in manufacturing policy, production engineering, plant operation, engineering economy, and industrial development. 3 cred per qtr.; prereq. permission of instructor; grad. only. Staff.

261-262-263*—PRODUCTION ENGINEERING PROBLEMS. Application of industrial engineering principles to the solution of manufacturing problems in local plants. 3-5 cred. per qtr.; prereq. permission of instructor; grad. only. Staff.

271-272-273*—INDUSTRIAL ENGINEERING RESEARCH. Research studies in selected areas of industrial engineering, production, and management; work of thesis quality but lesser scope. 3-5 cred. per qtr.; prereq. permission of instructor; grad. only. Staff.

Mathematics

2-3-4—LABORATORY. History of mathematics, foundations and mathematical logic, simple computing devices, library facilities, employment opportunities. 1 cred. per qtr.; no prereq. Staff.

9—HIGHER ALGEBRA. (High school.) Fundamental rules, fractions, linear simultaneous equations, graphs, theory of exponents, surds, complex quantities, quadratic equations, numerical exercises. No cred.; no prereq.; 5 rec. hrs. per week.

11—COLLEGE ALGEBRA AND TRIGONOMETRY I. Trigonometric functions, right triangles, slide rule, oblique triangles, vectors, radian measure. Factoring, fractions, functions and graphs, linear equations and determinants, exponents and radicals, quadratic equations, inequalities, systems of quadratic equations, logarithms. 5 cred.; prereq. 9 or equiv.; 5 rec. hrs. per week.

* May be taken out of sequence.

12—COLLEGE ALGEBRA AND TRIGONOMETRY II. Proportion and variation, mathematical induction, binomial theorem, progressions. Trigonometric formulas and identities, trigonometric curves, inverse trigonometric functions, trigonometric equations, complex numbers. Theory of equations, partial fractions. 5 cred.; prereq. 11; 5 rec. hrs. per week.

13—ANALYTIC GEOMETRY. Rectangular coordinate systems, locus and equation, straight line, conic sections. Transformation of coordinates. Polar coordinates, higher plane curves. Empirical equations, solid analytic geometry. 5 cred; prereq. 11 and 12; 5 rec. hrs. per week.

24—CALCULUS I: DIFFERENTIAL. Limit, derivative, slope, maxima and minima, differentials, rates, radius of curvature, indeterminate forms, partial differentiation, series, and expansion of functions. 5 cred.; prereq. 13; 5 rec. hrs. per week.

25—CALCULUS II: INTEGRAL. Integration of elementary forms, definite integral, geometric applications, liquid pressure, work, centroids, moments of inertia, double and triple integrals. 5 cred.; prereq. 24; 5 rec. hrs. per week.

80—ELEMENTARY DIFFERENTIAL EQUATIONS. Equations of the first order and first degree, higher degree, singular solutions; total, linear, and systems of simultaneous differential equations, integration in series. 3 cred.; prereq. 25; 3 rec. hrs. per week.

90—ELEMENTARY ENGINEERING STATISTICS. Probability, permutations, and combinations. Frequency distributions. Introduction to sampling, significance tests, regression charts. 3 cred.; prereq. 13; 3 rec. hrs. per week. McElrath.

91†—CALCULUS. (Arch., Prebus.) Short course, derivatives, maxima and minima, integration, definite integrals, areas. 4 cred.; prereq. 13; 4 rec. hrs. per week.

99—MATHEMATICAL PROBLEM SEMINAR. Problems ranging from elementary algebra and geometry through undergraduate mathematics will be assigned and discussed weekly. 3 cred.; prereq. 25. Fulks.

132-133-134—INDUSTRIAL STATISTICS. Statistics as applied to engineering problems and quality control. 3 cred. per qtr.; prereq. 25; 3 rec. hrs. per week. McElrath.

142-143—VECTOR AND MATRIX THEORY WITH APPLICATIONS. Topics in vectors, determinants, matrices, quadratic and bilinear forms, with applications to small vibrations, inertial and stress quadrics, electric net works. 3 cred. per qtr.; prereq. 25; 3 rec. hrs. per week. Milgram.

150—CALCULUS III. INTERMEDIATE CALCULUS. Review of limit concept, derivative, Riemann integral, vector algebra, partial differentiation, multiple integrals. 3 cred.; prereq. 25; 3 rec. hrs. per week. Turrittin.

151—ORDINARY DIFFERENTIAL EQUATIONS. Linear equations of second order, successive approximations. Existence theorems, systems of ordinary differential equations. Numerical integration and solution by series. 3 cred.; prereq. 80; 3 rec. hrs. per week. Polansky.

152—CALCULUS IV. ADVANCED CALCULUS. Maxima and minima in several variables, vector calculus, Green's and Stokes' theorems, integrals depending upon a parameter. 3 cred.; prereq. 150; 3 rec. hrs. per week. Koehler.

153—CALCULUS V. ADVANCED CALCULUS. Infinite series, computation with series, series with variable terms, uniform convergence, power series. Fourier series and orthogonal functions, special functions. 3 cred.; prereq. 152; 3 rec. hrs. per week. Koehler.

154—VECTOR ANALYSIS. 3 cred.; prereq. 25; 3 rec. hrs. per week. Wilcox.

155—VECTOR ANALYSIS AND DYADICS WITH APPLICATIONS. 3 cred.; prereq. 154; 3 rec. hrs. per week. Wilcox.

156—ELEMENTS OF TENSOR ANALYSIS. 3 cred.; prereq. 154; 3 rec. hrs. per week. Munro.

161-162-163—ANALYTICAL DYNAMICS. Moving axes, Eulerian angles, Lagrange's equations, generalized coordinates, dynamical problems soluble in terms of circular and elliptic functions, dynamical specifications of bodies, motion of a top, theory of vibrations, Hamilton's principle. Special problems. 3 cred. per qtr.; prereq. M.&M. 127 or permission of instructor; 3 rec. hrs. per week. Koehler.

167—SELECTED TOPICS IN MATHEMATICS FOR SENIOR AERONAUTICAL ENGINEERS. 3 cred.; prereq. 25; 3 rec. hrs. per week. Polansky.

168—ELEMENTARY THEORY OF COMPLEX VARIABLES. Derivative and integral of a function of a complex variable. Cauchy's integral theorem and formula, residues. Application to evaluation of integrals, conformal mapping. 3 cred.; prereq. 153; 3 rec. hrs. per week. Fulks.

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† See *Additional Course Information* section for permissible substitute.

169—MATHEMATICAL THEORY OF FLOW. Laplace's equation, steady flow of fluids, heat, electricity. Two-dimensional flow, Poisson's integral. Streamlines, circulation, and vortices, application to airfoils. 3 cred.; prereq. 168, Hydr. 103; 3 rec. hrs. per week. Turrittin.

173-174-175—ELEMENTARY PARTIAL DIFFERENTIAL EQUATIONS WITH APPLICATIONS. 3 cred. per qtr.; prereq. 80 and 153; 3 rec. hrs. per week. Koehler.

184—ELEMENTARY NUMERICAL ANALYSIS IN ENGINEERING. Operation of ordinary computers. Approximate solution of algebraic and transcendental equations, Newton's and Graffe's method. Numerical integration and interpolation. 3 cred.; prereq. 80. Munro.

185-186—ADVANCED NUMERICAL ANALYSIS IN ENGINEERING. Approximation of functions and least squares. Approximate solution of ordinary and partial differential equations, Moulton's, Runge's relaxation and iteration methods. Integral equations. Programming of computers. 3 cred. per qtr.; prereq. 151, 153, and 184. Munro.

190-191-192—ADVANCED TOPICS IN INDUSTRIAL STATISTICS. Industrial sampling inspection methods. Sequential analysis of statistical data. Design of experiments. Research problems from industry. 3 cred. per qtr.; prereq. 134 or permission of instructor. McElrath.

196-197-198—SPECIAL FUNCTIONS IN MATHEMATICAL ANALYSIS. Asymptotic expansions. Gamma and Beta functions. Hypergeometric functions as solutions of differential equations. Bessel functions using Sommerfeld's contour integrals. Legendre functions. 3 cred. per qtr.; prereq. 168; 3 rec. hrs. per week. Fulks.

199a-199b-199c—PROBLEM COURSE. Intended to develop problems solving techniques in many areas of mathematics. Topics considered range from elementary to advanced levels, adapted to students of varied backgrounds. 3 cred. per qtr.; prereq. for each part permission of instructors. Rosenbloom, Loud.

217-218-219—RIEMANNIAN GEOMETRY. Review of elementary differential geometry and tensor analysis. Introduction to exterior differential calculus and algebraic topology. Local properties of Riemannian manifolds. Connection with global properties. Generalization of the differential equations of mathematical physics. 3 cred. per qtr.; prereq. permission of instructor. Milgram.

227-228-229—MATHEMATICS OF COMPUTERS AND CONTROL DEVICES. Theory of elementary control and computing devices, open and closed systems, dynamic and transient responses. Synthesis and analysis of systems. Analog and digital computers. 3 cred. per qtr.; prereq. 186 or permission of instructor; 3 rec. hrs. per week. Munro.

230—ADVANCED TENSOR ANALYSIS. Selected topics in tensor analysis with applications. 3 cred.; prereq. 156; 3 rec. hrs. per week. Munro.

232-233-234—MATHEMATICAL THEORY OF CONTINUOUS MEDIA. 3 cred. per qtr.; prereq. 80, 153, and 154, M.&M. 127; 3 rec. hrs. per week. Turrittin.

238—JOINT SEMINAR. (Aero.E., I.T.M.) Topics covered will vary from year to year and will be announced each time the course is given. 3 cred.; prereq. permission of instructors. Graduate staff Aeronautical Engineering and Mathematics.

261-262-263—FUNCTIONS OF A COMPLEX VARIABLE. 3 cred. per qtr.; prereq. 153; 3 rec. hrs. per week. Warschawski.

264-265-266—CONFORMAL MAPPING. 3 cred. per qtr.; prereq. 263 or permission of instructor; 3 rec. hrs. per week. Warschawski.

267-268-269—SELECTED TOPICS IN THE THEORY OF ANALYTIC FUNCTIONS. Entire and meromorphic functions, functions analytic in the unit circle, interpolation theory (Pick-Nevanlinna). Subharmonic functions, extremal problems, Riemann surfaces. 3 cred. per qtr.; prereq. 263 or equiv. Warschawski.

274-275-276—PARTIAL DIFFERENTIAL AND INTEGRAL EQUATIONS OF APPLIED MATHEMATICS. 3 cred. per qtr.; prereq. 151, 153, 168 or permission of instructor. 3 rec. hrs. per week. Fulks.

277-278-279—PARTIAL DIFFERENTIAL EQUATIONS OF THE FIRST ORDER WITH APPLICATIONS TO MECHANICS. 3 cred. per qtr.; prereq. 151 and 153; 3 rec. hrs. per week. Warschawski.

281-282-283—POTENTIAL THEORY. 3 cred. per qtr.; prereq. 80 and 153; 3 rec. hrs. per week. Warschawski.

284-285-286—NONLINEAR ORDINARY DIFFERENTIAL EQUATIONS. 3 cred. per qtr.; prereq. 151 and 153; 3 rec. hrs. per week. Turrittin.

287-288-289—BANACH SPACES AND FUNCTIONAL ANALYSIS. Basic properties, linear transformations; conjugate spaces; polynomials; analytic functions; spectral theory; fix-point theorems; semigroups. Applications to integration, integral equations, partial differential equations, calculus of variations, and ergodic theory. 3 cred. per qtr.; prereq. Math. 245 or permission of instructor. Rosenbloom.

301-302-303—TOPICS IN ADVANCED DIFFERENTIAL GEOMETRY. Topic for 1953-54: Exterior Differential Forms. Grassman algebra, differential forms on Riemannian manifolds, closed and co-closed forms. Integrals, periods of closed forms. Harmonic forms, theorems of de Rham and Hodge. 3 cred. per qtr.; prereq. permission of instructor. Milgram.

304-305-306—ADVANCED TOPICS IN DIFFERENTIAL AND DIFFERENCE EQUATIONS. Topic for 1954-55: Ordinary Linear Differential and Difference Equations. Existence theorems, convergent and asymptotic solutions, distribution of zeros, and boundary value problems. 3 cred. per qtr.; prereq. permission of instructor. Turrittin.

307-308-309—MATHEMATICAL PROBLEMS OF THEORETICAL PHYSICS. Topic for 1953-54: Electromagnetic Theory. Maxwell's equations, wave equation, Riesz operators, transmission, reflection, and diffraction of waves, Dirac's new electrodynamics. 3 cred. per qtr.; prereq. 263 or Math. 208, or permission of instructor. Rosenbloom.

Mechanical Engineering

Heating, Ventilating, and Refrigeration:

Heating, ventilating and air conditioning: M.E. 160, 161, 162, 165, 166, 169, 265, 266, 267.

Refrigeration: M.E. 180, 181, 182, 189, 280, 281, 282.

Heat Power:

Internal combustion engines: M.E. 50, 150, 150A, 151, 151A, 152, 153, 154, 155, 156, 157, 158, 159, 250, 251, 252, 253, 255, 256, 257.

Steam power: M.E. 40, 41, 42, 138, 141, 142, 144, 146, 147, 148, 149, 242, 243, 244.

Thermodynamics: M.E. 131, 132, 133, 134, 135, 231, 232, 233, 234, 235.

Industrial:

Industrial engineering: I.E. 1, 90, 91, 92, 93, 94, 95, 150, 153, 154, 165, 167, 170, 171, 172, 173, 180, 181, 182, 190, 191, 192, 193, 194, 195, 196, 251, 252, 253, 261, 271, 272, 273. See page 100, Industrial engineering.

Industrial labs.: M.E. 12, 13, 14, 18, 110, 111, 112, 113, 114, 115, 118, 119, 170.

Machine Design and Instrumentation:

Machine design: M.E. 20, 21, 22, 23, 24, 120, 121, 122, 123, 124, 125, 127, 128, 129, 221, 222, 223, 224, 225, 226, 228, 229.

Instrumentation: M.E. 33, 34, 35, 198, 199, 298.

General: M.E. 1, 90, 91, 92, 93, 94, 95, 194, 195, 196, 290, 291, 292, 293.

1—MECHANICAL ENGINEERING ORIENTATION. A combination of lectures and inspection trips to acquaint the student with the field of mechanical engineering. 1 cred.; no prereq.; 3 lab. hrs. per week. Staff.

12—CASTING PROCESSES. Theory and practice in melting, alloying, and casting; molds, cores, patterns; special casting techniques. 2 cred.; prereq. Inorg.Chem. 15, Draw. 6 (Prebus. no prereq.); 2 lect. and 3 lab. hrs. per week. Holtby.

13—METAL PROCESSING. Theory and practice of mechanical working, welding, and heat treating of metals and alloys. 2 cred.; prereq. Inorg.Chem. 15, Draw. 6 (Prebus. no prereq.); 2 lect. and 3 lab. hrs. per week. Hughes.

14—METAL CUTTING. Operation and application of machine tools, jigs, fixtures, cutting tools, and precision measuring instruments. 2 cred.; prereq. Draw. 6; 2 lect. and 3 lab. hrs. per week. Crowder.

18—MATERIALS AND PROCESSES (Aero.E.) Properties of metals and alloys and their processing and fabrication. Casting, forming, welding, heat treating, and machining. 3 cred.; no prereq.; 2 lect. and 6 lab. hrs. per week. Holtby, Hughes, Crowder.

20—ELEMENTARY MACHINE DESIGN. Technique and knowledge necessary to convey information from engineering department to shop. Standard practices in design. 2 cred.; prereq. Draw 6; 1 lect. and 3 lab. hrs. per week. Palmer.

21—KINEMATICS AND MECHANISMS. Displacement, velocity, and acceleration analysis of basic mechanisms. Analysis and design of cams and gears. 3 cred.; prereq. Draw. 6; 2 lect. and 2 lab. hrs. per week. Kemler.

22—MECHANISMS OF AUTOMATIC MACHINERY. Analysis of various mechanisms, automatic transmissions, vending machines, feeding devices, packaging machinery. 3 cred.; prereq. 21; 2 lect. and 3 lab. hrs. per week. Larsen.

23—DYNAMICS OF MACHINERY. Study of combined static and inertia forces in machinery. Analysis of energy cycle diagrams. 3 cred.; prereq. M.E. 22, M.&M. 127; 2 lect. and 3 lab. hrs. per week. Larsen.

24—ELEMENTS OF MACHINE DESIGN. Applications of the fundamentals of stress analysis in the design of machines. Analysis of machine elements. 3 cred.; prereq. M.&M. 128; 2 lect. and 3 lab. hrs. per week. Kemler.

33—MECHANICAL ENGINEERING LABORATORY I. Principles of industrial measuring instruments. Humidity, pressure, vacuum, level, area, and temperature measuring systems. Telemetering and calibration procedures. 2 cred.; prereq. reg. in 131; 1 lect. and 4 lab. hrs. per week. LaJoy and others.

34—MECHANICAL ENGINEERING LABORATORY II. Dynamic response of instrument measurements, measuring systems for flow, viscosity, specific gravity, speed, and power. Gas analysis, calorimetry and other instrumentation procedures. 2 cred.; prereq. 33; 1 lect. and 4 lab. hrs. per week. LaJoy and others.

35—MECHANICAL ENGINEERING LABORATORY III. Study and use of computer and analogs. Lab. tests on strain gauges, elementary servomechanisms, bearing friction. 2 cred.; prereq. 34; 1 lect. and 3 lab. hrs. per week. LaJoy and others.

40-41—HEAT ENGINES. (E.E.) Elementary thermodynamics, fuels and combustion. Construction, operation, performance analysis, and selection of power plant and related equipment. 3 cred.; prereq. Phys. 14; 2 rec. and 3 lab. hrs. per week. Lee.

42—HEAT ENGINES. (C.E.) Elementary thermodynamics, fuels and combustion, construction operation, performance analysis, and selection of heat power equipment. 4 cred.; prereq. Phys. 14; 4 rec. hrs. per week. Lee.

50—AUTO AND AIRPLANE ENGINES. Principles and types. Electrical systems. Lubrication and cooling. Carburetors. Accessories. 3 cred.; no prereq.; 3 rec. hrs. per week. Murphy and others.

90-91-92-93-94-95†—INDUSTRIAL ASSIGNMENT. Cooperative work-study curriculum, industry laboratory quarters (work periods). Grades are based on a formal written report by the student, covering his work during the industrial assignment. 3 cred. per qtr.; prereq. reg. in cooperative work-study program. Algren.

110—CONTROL OF METAL WORKING PROCESSES. Inspection by X-ray, gamma-ray, magnetic particle, metallographic, and chemical methods; 3 cred.; prereq. 118; 1 lect. and 6 lab. hrs. per week. Holtby, Hughes.

111—ADVANCED CASTING PROCESSES. Advanced techniques and new developments in molding and casting; foundry control procedures. 3 cred.; prereq. 110, Met. 156; 2 lect. and 3 lab. hrs. per week. Holtby.

112—PROPERTIES AND FABRICATION OF PLASTICS. Materials, equipment, and processes for fabrication of plastics. Plastic product and mold design. 3 cred.; prereq. 12, 13, 14 or permission of instructor; 2 lect. and 3 lab. hrs. per week. Holtby.

113—ADVANCED METAL CUTTING. Advanced machine tool operations. Selection, tooling, and set-up of machine tools for production. 3 cred.; prereq. 118; 1 lect. and 6 lab. hrs. per week. Crowder.

114—ADVANCED WELDING. Theory and applications of welding processes; factors affecting weldability; considerations in the design of weldments. 3 cred.; prereq. 118 and Met. 156; 2 lect. and 3 lab. hrs. per week. Hughes.

115—CONTROL OF MANUFACTURING STANDARDS. Precision measuring instruments and gauges for dimensional control in interchangeable manufacture. 3 cred.; prereq. 118; 1 lect. and 6 lab. hrs. per week. Crowder.

118—ADVANCED PROCESSING TECHNOLOGY. Measurement, analysis, and control of the basic factors in metal processing. 3 cred.; prereq. M.E. 12, 13, 14 and M.&M. 141; 2 lect. and 3 lab. hrs. per week.

119—DESIGN FOR CASTING, FORMING, AND WELDING. Basic factors in the design of parts and structures for most efficient processing and fabrication and maximum performance. 3 cred.; prereq. 118; 1 lect. and 6 lab. hrs. per week. Holtby, Hughes.

120—ADVANCED ENGINEERING DESIGN DRAFTING. Studies in design and layout of a complete machine with emphasis on design modifications and improvements. 2 cred.; prereq. 20 and 24; 6 lab. hrs. per week. Palmer.

† The entire sequence must be completed before credit is given.

121—MACHINE DESIGN. Advanced machine elements. Design practice and machine layout. Analysis of complete machines. 3 cred.; prereq. 24; 2 lect. and 3 lab. hrs. per week. Ryan.

122—MECHANICAL ENGINEERING DESIGN I. Advanced statics, dynamics, and stress analysis applied to machines. Special design problems. 3 cred.; prereq. 121; 1 lect. and 6 lab. hrs. per week. Ryan.

123—MECHANICAL ENGINEERING DESIGN II. Application of fundamentals of engineering design with emphasis on creative aspects. 3 cred.; prereq. 121; 1 lect. and 6 lab. hrs. per week. Ryan.

124—EXPERIMENTAL STRESS ANALYSIS. Experimental application and theoretical evaluation of the methods of stress analysis. Strain gauges, surface coatings, photoelasticity, dynamic stress measurements, penetration methods, and fracture methods. 3 cred.; prereq. M.&M. 128; 2 lect. and 3 lab. hrs. per week. Ryan.

125—MACHINE DESIGN LABORATORY—Use of vibration instruments, stroboscopes, sound meters and analyzers, photoelastic, polariscope, electronic measuring devices and testing machines. 2 cred.; prereq. 24; 1 lect. and 3 lab. hrs. per week. Ryan.

127—LUBRICATION. Hydrodynamic theory of lubrication. Bearing design and construction, laboratory tests on 8-inch journal bearings. 3 cred.; prereq. 121; 3 lect. hrs. per week. Ryan.

128—PHOTOELASTIC STRESS ANALYSIS. Fundamentals of advanced stress analysis. Theory of photoelasticity and operation of polariscopes. Applications to solutions of special design problems. 3 cred.; prereq. M.&M. 128; 2 lect. and 3 lab. hrs. per week. Ryan.

129—VIBRATION ENGINEERING. Elementary vibration theory with application to vibration absorption and isolation. 3 cred.; prereq. M.&M. 127; 3 lect. hrs. per week. Kemler, Ryan.

131-132—THERMODYNAMICS. Properties and processes for working fluids in engineering devices. Application of the fundamental laws correlating energy with heat and work. 3 cred. per qtr.; prereq. I.T.M. 25, Phys. 14; 3 rec. and 2 computation hrs. per week. Hall and others.

133—HEAT TRANSMISSION. Introduction to conduction, convection, and radiation of heat and their utilization in engineering applications. Discussion of heat exchangers. 3 cred.; prereq. 132; 3 lect. or rec. hrs. per week. Eckert.

134—THERMODYNAMICS OF FLUID FLOW. The energy analysis of the flow of viscous and compressible fluids. Applications to flow processes and components in engineering systems. 3 cred.; prereq. 132; 3 rec. hrs. per week. Hall.

135—TURBOMACHINERY. Principles of turbomachinery. Application to turbines, compressors, pumps, and fluid power transmissions. 3 cred.; prereq. 131, 132; 3 rec. hrs. per week. Lee.

138—GENERAL LABORATORY. (Min.E. and Pet.E. only) Calibration, correction, and use of instruments. Operation, performance, and selection of power and compressor equipment. 2 cred.; prereq. Min. 122; 4 lab. hrs. per week. Lee.

141—HEAT POWER ENGINEERING. Study of application and control of fuels and combustion, thermodynamics, and heat transmission to steam power and process engineering. 3 cred.; prereq. 132; 3 rec. hrs. per week. Lee.

142—ADVANCED HEAT POWER ENGINEERING. Practice and economics relating to power plant cycles, steam generators, prime movers, plant controls, and plant auxiliaries. Trends in power development. 3 cred.; prereq. 141; 3 rec. hrs. per week. Lee.

146—FUELS AND COMBUSTION. Fuel classification and analysis, stoichiometry, rates, combustion processes, combustion equipment, and controls. 3 cred.; prereq. 141; 3 rec. hrs. per week. Lee.

147—DESIGN OF STEAM MACHINERY. Steam generating station layout. General design of all component parts. 3 cred.; prereq. 141; 1 lect. and 6 lab. hrs. per week. Lee.

148—DESIGN OF POWER PLANT UNITS. Steam generating station heat balance. Detail design of some component part-boiler, economizer, superheater, condenser, etc. 3 cred.; prereq. 147; 1 lect. and 6 lab. hrs. per week. Lee.

149—ADVANCED STEAM LABORATORY. Tests of steam engines, steam turbines, evaporators, air compressors, and multiple turbo-generator units simulating actual power plant conditions. 2 cred.; prereq. 141, 35; 4 lab. hrs. per week. Lee.

150—INTERNAL COMBUSTION ENGINES. Principles of gasoline engines; cylinder pressures, flame temperatures, combustion phenomena; heat losses, real cycle efficiencies. 4 cred.; prereq. 132; 3 rec. and 3 lab. hrs. per week. Murphy.

150A—INTERNAL COMBUSTION ENGINES. (Aero.E.) Principles of aircraft engines, explosion pressures, flame temperatures, and combustion phenomena; heat losses, real cycle efficiencies. 4 cred.; prereq. 132; 4 rec. hrs. per week. Murphy.

151—ADVANCED INTERNAL COMBUSTION ENGINES. Comprehensive study of fuels, lubrication, supercharging, carburetion, and cooling. 3 cred.; prereq. 150; 3 rec. hrs. per week. Murphy.

151A—ADVANCED INTERNAL COMBUSTION ENGINES. (Aero.E.) Comprehensive study of fuels, performance, cooling, lubrication, superchargers, and induction systems. 2 cred.; prereq. 150A or 150; 2 rec. hrs. per week. Murphy.

152—DIESEL ENGINES. Advanced course in the theory, design, operation, and economics of the Diesel engine with emphasis on high speed combustion and injection systems. 3 cred.; prereq. 150; 3 rec. hrs. per week. Murphy.

153—ENGINE SERVICE MANAGEMENT. Methods used in servicing or reconditioning engines. Causes of mechanical failure and wear. Lubrication and ignition service. 3 cred.; prereq. 150; 3 rec. hrs. per week. Murphy.

154-155—DESIGN OF INTERNAL COMBUSTION ENGINES. Detailed study of design, calculation of bearing loads, stresses in moving parts, and valve mechanisms. 3 cred. per qtr.; prereq. 121 and 150; 1 lect. and 6 lab. hrs. per week. Murphy.

156—HIGH SPEED ENGINE TESTING. Advanced laboratory procedure. Effects of fuel, mixture distribution, etc., upon general engine performance. 2 cred.; prereq. 158 or 159 and minimum honor-point average of 1.5; 6 lab. hrs. per week. Murphy.

157—GAS TURBINE AND JET PROPULSION POWER PLANTS. Gas turbine cycles and principles; characteristics of compressors and turbines; power and efficiency calculations; 3 cred.; prereq. 150 or 150A; 3 lect. hrs. per week. Murphy.

158—AERO ENGINE TESTING. Use of modern instruments for testing aircraft engines. Use of dynamometers and thrust stands in determining engine performance. 2 cred.; prereq. 150 or 150A or reg. in 150A; 6 lab. hrs. per week. Murphy and others.

159—INTERNAL COMBUSTION ENGINE LABORATORY. Tests of gasoline, aircraft, and Diesel engines. Problems on application of engine to vehicles or machines. 2 cred.; prereq. 150 or reg. in 150; 4 lab. hrs. per week. Murphy and others.

160—HEATING, VENTILATION, AND AIR CONDITIONING. Basic principles of heating, ventilation, and air conditioning. 3 cred.; prereq. 132; 3 lect. hrs. per week. Algren and others.

161-162—HEATING, VENTILATION, AND AIR CONDITIONING DESIGN. Heating and cooling loads; selection of equipment; design of complete systems. 3 cred. per qtr.; prereq. 160; 1 lect. and 6 lab. hrs. per week. Borry.

165—ADVANCED HEATING, VENTILATION, AND AIR CONDITIONING. Basic requirements for comfort, health, and industrial processes. Methods of control and application. 3 cred.; prereq. 160; 3 lect. hrs. per week. Algren.

166—INDUSTRIAL AIR CONDITIONING AND EXHAUST SYSTEMS. Requirements for manufacturing, processing, and preservation of materials. Classification of systems and design principles. 3 cred.; prereq. 160; 3 lect. hrs. per week. Algren and others.

169—HEATING AND VENTILATION LABORATORY. Tests and studies of heating, ventilation, and air conditioning equipment. 2 cred.; prereq. 35 and 160, or reg. in 160; 4 lab. hrs. per week. Algren and others.

170—TOOL DESIGN. Design of jigs, fixtures, and dies for machining, forming, welding, and assembly operations. 3 cred.; prereq. 118; 1 lect. and 6 lab. hrs. per week. Crowder.

180—REFRIGERATION. Basic principles of refrigeration including vapor compression, air cycle, steam jet, and absorption systems; refrigerants; equipment. 3 cred.; prereq. 132; 3 lect. hrs. per week. Threlkeld.

181—ADVANCED REFRIGERATION. Advanced refrigeration theory covering multistage and multiple evaporator systems; low temperature refrigeration; special topics. 3 cred.; prereq. 180; 3 lect. hrs. per week. Threlkeld.

182—REFRIGERATION DESIGN. Refrigeration loads; selection of equipment; design and layout of complete systems. 3 cred.; prereq. 180; 1 lect. and 6 lab. hrs. per week. Threlkeld.

189—REFRIGERATION LABORATORY. Tests and studies of refrigeration systems and component parts. 2 cred.; prereq. 180 or reg. in 180; 4 lab. hrs. per week. Borry.

190—SEMINAR. Reading of assigned articles in current technical press. Classroom presentation of principal features of assigned articles. 1 cred.; prereq. 5th yr.; 1 rec. hr. per week. Staff.

194—ADVANCED ENGINEERING PROBLEMS. Work pertaining to special investigations in the various fields of mechanical engineering. 2 to 4 cred.; reg. by permission of division chief concerned; open only to 5th yr. M.E. with 1.5 honor point average. Staff.

195—INSPECTION TRIP. During the spring vacation of the fifth year an inspection trip is made to various industrial plants to study mechanical equipment, manufacturing methods, and processes. 1 cred.; required of 5th yr. M.E.; register during winter qtr. registration. Staff.

196—INVENTIONS AND PATENTS. Study of problems associated with inventions, their patenting, development, evaluation, and exploitation. 3 cred.; prereq. 24 or permission of instructor; 3 rec. hrs. per week. Kemler.

198—INDUSTRIAL INSTRUMENTATION AND AUTOMATIC CONTROL. Theory and operation of instruments and automatic controls. Domestic and industrial control mechanisms. On-off, proportional, floating, and rate response in control instruments. 3 cred.; prereq. 5th yr.; 2 lect. and 3 lab. hrs. per week. LaJoy.

199—SERVOMECHANISMS. Study of basic servomechanisms. Mechanical and electrical error indicators. Analysis of various types of damping. 3 cred.; prereq. I.T.M. 80, E.E. 37; 2 lect. and 3 lab. hrs. per week. LaJoy.

221-222-223—ADVANCED MECHANICAL ENGINEERING DESIGN. Applications of elasticity to the solution of mechanical design problems. 3 cred. per qtr.; prereq. 121; grad. only; 3 rec. hrs. per week. Kemler.

224-225-226—ADVANCED APPLIED DYNAMICS. Application of principles of dynamics to selected mechanical engineering problems. 3 cred. per qtr.; prereq. 129; grad. only; 3 rec. hrs. per week. Kemler.

228—PHOTOELASTICITY. Advanced studies in stress analysis by photoelasticity. Studies of stress patterns. Frozen stresses. Solution of individual problems. 3 cred.; prereq. 128; grad. only; 2 lect. and 3 lab. hrs. per week. Ryan.

229—ADVANCED VIBRATION ENGINEERING. Advanced dynamics of vibration, vibration in mechanical, electrical, and equivalent systems. 3 cred.; prereq. 129; grad. only; 3 lect. hrs. per week. Kemler, Ryan.

231—ADVANCED THERMODYNAMICS. Thermodynamic equation of state for gases, liquids, and mixtures. Applications and interpretations of thermodynamic functions or processes, reactions, and equilibrium states. 3 cred.; prereq. 132; grad only; 3 rec. hrs. per week. Hall.

232—ADVANCED FLUID THERMODYNAMICS. The mechanism of thermodynamic actions in fluids, irreversible processes related to viscosity, heat transfer, diffusion, and chemical reaction. 3 cred.; prereq. 134, 231, or permission of instructor; grad. only; 3 hrs. per week. Hall.

233—CONDUCTION. Steady and unsteady heat conduction with and without heat sources or change of state, relaxation method, analogs, the regenerator. 3 cred.; prereq. 133; grad. only; 3 lect. or rec. hrs. per week. Eckert.

234—CONVECTION. Heat transfer in laminar and turbulent boundary layer and channel flow, dimensional analysis. Free convection. Condensation and evaporation. Convective mass transfer. 3 cred.; prereq. 233; grad. only; 3 lect. or rec. hrs. per week. Eckert.

235—RADIATION. Heat radiation of black bodies, or electrical conductors and nonconductors, of gases and flames. Heat exchange by radiation. Configuration and interchange factors. 3 cred.; prereq. 234; grad. only; 3 lect. or rec. hrs. per week. Eckert.

242—POWER PLANT SPECIFICATION. Estimating of initial installation, maintenance, and depreciation costs of power plant components, and their effect on selection of units. Specification of units and components. 2 cred.; prereq. 148; grad. only. Lee.

243—POWER PLANT LAYOUT. Power plant layout and selection of most economical fuel components for location and type of service. 2 cred.; prereq. 242; grad. only. Lee.

244—POWER PLANT MANAGEMENT. Maintenance and operating schedules. Records on performance. Operating problems. Load curves and efficient operation of plants. 3 cred.; prereq. 142; grad. only. Lee.

250—DYNAMICS OF HIGH SPEED ENGINES. Study of inertia forces; balancing high speed engines; engine torque analysis; torsional vibration, etc. Conferences, assigned readings, and problems. 3 cred.; prereq. 121 and 150; grad. only. Murphy.

252—ADVANCED RECIPROCATING ENGINES. Performance as affected by airflow, fuel-air ratio, mixture temperature, manifold pressure, and spark timing; cooling and lubrication requirements. 3 cred.; prereq. 151 or 151A; grad. only. Murphy.

253—ADVANCED GAS TURBINES. Study of gas turbines for aircraft performance, control, nozzles, axial and centrifugal compressors, and turbines; cooling, lubrication, and construction. 3 cred.; prereq. 157; grad. only. Hall, Murphy.

255—THERMAL JETS AND ROCKETS. Study of thermal jets and rockets with particular regard to the problems of design and calculations of the performance of ram jets and liquid fuel rockets. 3 cred.; prereq. 134, 157; grad. only. Eckert.

256—ENGINE TESTING AND RESEARCH. Problems involving volumetric efficiency, manifolding, friction losses, cylinder pressures, and other engine performance factors of current interest. Cred. ar.; prereq. 158 or 159; grad. only. Murphy.

257—COMBUSTION AND FUELS FOR GAS TURBINES AND ENGINES. Heating value, heat of formation, energy of reaction, flame temperatures, equilibrium in combustion. 3 cred.; prereq. 150, 157; grad. only. Hall.

265—ADVANCED AIR CONDITIONING. Advanced study of basic principles of heating, ventilation, and air conditioning. 3 cred.; prereq. 160; grad. only. Algren.

266—ADVANCED VENTILATION AND AIR DISTRIBUTION. Design principles and methods of air distribution; study of component parts of complete systems. 3 cred.; prereq. 160, 265, or permission of instructor; grad. only. Algren.

267—APPLIED HEATING, VENTILATION, AND AIR CONDITIONING. Field studies and practical problems related to heating, ventilating, and air conditioning. 3 cred.; prereq. 160 and 266, or permission of instructor; grad. only. Algren.

280—THEORETICAL REFRIGERATION. Advanced study dealing with problems involving the theory and design of refrigeration systems. Lectures, assigned reading, and reports. 3 cred.; prereq. 180; grad. only. Jordan.

281—APPLIED REFRIGERATION. Advanced study involving the applications of refrigeration systems to commercial and industrial equipment and processing. Lectures, assigned reading, and reports. 3 cred.; prereq. 180; grad. only. Jordan.

282—REVERSE APPLICATIONS OF REFRIGERATION—THE HEAT PUMP. Industrial, commercial, and residential applications of refrigeration systems as heat pumps. Lectures, assigned reading, and reports. 3 cred.; prereq. 180; grad. only. Jordan.

290-291-292—MECHANICAL ENGINEERING RESEARCH. Investigations in connection with special problems. Cred. ar. per qtr.; reg. by permission of division chief in charge of work; grad. only. Staff.

293—GRADUATE SEMINAR. Colloquium for graduate students and staff. Reports and discussion by members on research or specific problems to be assigned. Recommended for graduate students and junior staff members. No cred. Staff.

298—ADVANCED INSTRUMENTATION AND AUTOMATIC CONTROL. Controller characteristics under simulated process conditions; effect of process time constants; methods of controller calibration; 3 cred.; prereq. 198; grad. only; hrs. ar. LaJoy.

Mechanics and Materials

26—ENGINEERING STATICS. Concurrent force systems, parallel forces, couples, center of gravity, statics of rigid bodies, graphical methods, friction, work, theory of moment of inertia. 5 cred.; prereq. I.T.M. 25; 5 rec. hrs. per week.

84—ENGINEERING MECHANICS. (Chem., Chem.E., and Prebus.) Statics, resolution of forces, conditions of equilibrium, center of gravity, moment of inertia, stresses in framed structures and machines, kinematics, dynamics of a particle. Newton's laws of motion, work, energy, power, impulse, and momentum. 5 cred.; prereq. I.T.M. 25 or 91; 5 rec. hrs. per week.

85—MECHANICS OF MATERIALS. (E.E., Chem.E., and Prebus.) Mechanical and elastic properties of materials of construction, beams, shafts, columns, combined stresses, dynamic stresses. 3 cred.; prereq. 26 or 84; 3 rec. hrs. per week.

87—MATERIALS TESTING LABORATORY. (E.E., Chem.E., and Prebus.) Investigation of the physical properties of various metals and engineering materials (steel, cast iron, wood, brick, etc.). Standard methods of testing. 1 cred.; prereq. reg. in 85; 2 lab. hrs. per week.

92—MECHANICS FOR ARCHITECTS. Statics, resolution of forces, conditions of equilibrium, center of gravity, moment of inertia of plane sections, stresses in framed structures. 4 cred.; prereq. I.T.M. 91; 4 rec. hrs. per week.

93—MECHANICS OF MATERIALS. (Arch.) Mechanical and elastic properties of materials of construction, design of riveted joints, beam theory, columns, arches. 4 cred.; prereq. 92; 4 rec. hrs. per week.

127—ENGINEERING DYNAMICS. Kinematics of the particle and rigid body, theorem of Coriolis, particle dynamics, dynamics of a rigid body in plane motion, the energy equation, impulse and momentum, applications to technical problems. 5 cred.; prereq. 26; 5 rec. hrs. per week.

128—MECHANICS OF MATERIALS. Mechanical and elastic properties of materials of construction; stresses and deformations in beams, shafts, and columns; stresses in statically indeterminate structures; combined stresses. 5 cred.; prereq. 26; 5 rec. hrs. per week.

129—FUNDAMENTALS OF MATERIALS ENGINEERING. Analysis of fundamental engineering properties of materials, their evaluation in the laboratory and relationship to service behavior. Introduction to engineering physical metallurgy, including metallographic structure, phase diagrams, heat treatment, mechanical metallurgy, etc., and its relationship to engineering properties. Systematic study of important engineering materials including ferrous and nonferrous metals, plastics, concrete, and timber. 5 cred.; prereq. 85 or 93 or 128; 4 rec. hrs. and 3 lab. hrs. per week.

141—MATERIALS TESTING LABORATORY. Investigation of the physical properties of various metals and engineering materials (steel, cast iron, wood, brick, etc.). Standard methods of testing. 1 cred.; prereq. reg. in 128; 2 lab. hrs. per week.

164-165-166*—SPECIAL PROBLEMS IN MECHANICS AND MATERIALS. Short duration research problems on dynamic properties of materials, theories of mechanical failure, and experimental mechanics. Literature studies, conferences, seminars, and reports on special problems. 3 cred. per qtr.; prereq. permission of instructor.

180—ADVANCED MECHANICS OF MATERIALS. Stress analysis in statically indeterminate structures. Theory of superposition. Energy of strain. Elastic stability. 3 cred.; prereq. 128; 3 lect. hrs. per week.

181-182-183—APPLIED ELASTICITY. Special problems in stress analysis. 3 cred. per qtr.; prereq. 128; 3 lect. hrs. per week; must be taken as a 3-qtr. course.

193-194-195—THEORY OF VIBRATIONS. Mathematical treatment of one, two, and many degrees of freedom, forced and damped vibrations. Critical speeds, torsional vibrations, criterion of stability, nonlinear characteristics, vibrations of plates and shells. 3 cred. per qtr.; prereq. 127, I.T.M. 80 and reg. in I.T.M. 152; must be taken as a 3-qtr. course.

235-236-237—ADVANCED MATERIALS ENGINEERING. Physics of metal. Theories of failure of materials under static, impact, fatigue, creep, and other types of stresses. Theory of plasticity. Classification and study of conditions which cause service failure. Laboratory techniques for evaluating fundamental properties of engineering materials and relationship to service behavior. Experimental mechanics. 3 cred. per qtr.; prereq. permission of instructor; must be taken as a 3-qtr. course.

290-291-292—THEORY OF PLATES AND SHELLS. 3 cred. per qtr.; prereq. 294 and I.T.M. 153; 3 rec. hrs. per week; must be taken as a 3-qtr. course.

294-295-296—THEORY OF ELASTICITY. 3 cred. per qtr.; prereq. 128 and I.T.M. 153; 3 rec. hrs. per week; must be taken as a 3-qtr. course.

Metallography

152—METALLOGRAPHY FOR AERONAUTICAL ENGINEERS. Principles; metallography of iron and steel with special reference to alloy steels, and light alloys used in airplane construction. Laboratory work and demonstrations. 3 cred.; prereq. 4th yr. Aero.E.; 2 lect. and 2 lab. hrs. per week. Mackay.

153-154-155—METALLOGRAPHY. (Long course for metallurgical engineers.) Theory of metallic alloys. Metallographic technique. Properties of metals and alloys. Metallography of steel and nonferrous alloys. Laboratory work. 4 cred. per qtr.; prereq. Met. 12 or permission of instructor; 3 lect. and 4 lab. hrs. per week. Jerabek.

156—METALLOGRAPHY FOR MECHANICAL, MINING, AND PETROLEUM ENGINEERS. Principles of metallography, including pyrometry, thermal analysis, constitution diagrams, microscopic technique; metallography and heat treatment of iron and steel. 3 cred.; prereq. 4th yr.; 2 lect. and 2 lab. hrs. per week. Mackay.

159—DENTAL METALLOGRAPHY. Metallography of dental alloys. Basic course for dental students involving phase diagrams, metallography, heat treatment, and application of dental metals and alloys. 2 cred.; no prereq. Mackay, Jerabek.

160—METALLOGRAPHY. (Chem.E.) Principles of metallography and some nonferrous alloys. 3 cred.; prereq. Anal.Chem. 1, 2; 2 lect. and 2 lab. hrs. per week; Institute of Technology elective. Mackay, Jerabek.

161—ADVANCED METALLOGRAPHY. Metallography and heat treatment of iron and steel, including alloy steels, commercial uses of various steels, and engineering specifications. 2 or 3 cred. depending on lab.; prereq. 152, 156, or 160; 2 lect. and 3 lab hrs. per week; Institute of Technology elective. Mackay.

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* May be taken out of sequence.

162—ADVANCED METALLOGRAPHY. Metallography of the nonferrous metals with a study of the constitution diagrams, properties, and uses of important commercial alloys. 2 or 3 cred. depending on lab.; prereq. 152, 156, or 160; 2 lect. and 3 lab. hrs. per week; Institute of Technology elective. Mackay.

163—ADVANCED METALLOGRAPHY. Seminar work on recent advances in metallography. Lectures and recitations, with outside reading and special reports. May be accompanied by laboratory work. 3 cred.; prereq. 6 cred. in metallography; 3 lect. hrs. per week. Dowdell.

164—ADVANCED METALLOGRAPHY. Advanced consideration of the structures, properties, and uses of metals and alloys. May be accompanied by laboratory work. 3 cred.; prereq. 6 cred. in metallography; 3 lect. hrs. per week. Dowdell.

165—ADVANCED METALLOGRAPHY. Technical metallography as applied to the automotive industry. Lectures and special reports. May be accompanied by laboratory work. 3 cred.; prereq. 6 cred. in metallography; 3 lect. hrs. per week. Dowdell.

166-167-168*—LABORATORY. Laboratory work on special problems in ferrous, nonferrous, and X-ray metallography. 1, 2, or 3 cred. per qtr.; prereq. 154; 1 lect. and 4 lab. hrs. per week for 166 and 168, 9 lab. hrs. per week for 167. Dowdell, Jerabek.

170-171-172*—SPECIAL PROBLEMS IN METALLOGRAPHY. 1, 2, or 3 cred. per qtr.; hrs. ar.; prereq. 5th yr. Met.E. or grad. Dowdell, Jerabek.

201-202-203*—ADVANCED METALLOGRAPHY FOR GRADUATE STUDENTS. Intended primarily for research work. Cred. and hrs. ar. Dowdell, Jerabek.

204-205-206*—SEMINAR IN METALLOGRAPHY. Special research and seminar in physical metallurgy. Cred. and hrs. ar. Dowdell, Jerabek.

210-211-212*—THESIS COURSES FOR GRADUATE STUDENTS. Intended primarily for research work. Cred. and hrs. ar. Dowdell, Jerabek.

Metallurgy

11—METALLURGY OF PIG IRON. Raw materials, construction, and basic principles of the blast furnace process. Chemistry of the process. Fluxes and slags. Principles for controlling operation and products. 3 cred.; prereq. Inorg.Chem. 2 or 5; 3 lect. hrs. per week. Joseph.

12—METALLURGY OF STEEL. The chemistry and technology of the principal steelmaking processes. 3 cred.; prereq. 11; 3 lect. hrs. per week. Martin.

75—STUDY OF METALLURGICAL OPERATIONS IN IMPORTANT IRON AND STEEL CENTERS. 2 cred.; prereq. 4th yr.; hrs. ar.; duration 1 week.

106—NONFERROUS METALLURGY. Principles involved in the metallurgy of copper including roasting, smelting, and refining. 3 cred.; prereq. Inorg.Chem. 2 or 5; 3 lect. hrs. per week. Bitsianes.

107—NONFERROUS METALLURGY. Principles underlying the recovery and refining of lead and zinc. 3 cred.; prereq. 106; 3 lect. hrs. per week. Bitsianes.

108—NONFERROUS METALLURGY. Principles underlying the metallurgy of the lighter metals, the ferroalloy metals, and the precious metals. 3 cred.; prereq. 107; 3 lect. hrs. per week. Bitsianes.

110—MINERAL DRESSING. Study of jaw and gyratory crushers, ball mills, rod mills, tube mills, volumetric sizing, gravimetric sizing. 4 cred.; prereq. Geol. 24; 3 lect. and 3 lab. hrs. per week. Cooke.

111—MINERAL DRESSING. Principles of ore beneficiation by gravity concentration. Concentration by jigs, tables, classifiers, log washers, and miscellaneous devices. 4 cred.; prereq. 110; 3 lect. and 3 lab. hrs. per week. Cooke.

112—MINERAL DRESSING. Principles of flotation in ore beneficiation. Special attention to chemical and physical action of the different reagents used, such as frothing, collecting, depressing, activating, conditioning, etc. 4 cred.; prereq. 111; 3 lect. and 3 lab. hrs. per week. Cooke.

121—ORE TESTING (IRON ORES). Methods of beneficiation, principles, methods and machines, concentration, formulas, metallurgical and economic considerations. 2 cred.; prereq. 110; 1 lect. and 3 lab. hrs. per week. Davis.

122—ADVANCED MINERAL DRESSING. Determination of methods for metallurgical and economic extraction of nonferrous minerals from ores. 3 cred.; prereq. 112; 2 lect. and 1 rec. hr. per week. Cooke.

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* May be taken out of sequence.

123—ADVANCED MINERAL DRESSING. Continuation of Course 122. Consideration of factors affecting extraction. Study of distribution of values in mill and metallurgical products. 3 cred.; prereq. 122; 2 lect. and 1 rec. hr. per week. Cooke.

124-125-126*—SPECIAL PROBLEMS IN MINERAL DRESSING. Detailed study of mineral dressing problems. Cred. and hrs. ar.; prereq. 112. Cooke.

130-131-132*—SPECIAL PROBLEMS IN NONFERROUS METALLURGY. Seminar work on metallurgical problems, primarily for graduate students. Cred. and hrs. ar.; prereq. 123. Bitsianes, Martin.

133—ELECTROMETALLURGY. A study of arc, induction, and resistance furnaces used in the metallurgical industry. Acid and basic processes of steelmaking in the electric arc furnace. 3 cred.; prereq. 12; 3 lect. hrs. per week. Martin.

134—ADVANCED METALLURGY OF STEEL. A detailed study of the basic open hearth process of making steel. 3 cred.; prereq. 12; 3 lect. hrs. per week. Martin.

135—ADVANCED METALLURGY OF PIG IRON. Detailed study of the blast furnace process. Economics of raw materials, their size, preparation, and physical properties. Control of slag-metal reactions. Trend in furnace design and practice. 3 cred.; prereq. 11; 3 lect. hrs. per week. Joseph.

136—REFRACTORIES. Raw materials, manufacture, properties and uses of refractories. 3 cred.; prereq. 12; 3 lect. hrs. per week. Martin.

137—METALLURGICAL CALCULATIONS. Calculations applied to metallurgical operations. 2 cred.; prereq. 12 and 108; 2 lect. hrs. per week. Martin.

138—METALLURGICAL PHYSICAL CHEMISTRY. The application of physical chemistry to process metallurgy. 2 cred.; prereq. 134 and Phys.Chem. 103; 2 lect. hrs. per week. Martin.

139—METALLURGICAL LABORATORY. A study of the heterogeneous reactions pertaining to the iron blast furnace. 1 cred.; prereq. 135; 4 lab. hrs. per week. Bitsianes.

140—ADVANCED ORE TESTING (IRON ORES). Continuation of Course 121. Metallurgical calculations and report writing. 2 cred.; prereq. 121. Davis.

141-142-143*—SPECIAL PROBLEMS. Special problems in the production of iron and steel. Conferences, laboratory work. 3 cred. per qtr.; prereq. 5th yr. Met.E. or grad.; 9 lab. hrs. per week. Joseph, Martin, Bitsianes.

213-214-215*—THESIS COURSE FOR GRADUATE STUDENTS. Intended primarily for research work. Cred. and hrs. ar. Joseph, Martin, Bitsianes, Cooke.

216-217-218*—SEMINAR IN PROCESS METALLURGY. 1 cred. per qtr.; prereq. grad.; 1 hr. ar. Martin.

219-220-221*—SPECIAL PROBLEMS IN ADVANCED METALLURGY. Intended primarily for research work. Cred. and hrs. ar. Joseph, Martin, Bitsianes, Cooke.

Military Science and Tactics (ROTC)

Courses offered in Military Science and Tactics are designed to qualify selected students for commission as an officer in the Army Reserve, a component of the United States Army. The objective of the national ROTC program is to provide the nation with an adequate reserve of trained officers available for leadership and direction in any future national emergency.

The Basic Course in ROTC consists of studies of the basic military problems in the first year and specialized training in one of the following Army branches in the second year: Antiaircraft Artillery, Corps of Engineers, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. Credit may be received for the first year of basic training by students who have completed six months or more of service. No expense is attached to this course; uniforms and textbooks are furnished by the Army.

The last two years of ROTC is known as the Advanced Course. Students continue specialized training in the branch they chose at the beginning of the second year of the Basic Course. The Advanced Course includes a summer camp of six weeks' duration between the two years, consisting of practical application of the class studies. A liberal monthly monetary allowance for the two school years and summer camp is paid each enrolled student (approximately $650). Students in the Advanced Course are selected on the basis of demonstrated leadership ability and scholastic standing.

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* May be taken out of sequence.

Students accepted in either the Basic or Advanced Courses must be citizens of the United States, physically qualified, meet age limits, and have the time remaining in school required to complete the course.

1-2-3—FIRST-YEAR BASIC COURSE ROTC. Military organization, leadership, first aid, maps and aerial photographs, individual weapons and marksmanship, military policy and military problems. 1 cred. per qtr.; 3 hrs. per week.

4-5-6—SECOND-YEAR BASIC COURSE ROTC. Tactics and technique of one of the following Army branches: Antiaircraft Artillery, Corps of Engineers, Ordnance Corps, Quartermaster Corps, Signal Corps, Transportation Corps. 1 cred. per qtr.; 3 hrs. per week; prereq. 1-2-3 or 6 months of military service.

151-152-153—FIRST-YEAR ADVANCED COURSE ROTC. Continued study of tactics and technique of one of the branches listed for the Second-Year Basic Course ROTC. 3 cred. per qtr.; 5 hrs. per week; prereq. 4-5-6 or one year of military service.

154-155-156—SECOND-YEAR ADVANCED COURSE ROTC. Continued study of tactics and technique of one of the branches listed above, and subject matter common to all branches such as: Military Administration, Military Law, Military Teaching Methods, Command and Staff Organizations, Leadership, Psychological Warfare. 3 cred. per qtr.; 5 hrs. per week; prereq. 151-152-153.

Additional information may be procured from the Professor of Military Science and Tactics, Room 106, Armory, Minneapolis Campus.

Mining Engineering

11-12-13—SURVEYING. Land subdivision and description, stadia, triangulation, railroad curves, cross sections, earthwork, areas, differential and trigonometric leveling, plane-table, topographic map reading, solar and stellar observations, mining claims, bore holes, shaft plumbing, underground traversing and leveling. 3 cred. per qtr. for 11 and 12, 2 cred. for 13; prereq. I.T.M. 12; 3 lect. and 1 quiz hr. per week for 11 and 12, 2 lect. and 1 quiz hr. per week for 13. Heilig.

14—SURVEYING FIELD WORK. General work in plane surveying and adjustment of instruments. 5 cred.; prereq. 12; 20 hrs. per week. Heilig, Hartman.

15—MINE SURVEYING FIELD WORK. Surveying of an underground mine, including shaft plumbing. Survey of open-pit mine including an estimate of the surface stripping. Solar and stellar observations. 6 cred.; prereq. 13, 14; 4 weeks beginning about June 15. Lacabanne, Hartman.

106—MINE MAPPING. Mine mapping in accordance with prevalent practice in various mining districts including a map of the mine surveyed during the sophomore field trip. Ore estimating, based on current practice. 2 cred.; prereq. 15; 8 lab. hrs. per week. Heilig, Yardley.

111-112-113—ELEMENTS OF MINING. Fundamentals of mining, embracing and exploration, development, and exploitation of mineral deposits. The principles and technology of prospecting, drilling, blasting, hoisting, and transporting of ores, mine drainage. Support of excavations, tunneling, and underground mining methods. 3 cred. per qtr.; prereq. Geol. 25 or permission of instructor; 4 lect. hrs. per week. Pfleider, Yardley.

121—MINE PLANT DESIGN. Application of basic engineering principles to the design and selection of mine plant equipment. Calculations involving power transmission and the drilling, transporting, and hoisting of materials. 2 cred.; prereq. M.&M. 84, M.E. 131; 2 lect. hrs. and 4 lab. hrs. per week. Hartman.

122—MINE AND PETROLEUM PLANT DESIGN. Application of basic engineering principles to the design and selection of mine and petroleum plant equipment. Calculations involving compressed air, pumping, transmission of gases and fluids, electrical equipment and power systems. 3 cred.; prereq. Hydr. 102, M.E. 131, and E.E. 41; 3 lect. and 3 lab. hrs. per week. Hartman.

123—MINE AIR CONDITIONING. Study of mine gases, dust control, and physical properties of air; measurement of air properties; selection and application of mechanical ventilation equipment; design of ventilation, heating, and refrigeration systems. 3 cred.; prereq. 113, Hydr. 102; 3 lect. and 3 lab. hrs. per week. Hartman.

126—ENGINEERING CONSTRUCTION. Theory of structures, loading, analytic and graphic resolution of stresses in frame and masonry structures, beams, ore bins, head frames, derricks, etc. 2 cred.; prereq. M.&M. 85; 6 lab. hrs. per week. Hartman.

127—ENGINEERING CONSTRUCTION. Design of structures in steel, timber, and reinforced concrete for mining and petroleum plant. 3 cred.; prereq. 126; 9 lab. hrs. per week. Hartman.

139—MINING FIELD TRIP—Study of mining operations, mine plant, and metallurgical plants in several mining camps. 6 cred.; prereq. permission of instructor; three weeks beginning about September 1. Pfleider, Yardley.

141—MINERAL ECONOMICS. Mine and oil field examinations and reports; mineral economics, taxation, capitalization, and amortization. Organization and administration. 3 cred.; prereq. 113 or Pet. 112; 4 lect. hrs. per week. Pfleider.

142—SURFACE MINING. The development, engineering planning and operation of open cut properties. Excavation by shovels and draglines; handling materials by railroad, trucks and conveyors. Quarries; methods, equipment, field for product. Placers: dredging, hydraulicking. 3 cred.; prereq. 112; 4 lect. hrs. per week. Pfleider.

143—COAL MINING. The economics and technology of coal. Production and preparation including mining methods and mechanization. Time study applications. Mine gases; safety work and organization. 3 cred.; prereq. 113; 4 lect. hrs. per week. Yardley.

144-145—ADVANCED MINING. Preparation of a report on a mining property or some phase of the mineral industry. 2 cred. for 144, 4 cred. for 145; prereq. 141; 6 lab. hrs. per week for 144, 10 lab. hrs. per week for 145. Pfleider and staff.

151-152-153*—SPECIAL PROBLEMS IN MINING. Literature survey or research work on mining problems. Cred. and hrs. ar.; prereq. 113. Staff.

160—INDUSTRIAL MINERALS AND ROCKS. Survey of minerals and rocks industrially important but primarily not mined for recovery of metals. Origin, geographic distribution, mining methods, processing, uses, etc. 2 cred.; prereq. 112 or permission of instructor; 2 lect. hrs. per week. Heilig.

Natural Science

(College of Science, Literature, and the Arts)

7-8-9†—GENERAL BIOLOGY. The main principles of plant and animal life with particular reference to man and his place in the biological world. 10 cred.; no prereq.; 2 lect. hrs. and 4 lab. hrs. per week.

Naval Science

The courses in Naval Science are primarily for those students, both Regular and Contract, enrolled in the Naval ROTC program but are available to students in the Institute of Technology as well as to students in the other colleges of the University. These courses are acceptable electives in the Institute of Technology.

All courses require three recitation-lecture periods, plus a two-hour laboratory period per week. For information concerning the requirements and the opportunities in the NROTC program, consult the *Bulletin of General Information*, or call at the Naval Science office, 203 Armory.

11—NAVAL ORIENTATION, NAVAL HISTORY AND SEA POWER. 3 cred.

12—NAVAL ORIENTATION, FUNCTIONS OF THE NAVY WITHIN THE NATIONAL ESTABLISHMENT. 3 cred.

13—NAVAL ORIENTATION, DUTIES AND RESPONSIBILITIES OF A NAVAL OFFICER. 3 cred.

21—NAVAL WEAPONS. 3 cred.

22—PRINCIPLES OF FIRE CONTROL. 3 cred.

23—APPLIED NAVAL ELECTRONICS. 3 cred.

51—AEROLOGY AND NAVIGATIONAL PILOTING. 3 cred.

52—CELESTIAL NAVIGATION. 3 cred.

53—NAVIGATIONAL RULES OF THE ROAD AND MANEUVERING BOARD. 3 cred.

54—EVOLUTION OF THE ART OF WAR I. 3 cred.

55—EVOLUTION OF THE ART OF WAR II. 3 cred.

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* May be taken out of sequence.

† To receive credit for any part of this course a student must complete the parts preceding the dagger.

56—MODERN BASIC STRATEGY AND TACTICS. 3 cred.
57—INTRODUCTION TO SUPPLY, NAVAL FINANCE, AND NAVAL ACCOUNTING. 3 cred.
58—SUPPLY ASHORE. 3 cred.
59—SUPPLY AFLOAT. 3 cred.
61—MARINE POWER PLANTS. 3 cred.
62—DIESEL ENGINES; DAMAGE CONTROL. 3 cred.
63—MILITARY JUSTICE AND LEADERSHIP. 3 cred.
64—AMPHIBIOUS WARFARE I. 3 cred.
65—AMPHIBIOUS WARFARE II. 3 cred.
66—ADVANCED SUPPLY AFLOAT AND SHIP'S STORE. 3 cred.
67—NAVAL CLOTHING AND SMALL STORES AND COMMISSARY. 3 cred.

Petroleum Engineering

111—OIL FIELD DEVELOPMENT. Drilling and completion of oil wells, methods and equipment involved. Problems and protection of completed well; directional drilling, well surveying; electrical and mechanical logging and other methods of securing underground information; well records. 3 cred.; prereq. Geol. 25 or permission of instructor; 4 lect. hrs. per week. Lacabanne.

112—OIL FIELD PRODUCTION. Principles and methods of producing oil. Characteristics of oil reservoirs; of oil and gas, phase relations under reservoir conditions; condensate fields; sand drainage; oil reservoir performance; lifting oil; secondary methods of recovery; gas wells. 3 cred.; prereq. 111; 4 lect. hrs. per week. Lacabanne.

131—PETROLEUM REFINING. Distillation and fractionation processes used in making commercial products from crude petroleum. General physical and chemical properties of petroleum; oil refinery methods, principles of cracking; polymerization; alkylation. 2 cred.; prereq. Inorg.Chem. 12, Phys. 7; 2 lect. hrs. per week. Lacabanne.

134—NATURAL GAS ENGINEERING. Properties of natural gas, gravities, etc. Critical condition of gases, deviations, compressibility factor, reduced and pseudo states; retrograde condensation. Estimation of gas reserves. Orifice meters, measuring of gas flow. Gas well capacities by back-pressure. Gas hydrates. 2 cred.; prereq. 152 or permission of instructor; 2 lect. hrs. per week. Lacabanne.

135—STUDY OF OIL WELL DRILLING AND PRODUCTION METHODS AND REFINING PRACTICE IN ONE OR MORE OIL FIELDS. 3 cred.; prereq. permission of instructor; two-week field trip to be arranged. Lacabanne.

138—OIL FIELD MAPPING. A study of the methods and practices of graphically displaying, studying, and interpreting oil field data. Oil and gas well logs; property, contour, cross-section, and correlation maps; methods of displaying data and records, etc. 2 cred.; prereq. 112; 6 lab. hrs. per week. Lacabanne.

144-145—ADVANCED PETROLEUM ENGINEERING. Preparation of report on the exploration and development of an oil property or some phase of the industry. 2 cred. for 144, 4 cred. for 145; prereq. Min. 141; 6 lab. hrs. per week for 144, 10 lab. hrs. per week for 145. Pfleider.

152-153-154—PETROLEUM PRODUCTION TECHNOLOGY. Problems in oil and gas production. Mud fluids, core analysis, permeability and porosity, electrical and mechanical coring and other logging methods, oil well cements, oil flow and drainage through porous formations, water analysis, problems. 3 cred. per qtr.; prereq. 112; 1 lect. and 6 lab. hrs. per week. Lacabanne, Yardley.

155-156-157*—SPECIAL PROBLEMS IN PETROLEUM ENGINEERING. Seminar in petroleum problems. Cred. and hrs. ar.; prereq. reg. in 144-145 or permission of instructor. Lacabanne.

Philosophy

(College of Science, Literature, and the Arts)

1—PROBLEMS OF PHILOSOPHY. Introduction to the subject; the main fields of investigation; permanent problems; principal methods and schools of philosophy; historical and contemporary views. 5 cred.; no prereq.; 5 lect. hrs. per week.

2—LOGIC. A study of the difference between logical and fallacious reasoning; the functions and uses of language; rules of good definition and sound argument. 5 cred.; no prereq.; 3 lect. hrs. and 2 quiz sections per week.

* May be taken out of sequence.

3—ETHICS. An examination of the problems which arise when human beings attempt to think systematically about conduct and values (are there absolute standards?) the problem of free will, and a survey of historical views about the right and the good. 5 cred.; no prereq.; 5 lect. hrs. per week.

2A-1A-3A—SELECTED PROBLEMS OF LOGIC, OF PHILOSOPHY, OF ETHICS. A special sequence of courses in philosophy especially for prelegal freshmen, but open to other students. Only by special permission of the instructor will prelegal students be admitted to 1A-3A without 2A, or to 3A without 1A. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week.

10—SCIENCE AND RELIGION. An inquiry into the nature of science and religion as currently interpreted, with an attempt to find grounds of conflict and/or reconciliation. 2 cred.; soph., jr., sr.; no prereq.

20—SOCIAL PHILOSOPHY. A study of conflicting social philosophies of today; liberalism vs. authoritarianism; evaluation of various social, political, and economic institutions in terms of ethical ideals; other problems of social morality; social reconstruction; social utopias. 3 cred.; soph., jr., sr.; no prereq. (Not offered 1953-54.)

40—LOGIC OF SCIENTIFIC REASONING. An introduction to the principles of scientific method; definition and classification; observation, measurement, experiment; elementary statistical concepts; hypotheses, theories, evidence and confirmation; the nature and limits of the scientific enterprise. 3 cred.; fr., soph., jr., sr.; prereq. 2; 3 lect. hrs. per week. (Offered spring quarter only.)

81-82-83—SCIENCE AND CIVILIZATION. (Formerly 80-81-82.) The course attempts to provide an adequate understanding of the evolution of the sciences and of the scientific point of view within the frame of the history of civilization; the meaning of the fundamental problems, methods, concepts, and assumptions of modern science; and the human and social implications of science in the contemporary world. 3 cred. per qtr.; designed primarily as a senior integrative course, but open to juniors on consent of instructor; no prereq. Brodbeck.

Physical Education for Men

The courses in sports education are offered in the Department of Physical Education to men students of the University for the purpose of providing instruction and practice in sports of a recreational nature in which men may participate as a means of obtaining recreation, regular exercise, and social intercourse.

The facilities of the Department of Physical Education including the golf course, tennis courts, gymnasium, swimming pools, skating rink, handball and squash courts, golf gymnasium, and playing fields are available for use by the general student body. All men are invited to participate in some form of physical activity. For information regarding the intramural and intercollegiate athletic programs see the physical education handbook published by the Department of Physical Education for Men or inquire at the offices of Cooke Hall.

SPORTS EDUCATION

1A-B-C—SPORTS EDUCATION. 1 cred. per qtr.; no prereq.

2A-B-C—SPORTS EDUCATION. 1 cred. per qtr.; no prereq.

Physics

1-2-3—INTRODUCTION TO PHYSICAL SCIENCE. Lectures and experimental demonstrations of the principles underlying physical phenomena. Open to students in architecture. 3 cred. per qtr.; prereq. higher algebra; 3 lect. hrs. per week.

7-8-9—GENERAL PHYSICS. Mechanics, heat, electricity, sound, and light. Laboratory work an integral part of course. 5 cred. per qtr.; prereq. reg. in differential calculus for 7; 4 lect., 1 quiz, and 2 lab. hrs. per week; courses must be taken in order.

11-12-13—GENERAL PHYSICS FOR ENGINEERS. Mechanics, heat, electricity, sound, and light. Courses must be taken in order. 5 cred. per qtr.; prereq. concur. regis. I.T.M. 11 for 11, I.T.M. 12 for 12, I.T.M. 13 for 13; 4 lect., 1 quiz, and 2 rec. hrs. per week for 11, 2 lab. hrs. per week for 12 and 13.

14—INTERMEDIATE GENERAL PHYSICS. Mechanics, heat and electricity, selected topics. 4 cred.; prereq 11, 12, 13, and concur. reg. in differential calculus; 4 lect. and 1 quiz hr. per week.

14A—PHYSICS LABORATORY. (Optional; parallel to Phys. 14.) 1 cred.; prereq. concur. reg. in 14; 2 lab. hrs. per week.

50—INTERMEDIATE GENERAL PHYSICS. Selected topics in modern physics. 4 cred.; prereq. 14 and reg. in integral calculus; 4 lect. and 1 quiz hr. per week.

50A—PHYSICS LABORATORY. (Optional; parallel to Phys. 50.) 1 cred.; prereq. reg. in 50; 2 lab. hrs. per week.

51—INTERMEDIATE GENERAL PHYSICS. Thermodynamics, kinetic theory. Sound and light. Selected topics. 4 cred.; prereq. 14 and integral calculus; 4 lect. and 1 quiz hr. per week.

51A—PHYSICS LABORATORY. (Optional; parallel to Phys. 51.) 1 cred.; prereq. reg. in 51; 2 lab. hrs. per week.

101-103-105*—THEORETICAL PHYSICS. An analytical survey of fundamental principles of mechanics, thermodynamics, kinetic theory of gases, electricity, and magnetism, designed to supplement the general course and to prepare students for more specialized graduate courses. 5 cred. per qtr.; 3rd yr. or above; prereq. 15 cred. in physics and differential equations or reg. in differential equations; 5 rec. hrs. per week. Nier.

107-109-111*—MODERN PHYSICS. Selected topics in modern physics such as photoelectric effect, mass spectroscopy, ionization of gases, optical spectra, nuclear physics, radioactivity, X rays. 3 cred. per qtr.; 3rd yr. or above; prereq. 15 cred. in physics and integral calculus; 3 lect. hrs. per week. Collins.

114-116-118*—ELEMENTARY PHYSICAL INVESTIGATION. Special problems, either experimental or theoretical, in which the student may have some special interest. Permission of department chairman required for registration. 3 cred. per qtr.; 3rd yr. or above; prereq. 15 cred. in physics, integral calculus. Staff.

120—ATOMIC PHYSICS. A laboratory course to introduce techniques and methods used in physics research laboratories. Vacuum gauges and systems, properties of charged particles, X ray diffraction, ionization of gases, mass spectroscopy, photoelectricity, secondary electron emission. 3 cred.; 3rd yr. or above; prereq. 50 or reg. in 107, integral calculus, or permission of instructor; 8 hrs. per week. Blair.

121—EXPERIMENTAL NUCLEAR PHYSICS I. A laboratory course in nuclear physics not requiring extensive knowledge of electronic circuits. Natural radioactivity, cloud chambers, ionization chambers, properties of nuclear radiations, alpha, beta, and gamma rays, neutrons; shielding artificial radioactivity, photographic techniques, health protection. 3 cred.; 3rd yr. or above; prereq. 50 or reg. in 107, integral calculus, or permission of instructor; 8 hrs. per week. Blair.

122—EXPERIMENTAL NUCLEAR PHYSICS II. A laboratory course in techniques in nuclear physics requiring knowledge of electronic circuits. Geiger, proportional, scintillation, and coincidence counters. Cosmic rays. Nuclear resonance phenomena. Health monitoring instruments. 3 cred.; 3rd yr. or above; prereq. 121, 146 or permission of instructor; 8 hrs. per week. Blair.

131—GEOMETRICAL OPTICS. Theory of mirrors, prisms, and lenses. Theory of diaphragms and brightness of images. Optical instruments. 3 cred.; 3rd yr. or above; prereq. 15 cred. in physics, integral calculus; 3 lect. hrs. per week. Valasek.

133—PHYSICAL OPTICS. Theory of interference and interferometers. Theory of diffraction, resolving power, and diffraction gratings. Polarized light, crystal optics, and applications. 3 cred.; prereq. 15 cred. in physics and integral calculus. Valasek.

134—EXPERIMENTAL OPTICS. Laboratory work in spectrometry, optics of compound lenses, photometry, absorption, interferometry, and polarized light. 3 cred.; 3rd yr. or above; prereq. 15 cred. in physics, integral calculus; 6 lect. and lab. hrs. per week. Valasek.

135—SPECTROSCOPY. Light sources, instruments, and methods used in spectroscopy or the X ray, ultraviolet, visible, and infrared regions of the spectrum. 3 cred.; prereq. 15 cred. in physics and integral calculus. (Not offered 1953-54.)

136—SPECTRUM ANALYSIS. Laboratory work dealing with the measurement of wave lengths, intensities, and absorption coefficients in the infrared, visible, and ultraviolet regions of the spectrum. 3 cred.; 3rd yr. or above; prereq. 15 cred. in physics and integral calculus; 6 lect. and lab. hrs. per week. Valasek.

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* May be taken out of sequence with permission of instructor.

144—ELECTRICAL MEASUREMENTS. An experimental course covering ballistic and current galvanometers, magnetic flux measurements, potentiometer methods, D.C. bridges, and audiofrequency A.C. bridges. 4 cred.; prereq. 15 cred. in physics and integral calculus; 3 lect. and 3 lab. hrs. per week. Blair.

146—PHYSICS OF VACUUM TUBES. Thermionics, vacuum tube circuits. 3 cred.; prereq. 144 or permission of instructor.

148—APPLICATION OF ELECTRONIC CIRCUITS. A study of the application of various electronic circuits which are useful in physics research. Lecture and laboratory work involving amplifiers, computing circuits, servo-mechanisms, regulating circuits, and others especially adapted to work in physics. 3 cred.; 3rd yr. or above; prereq. 146 or permission of instructor; for those who already have a basic knowledge of electronics; 6 hrs. per week.

181-183-185*—ATOMISTICS AND ELEMENTARY QUANTUM MECHANICS. An introduction to wave mechanics, atomic structure, and nuclear physics. 3 cred. per qtr.; prereq. 101-103-105 or permission of instructor. Williams.

191-192-193*—INTRODUCTION TO MATHEMATICAL PHYSICS. Intensive treatment of the equations of mathematical physics using material drawn from the fields of mechanics, small vibrations of continuous media, acoustics, electromagnetic theory, and heat conduction. 3 cred. per qtr.; prereq. 101-103-105, Math. 105, 107, 108 or I.T.M. 80, 150, 152, 153 or equiv.

Plant Pathology and Botany

(College of Agriculture, Forestry, and Home Economics)

3—WEEDS. A study of the identification, structures, and habits of weed plants in relation to methods of controlling them. 3 cred.; fr., soph., jr., sr.; prereq. 6 cred. in botany.

Political Science

(College of Science, Literature, and the Arts)

1-2†—AMERICAN GOVERNMENT AND POLITICS. An analysis of the principles, organization, procedures, and functions of government in the United States—national, state, and local. Attention will be given throughout to current issues. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week. Christensen.

A-B†—THE STATE IN THE MODERN WORLD. An examination of principles, structure, and operation of the modern state. Emphasis on nation state; historical development; democratic government: United States, Great Britain; totalitarian government: Nazi Germany, Soviet Russia; conflict between states. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week. Lippincott.

5—AMERICAN GOVERNMENT AND POLITICS. This course covers essentially the same materials as Pol.Sci. 1-2. 5 cred.; no prereq.; 5 lect. hrs. per week. Naftalin.

25—WORLD POLITICS. Introduction to contemporary international relations; the policies of the great powers; nationalism; imperialism; internationalism. 3 cred.; no prereq.; 3 lect hrs. per week. Mills.

Senior College courses in political science are grouped into four fields: (a) American government—including politics, administration, public law, and local government; (b) comparative government; (c) political theory; and (d) international relations. See the *Bulletin of the College of Science, Literature, and the Arts.*

Psychology

(College of Science, Literature, and the Arts)

1-2†—GENERAL PSYCHOLOGY. A general introduction to the study of human behavior with emphasis on the development of the individual. 3 cred. per qtr.; no prereq.; 3 lect. hrs. per week.

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* May be taken out of sequence with permission of instructor.

† To receive credit for any part of this course a student must complete the parts preceding the dagger.

3—PSYCHOLOGY APPLIED TO DAILY LIFE. A course in the use of psychological methods in solving such problems as come up in the treatment of ill health, in the court-room, reformatory, and prison, in business offices and factories, in advertising, in education, in social and political life, in artistic creation and esthetic enjoyment, and in everyday life. 3 cred.; prereq. 1-2; 3 lect. hrs. per week.

130—VOCATIONAL AND OCCUPATIONAL PSYCHOLOGY. Psychology of individual differences in intelligence, aptitudes, interests, and training, with special reference to vocational guidance and problems of occupational adjustment. Lectures and laboratory work. 3 cred.; jr., sr., grad.; prereq. 9 cred. in psychology; 2 lect. hrs. and 2 lab. hrs. per week.

155—INDUSTRIAL PSYCHOLOGY. Psychological problems in industrial production with special reference to biomechanics (the adaptation of the machine to the capacities and limitations of the operator), work and effort, and the role of communication in an industrial organization. 3 cred.; jr., sr., grad.; prereq. 1-2 and Math. 15, 16 or equiv. or 10 cred. in statistics. Russell, Jenkins.

160—PSYCHOLOGY IN PERSONNEL WORK. Psychology as applied to selection and retention of a stabilized personnel. The standardized interview; principles and techniques of employment tests; methods of judging character qualities; the rating scale; personnel classification methods. 3 cred.; jr., sr., grad.; prereq. 1-2, 4-5, or 3 cred. in statistics, and Principles of Economics or permission of instructor; 3 lect. hrs. per week. Longstaff.

Public Health

(School of Public Health)

3—PERSONAL HEALTH. Normal body function; causes and prevention of disease. 2 cred.; fr., soph.; no prereq.; not open to students who have taken G.C. 10C. Thomson.

100—ELEMENTS OF PREVENTIVE MEDICINE AND PUBLIC HEALTH. Occurrence and prevention of communicable, degenerative, and industrial diseases; protection of food, water, and milk; maternal and child health. 5 cred.; 6 cred. for medical students; prereq. 3 or 50, and course in bacteriology. Anderson, Thomson.

102—ENVIRONMENTAL SANITATION I. Methods for promoting man's health and comfort by controlling environment. 3 cred.; sr., grad.; prereq. 50 or 51 or 100 or concurrently with any of these. Bosch.

Rhetoric

(College of Agriculture, Forestry, and Home Economics)

22—PUBLIC SPEAKING. A practical course in the fundamentals of speech making. Particular emphasis upon organizing the speech and projecting it to the audience. 3 cred.; soph., jr., sr.; prereq. Engl. 6 or Rhet. Communication requirement.

Social Science

(College of Science, Literature, and the Arts)

1-2-3—INTRODUCTION TO SOCIAL SCIENCE. An integrated study of the factors—historical, political, economic, social, psychological, and cultural—that influence man's behavior. The course is organized around three basic themes: (1) development of personality, (2) work as a central aspect of modern life, and (3) the quest for community. 4 cred. per qtr.; no prereq.; 4 hrs. per week.

51-52-53—INTRODUCTION TO SOCIAL SCIENCE. This course is similar to Soc.Sci. 1-2-3 except that it is confined to juniors and seniors and is conducted on a more advanced level. It is designed for students with little background in social science and hence is not open to majors in a social science department or to anyone who has taken several social science courses. A student may not receive credit for any quarter of this course if he has completed the corresponding quarter of 1-2-3. 4 cred. per qtr.; no prereq.; 4 hrs. per week.

Sociology

(College of Science, Literature, and the Arts)

1—INTRODUCTION TO SOCIOLOGY. A study of the characteristics of human group life. An analysis of the factors associated with the development of human group life and man's social environment; the structure of the social environment and its influence upon the individual's behavior. 3 cred.; no prereq.; 3 lect. hrs. per week.

2—INTERMEDIATE SOCIOLOGY. A sociological analysis of modern American society. Topics emphasized include the distribution of population, urban-rural differences, social factors in the business system, occupational groups, the determination of social status, and minority group adjustment. An attempt is made to familiarize the student with current research methods. 3 cred.; prereq. 1; 3 lect. hrs. per week.

14—RURAL SOCIOLOGY. A presentation of factual data necessary to an understanding of the problems of rural social life. 3 cred.; prereq. 1; 3 rec. hrs. per week.

Soils

(College of Agriculture, Forestry, and Home Economics)

4—SOILS. Origin, formation, and classification. The soil profile and its development; physical and chemical properties of soils; organic matter and biological relationships; forms and movement of soil water; erosion control. 3 cred.; soph., jr., sr.; prereq. Inorg.Chem. 1-2 or 4-5; 3 lect. hrs. per week. Caldwell.

5—SOIL MANAGEMENT. Nutrient requirements of crops; fertilizers and fertilizer materials; fertilizer practices; use of lime; farm manures, their composition, value, and use; green manuring; soil management and fertility maintenance. 3 cred.; soph., jr., sr.; prereq. 4; 3 lect. hrs. per week. Rost.

103—PRINCIPLES OF SOIL EROSION AND EROSION CONTROL. Causes and forms of erosion; relation of erosion to climate, vegetation, slope, soil type, and soil management. Control practices. Organizations dealing with soil erosion control. Lab. and field trips required. 4 cred.; jr., sr., grad.; prereq. 4.

108—PHYSICAL PROPERTIES OF SOILS. Determination of physical constants of soils, including mechanical composition. 3 cred.; jr., sr.; prereq. 4; 1 lect. and 4 lab. hrs. per week. McMiller, Arneman.

Technical Aid

11—ENGINEERING DRAFTING. A beginning course in drafting, including the use of instruments, geometric constructions, lettering, freehand sketching, orthographic projection, isometric and oblique drawing, and dimensioning. 5 cred.; no prereq.; 2 lect. and 13 lab. hrs. per week.

12—ENGINEERING DRAFTING. A continuation of Course 11 including sectional and auxiliary views, detail and assembly drawings, fastenings, piping, wiring diagrams, gears, and cams; tracing and reproduction. 5 cred.; prereq. 11; 2 lect. and 13 lab. hrs. per week.

13—ENGINEERING DRAFTING (APPLIED DESCRIPTIVE GEOMETRY). The solution of space problems, intersections, developments, triangulation, true shapes and true angles. Use of planimeter, construction of scale models. 5 cred.; prereq. 12; 2 lect. and 13 lab. hrs. per week.

14—ENGINEERING DRAFTING (STRUCTURAL DETAILING). Detail, assembly, and construction drawings of riveted and welded steel, reinforced concrete and timber structures. Use of steel handbook and drafting machines. 5 cred.; prereq. 13; 2 lect. and 13 lab. hrs. per week.

15—PRODUCTION ILLUSTRATION. Pictorial drawing as used in industry. Detail and assembly drawing by the use of axonometric and perspective drawings, shaded drawings. 5 cred.; prereq. 14; 2 lect. and 13 lab. hrs. per week.

16—LETTERING. Construction and analysis of gothic, modern roman, and italic styles. Exercises in composition and title construction. Use of mechanical lettering devices. 1 cred.; no prereq.; 1 lect. per week.

17—SLIDE RULE. A practical course in computation. Location of the decimal point. Basic theory. 1 cred.; no prereq.; 1 lect. per week.

18—CHARTS AND GRAPHS. Elementary course dealing with the construction of simple charts and graphs. 1 cred.; no prereq.; 1 lect. per week.

21—APPLIED MATHEMATICS. Principles and formulas of mensuration, slide rule, fractions, ratio, proportion, percentage, powers, roots, screw threads, belts, and pulleys. 6 cred.; no prereq.; 5 lect. and 3 rec. hrs. per week.

22—APPLIED MATHEMATICS. Fundamental principles of algebra, equations, fractions, exponents, powers and roots, quadratic equations, variation graphical functions. 6 cred.; prereq. 21; 5 lect. and 3 rec. hrs. per week.

23—APPLIED MATHEMATICS. Logarithms, trigonometric functions, solutions of right and oblique triangles, relations between trigonometric functions, graphical representation, double and half angles. 6 cred.; prereq. 22; 5 lect. and 3 rec. hrs. per week.

24—APPLIED MATHEMATICS. Trigonometric solution of shop layout problems, railroad curves, spirals, vectors, resolution of velocity and forces, resultant and condition of equilibrium, moments. 6 cred.; prereq. 23; 5 lect. and 2 rec. hrs. per week.

25—APPLIED MATHEMATICS. Study of motion, work, power, energy, momentum, friction, machines. Elasticity and strength of materials. 6 cred.; prereq. 24; 5 lect. and 2 rec. hrs. per week.

26—APPLIED MATHEMATICS. Coordinate geometry, straight line, circle, second degree functions, polar coordinates, curve fitting, linear, power, logarithmic and exponential type graphing of statistical data. 6 cred.; prereq. 25; 5 lect. and 2 rec. hrs. per week.

27—ENGINEERING PROBLEMS. Use of handbooks. 3 cred.; prereq. 25; 3 lect. hrs. per week.

28—BASIC PHYSICAL SCIENCE. An introduction to the basic principles of electricity and magnetism, heat, light, and sound which are of special interest to the design engineers. 2 cred.; no prereq.; 3 lect. hrs. per week.

34—TECHNICAL WRITING. Written descriptions of devices and explanations of processes, integrated with speaking and reading exercises and grammar review. 3 cred.; no prereq.; 3 rec. hrs. per week.

35—TECHNICAL WRITING. Written interpretation of tables and diagrams in long and short form of reports. Related exercises in speaking and reading. 3 cred.; prereq. 34; 3 rec. hrs. per week.

36—TECHNICAL WRITING. Business letters, library research report, talks and reading of a book. 3 cred.; prereq. 35; 3 rec. hrs. per week.

37—ORAL COMPOSITION. Collecting material and delivering prepared talks; training in the spur-of-the-moment comment and conference technique. 3 cred.; prereq. 36; 3 rec. hrs. per week.

41—ENGINEERING DRAFTING (ARCHITECTURAL DRAWING). Objectives and special techniques of architectural drafting. Sketches and presentation drawings, working drawings, conventions and dimensioning, theory of shades and shadows, theory of perspective. 5 cred.; prereq. 14; 2 lect. and 13 lab. hrs. per week.

42—ENGINEERING MATERIALS (BUILDING MATERIALS). Basic types of construction. Characteristics and use of principal building materials; wood, steel, concrete, and masonry. 2 cred.; no prereq.; 2 lect. hrs. per week.

82—FOUNDRY. Foundry practice and control techniques. Ferrous and nonferrous melting. Die casting and permanent mold technique. 2 cred.; no prereq.; 2 lect. and 3 lab. hrs. per week.

83—FORGING, WELDING, AND HEAT TREATING. Forging methods and techniques. Welding. Heat treatment of commercial alloys. 2 cred.; prereq. 82; 2 lect. and 3 lab. hrs. per week.

84—MACHINE SHOP. Operation of drill press, lathe, shaper, and other machine tools. Use of measuring tools. Use and care of cutting tools. 2 cred.; prereq. 83; 2 lect. and 3 lab. hrs. per week.

85—MACHINE DESIGN. Elementary machine design. Standard practices in design involving material and heat treatment specifications, tolerances and allowances, and manufacturing standards. 2 cred.; prereq. 84; 2 lect. and 3 lab. hrs. per week.

Zoology

(College of Science, Literature, and the Arts)

1-2-3†—GENERAL ZOOLOGY. Structure, physiology, embryology, classification, and evolution of animals. 10 cred.; no prereq.; 2 lect. and 4 lab. hrs. per week. Minnich.

14-15†—GENERAL ZOOLOGY. A shorter version of Zool. 1-2-3 with similar content. Primarily for students in the College of Agriculture, Forestry, and Home Economics. 6 cred.; no prereq.; 2 lect. and 4 lab. hrs. per week. Olson.

† To receive credit for any part of this course a student must complete the parts preceding the dagger.

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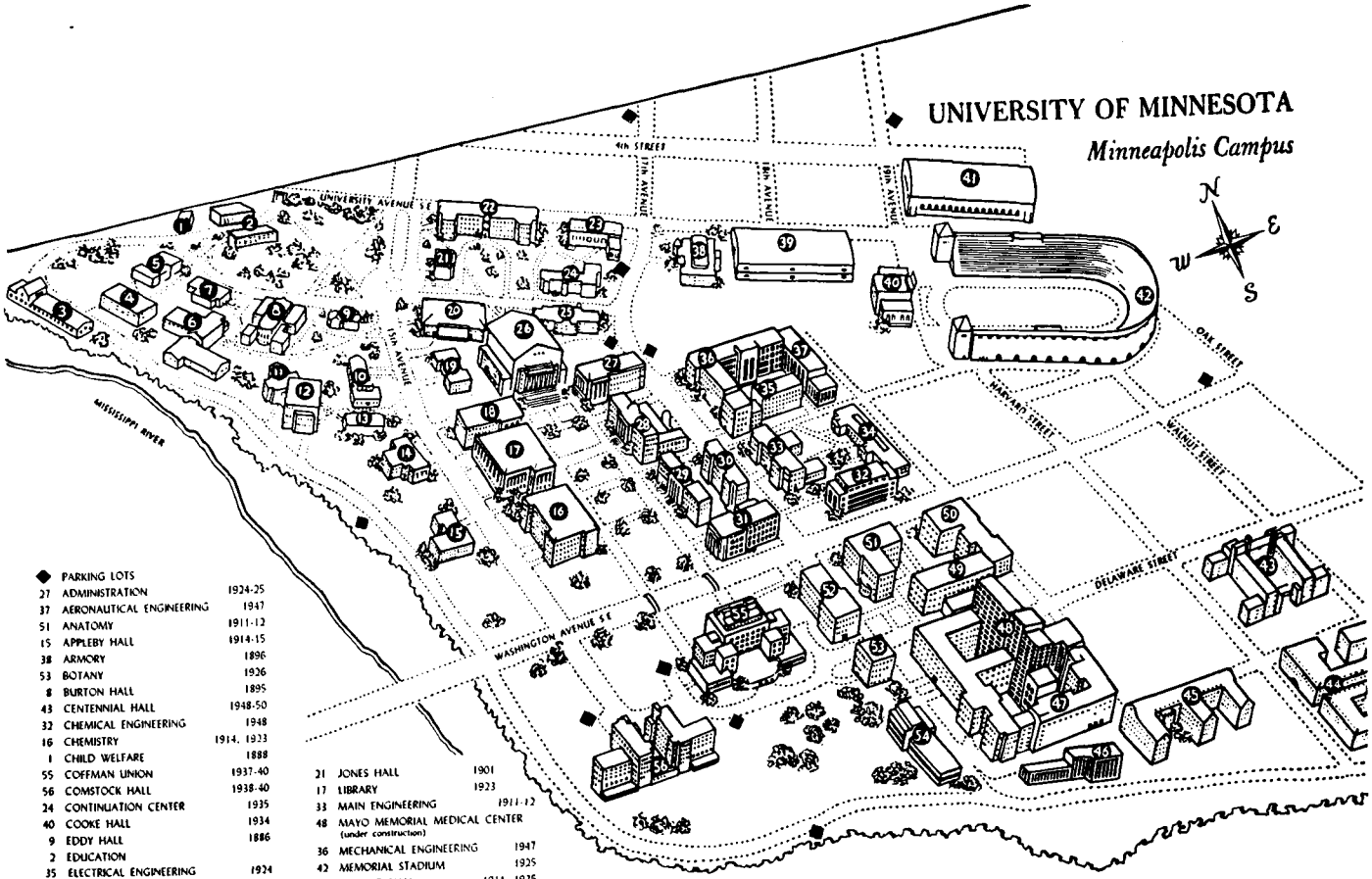
UNIVERSITY OF MINNESOTA

Minneapolis Campus



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