XIV-17

Institute of Technology

1961-1963

Student measuring the electrical properties of a semiconductor crystal with microwaves.

Bulletin

of the UNIVERSITY of MINNESOTA

HOW TO USE THIS BULLETIN

Preserve this booklet as your basic guide to the Institute of Technology. Use it as your official source for the following:

I. GENERAL INFORMATION

The general section applies to everyone. Familiarize yourself with what it covers: objectives and organization of the Institute of Technology, curriculums offered, and degrees conferred; admission requirements (including Upper Division), registration procedure, types of academic work, academic standards and cancellation of courses; graduate programs; student personnel services, student activities, employment services, and financial assistance.

II. GENERAL CURRICULAR REQUIREMENTS

A discussion of the general curricular requirements is included in this section. Also, the elective groups and the general elective requirements are included.

III. CURRICULUMS

Master what applies to you in the detailed requirements given in this section for each degree offered by the Institute. Note particularly the curriculums during the first 2 years and the basic courses you must have before you can take advanced work. Try to see the trend of the whole pattern.

IV. DESCRIPTION OF COURSES

To interpret the complete information about courses in this section, refer to the conventions and symbols as listed below:

* Graduate students may prepare Plan B papers.

† To receive credit, all courses listed before dagger must be completed.

‡ A sequence course may be entered any quarter preceding double dagger.

§ No credit if credit has been received for equivalent course listed after section mark.

¶ Means "concurrent registration in" (i.e., course must be taken simultaneously).

‡ Means "consent of instructor."

△ Means "consent of division, department, or school offering course."

A hyphen in a course number (4-5-6) indicates a sequence course which must be taken strictly in the order listed.

Courses numbered 200 or above are for graduate students only, except by specific permission of the dean of the Graduate School.

Class rank prerequisite (3rd yr) means that no one below that rank may register for the course without specific permission from the Scholastic Standards Committee.

A prerequisite course listed by number only (prereq 89) is always in the same department as the course being described.

Prerequisite credits listed by amount only (prereq 6 cr) mean credits which must have been earned in the same department offering the course being described.

For information about the University as a whole (tuition, fees, other expenses, etc.) consult the separate *Bulletin of General Information* obtainable at the information window in the Administration Building. For room and hour of class meetings, use the *Class Schedule* for each quarter and note the departmental announcements in the Official Daily Bulletin of the *Minnesota Daily*.

Ready reference to specific items in the present bulletin is provided by the Index at the end. Do not register without this bulletin as your guide.

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Institute of Technology

I. GENERAL INFORMATION

General Objectives and Curriculums

Organization and Objectives—The Institute of Technology (oftentimes called IT) consolidates five related curricular units:

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

Students enrolled in one of these may take suitable courses from the others, and from the University at large. Together they offer complete sequences of college studies, or curriculums, leading to the many degrees soon to be described.

Each curriculum is designed to prepare the student for leadership in his chosen field. To that end, the curriculums first provide him fundamental training in science and mathematics, and then base on that foundation the more specialized professional courses in his selected area. The purpose is to develop in the student a thorough understanding of fundamental principles and an ability to apply that knowledge to new problems he may meet after graduation, rather than to train him only in the detailed aspects of current specialized industrial and professional practice. Besides his professional studies, the student also takes a program including communication, the life and social sciences, and humanities, which is intended to round out his points of view. The final objective of each full curriculum is to produce well-balanced graduates prepared for constructive careers in the world they enter.

Curriculums and Degrees—The Institute of Technology offers various programs leading to the Bachelor's degree in its five colleges and schools. The colleges and schools and the degree curriculums they offer are tabulated below. Both 4-year and 5-year curriculums are available, as described below.

College of Engineering—Aeronautics and engineering mechanics; agricultural, civil, electrical, and mechanical engineering; mathematics

School of Architecture—Architecture

School of Chemistry—Chemical engineering, chemistry, metallurgy

School of Mines and Metallurgy—Geological engineering (mining or petroleum), geophysics, metallurgical engineering, mining engineering (mining or petroleum)

School of Physics—Physics

Most of the curriculums in the College of Engineering, in the School of Mines and Metallurgy, and in the Department of Chemical Engineering and the Department of Metallurgy of the School of Chemistry are 5-year curriculums. Students who attain the necessary standards of performance and who desire to proceed to graduate work may obtain a bachelor of science degree by petition at the end of 4 years. The student may then begin a graduate program in his fifth year. (See the section on Requirements for Graduation).

The School of Architecture offers a 5-year curriculum in the Institute of Technology; also, a 6-year curriculum in co-operation with the College of Science, Lit-

erature, and the Arts. The Department of Chemistry, the Department of Mathematics, and the School of Physics offer 4-year curriculums.

Certain engineering departments, including mechanical and electrical, permit specified work in industrial engineering to replace some of the optional engineering study of the fifth year and thereby provide an alternative path to the professional degree. This option accommodates students who plan a career in engineering joined with industrial organization, scientific management, and operational research.

Co-operative work-study programs in mechanical, metallurgical, and mining engineering providing practical work experience in conjunction with regular classes and laboratory work are available through co-operation with nearby industrial concerns. During part of their collegiate program students in the work-study curriculums are on a 12-month basis and spend alternative quarters in industry. While on the work assignments students are paid at regular rates by the company.

A 5-year combined curriculum linking some fields of engineering (agricultural, chemical, civil, geological, metallurgical, and mining) with work in the School of Business Administration culminates in a degree in engineering and another in business administration. A 4-year combination of courses in the College of Engineering and the School of Business Administration leads to a degree in business administration.

The Law School and the Departments of Civil, Electrical, and Mechanical Engineering have arranged a joint 7-year program leading to the degrees of bachelor of laws and bachelor of science in engineering. Details of the program appear in this bulletin under the departmental curriculums and may be worked out with the adviser in the particular department.

A combined 5-year program with the College of Education is designed to make it possible for students to qualify for the bachelor of physics degree, the bachelor of chemistry degree, or the bachelor of mathematics degree from the Institute of Technology and for the master of education degree from the College of Education, carrying courses in the two colleges concurrently during the fourth and fifth years. The 2 degrees are awarded upon completion of the 5-year program. Further information regarding this program appears in this bulletin under the departmental curriculums of chemistry, mathematics, and physics, and in the *Bulletin of the College of Education.*

Admission Requirements

General—The undergraduate curriculums of the Institute of Technology are separated into a Lower Division (consisting of the first 2 years of work) and an Upper Division consisting of the remaining years of work required (see section on Curriculums). New freshman students are admitted to the work of the Lower Division only. Upon satisfactory completion of the work in the Lower Division, the student applies for admission to the Upper Division. Students must complete the work of the Lower Division within 8 quarters. These regulations apply to all Institute of Technology units except the School of Architecture. The admissions requirements are detailed in the *Bulletin of General Information.*

High School Requirements—It is recommended that students wishing to enter the Institute of Technology complete 4 years of mathematics, divided approximately among 2 years of algebra and 2 years of geometry of 2 and 3 dimensions, including trigonometry. Courses in physics and chemistry are also highly desirable. If these courses are unavailable in the student's high school, consideration should be given to available correspondence courses (see *Bulletin of Correspondence Study*) and extension classes (see *Bulletin of Evening and Special Classes*). To be admitted to

the Institute of Technology a high school graduate must satisfy the two major qualifications detailed below:

1. *Course requirements*
   a. Twelve units completed in grades 10-12, including 3 units in English and 3 or more units from the following: foreign language, history, social science, physical science, and biological science.
   b. A minimum of 3 units in mathematics, including 1½ units of algebra and 1½ units in geometry. The 1½ units in algebra may include 1 unit of ninth grade algebra; the 1½ units of geometry may include ½ unit of trigonometry, and must include the essentials of solid geometry. A full unit of general mathematics followed by a full unit of higher algebra may be substituted for the 1½-unit algebra requirement.
2. *Academic Standing*

   A student is admitted on the basis of an aptitude rating which combines his high school rank and his achievement in an entrance examination in mathematics. In general, the student must be in the upper half of his high school class. However, a student below the 50-percentile high school rank can qualify for admission on the basis of above-average performance on the mathematics examination; similarly, a student above the 50-percentile high school rank will not be admitted when his achievement in the mathematics examination indicates that he does not qualify for admission. The required mathematics test is made available to Minnesota high schools so that these high shcools that wish to do so may administer the test. Seniors interested in applying for admission to the Institute of Technology should contact their principal or counselor by March 1 to determine availability of the test. Those prospective applicants who are not able to take the test in high school should write to the Office of Admissions and Records, 105 Administration Building, University of Minnesota, Minneapolis 14, for information about procedures to follow.

New students receive their English classification on the basis of tests taken prior to registration. If students are assigned to Preparatory Composition by the English assignment card, they must complete this course during the quarter assigned. No credit is given for this course. Registration for Preparatory Composition is in 210 Johnston Hall; a fee of $21 is charged.

A student assigned to Preparatory Composition, a no-credit course, would ordinarily be expected to complete his requirement by taking Engl 1B-2B-3B. However, if a student makes a grade of A or B in Preparatory Composition, he may, on the recommendation of his instructor, complete his English requirement by completing 1B and 2B with a minimum grade of C.

Removal of Deficiencies—If a student lacks either higher algebra or solid geometry, but not both, he can be admitted on the condition that he make up the deficiency by the end of his first quarter in residence. If this deficiency is not removed by the end of the first quarter, the student will not be permitted to continue in the Institute of Technology.

It is strongly recommended that a student make up his mathematics deficiency before entering IT. He may do so during the summer or any other period preceding entrance through correspondence or extension courses offered by the University (see *Bulletin of Evening and Special Classes* and *Bulletin of Correspondence Study Courses*).

As a last resort, a student may make up his deficiency in solid geometry or in higher algebra during his first quarter in residence (without IT credit) by one of the following procedures:

(a) Correspondence study (see *Bulletin of Correspondence Study Courses*).
(b) Evening extension classes (see *Bulletin of Evening and Special Classes*).
(c) Registering in ITM 8 or in ITM 9 (information available at the College of Engineering office, 133 Main Engineering). A fee of $21 is charged.

It should be emphasized that the first quarter in the Institute of Technology is a difficult one and the added burden caused by mathematics deficiencies should be avoided if at all possible.

Students not eligible for admission to the Institute of Technology directly may apply for transfer to the Institute of Technology after a year's satisfactory work in some other college, including General College. This work must meet the scholastic

requirements of the Institute of Technology. Students who enter another college hoping to earn a later transfer to the Institute of Technology must consult with the counselors in that college at the very beginning of the school year in order to learn the exact requirements for this transfer and to receive help in planning their programs in relation to this goal. These students should include course work, preferably in mathematics, physics, or chemistry, which will satisfy an Institute of Technology course requirement. In general, transfer students from within the University are not admitted without having completed one of the course sequences indicated above.

Admission with Advanced Standing—If a student has finished a year or more of satisfactory work at an accredited college or university, he may be admitted to the Institute of Technology with *advanced standing,* that is, with credit for courses satisfactorily completed.

No credit will be given for work in which a grade of D has been received.

If the student has less than 1 year of advanced work, he must meet regular requirements for admission from high school. He will receive credit for the college courses completed satisfactorily. He must file official college transcripts to cover all work done, whether it has been satisfactory or unsatisfactory. The student should make application and supply transcripts to the Office of Admissions and Records at least 1 month before the beginning of the quarter in which he wishes to enter.

Students with advanced standing will be admitted either to the Upper Division or to the Lower Division depending upon their course background at the time of admission. Those who are admitted to the Lower Division must at a later date apply for admission to the Upper Division. Students who are in the Lower Division may register for Upper Division courses provided they have the prerequisites for the Upper Division courses.

Admission to the Upper Division—Requirements for admission to the Upper Division are as follows:

a. Completion by the applicant of the Lower Division curriculum for the department to which he seeks admission in the Upper Division.
b. A grade point average (G.P.A.) of 2.00 or better.
c. For students who do not meet the requirements set forth in a and b above, the several Scholastic Standards Committees in the individual departments will act on the petitions for admission to the Upper Division.

Admission as an Adult Special—A student who wishes a special and limited program of study may be admitted as an adult special student provided he is not a candidate for a degree. A student asking admission as an adult special student should obtain an application blank at the Office of Admissions and Records. The application must receive the approval of the Scholastic Standards Committee and the dean of Admissions and Records. To be accepted, the student must have a Bachelor's degree or show satisfactory evidence of maturity.

Registration and Types of Academic Work

Registration for Credit in Regular Courses—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, the School of Architecture, or the School of Physics will begin their registration in the Main Engineering building (E 135). Those entering the School of Chemistry will begin in the Chemistry building (C 127); those entering the School of Mines and Metallurgy in the Mines and Metallurgy building (MinMet 112); and those entering the Metallurgy Department of the School of Chemistry in the Mines and Metallurgy building (MinMet 403). Registration instructions furnished by the Institute of Technology Registration Committee and placed on bulletin boards in the buildings mentioned above should be followed.

A student is required to take courses in the order shown by his curriculum. The prerequisites of any course must be met unless special permission to waive the prerequisites is granted by the head of the department giving the course or by his representative. The "Waiver of Prerequisite" form properly filled out and approved is filed with the Registration Committee.

Program conflicts are not permitted except under very special circumstances and unless special approval has been granted by the head of the department or his representative. The "Approval of Conflict" form properly filled out and approved must be filed with the Registration Committee.

Cancellation of Courses—A student may not cancel a course without failure unless he receives the consent of his adviser. After the first 6 weeks of class, permission to cancel without failure will be granted only with adviser approval and on petition to, and with the consent of, the Scholastic Standards Committee. For the Summer Session the deadline shall be the end of the first half of each term. During the last 2 weeks before the beginning of final examinations, cancellation is not permitted except under the most unusual circumstances.

Cancellation of back work will not be granted except in case of emergency.

Auditing Courses—In special cases, a course may be audited upon the recommendation of the instructor and approval by the Scholastic Standards Committee as noted on the "Audit" slips obtainable in the college office. In auditing a course, the student may not participate in the activities of the class nor take the final examination, and no grade is recorded. The total load including audits may not exceed the maximum of 19 credits.

Credit for Independent Study—Credit for work done outside of regular classes may be obtained by comprehensive examination. Students may by petition to the Scholastic Standards Committee request permission to take comprehensive examinations in courses which have been thoroughly mastered through independent study. The superior student by this means may be able to accelerate his educational progress.

The comprehensive examination will be so thorough and searching as to determine whether the student has done all the work of the course. It will normally 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.

Comprehensive examinations ordinarily cannot be used for the removal of failures and in no event will approval be granted in less than 90 days after the failure has been recorded. A fee of $5 for each special examination must be paid unless it be taken within 6 weeks after the student enters the University.

Evening and Correspondence Courses—Many Institute of Technology courses 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 thus obtain valuable instruction after working hours or by mail. Information as to the credits which will be accepted toward a degree in the Institute of Technology appears on page 29 of this bulletin and in the *Bulletin of Evening and Special Classes* and *Bulletin of Correspondence Courses.*

Regularly enrolled students in residence must have the permission of the Scholastic Standards Committee to register for courses in the General Extension Division.

Field Trips—Field trips are required in the School of Mines and Metallurgy as indicated in the various curriculums.

Reserve Officers Training Corps—Information concerning requirements, opportunities, and courses in air science, military science, and naval science may be pro-

cured in the *Bulletin of the Army-Navy-Air Force ROTC* and from the professors of air, military, and naval science in the Armory.

Academic Standards

Faculty Scholastic Standards Committee—The interpretation and enforcement of the faculty regulations and academic standards are lodged in committees of the faculty designated as the Scholastic Standards Committees. Occasionally these regulations may work a hardship on a particular student. In this event he may ask for an exemption by submitting a petition to his Scholastic Standards Committee. The committee is empowered to make exceptions to a requirement provided the exemptions work to the educational advantage of the student. Regular petition blanks are available in the various college offices listed in the section on Registration. When the petition form has been completed, it should be left in the college office for the appropriate action. When the committee has taken action, the reply will be mailed to the student's city address.

Unit of Credit and Allowable Credit Load—The standard unit of credit in the University is the quarter credit or simply, the credit. It corresponds to 1 class period per week for 1 quarter. This class period may be a 1-hour lecture or recitation, or a 2- or 3-hour class in laboratory, drawing, surveying, or computations. In any case, 1 credit is supposed to require 3 actual hours of the average student's time per week for 1 quarter. One hour of recitation is assumed to require 2 hours of preparation or study. A 2-hour laboratory period may require 1 hour of home work to complete the credit. A 3-hour period usually carries 1 credit and requires no outside work.

The normal work load of a student is 17 credits per quarter after the first year. The maximum load that a student may carry without special approval is 19 credits. To carry a larger load, the student must obtain the approval of the Scholastic Standards Committee. Usually the approval will be noted on the office copy of the registration blank.

Class Attendance—All students are expected to be punctual and regular in attendance at all class exercises and to do all the work of their courses. Irregularities in attendance or habitual tardiness will be sufficient reason for exclusion from class.

An absence does not exempt the student from completing the work missed while he was absent.

Examinations—No student may be excused from taking the examinations in a course except under circumstances which make it impossible for the student to be present.

A student who has been absent from an examination and who does not present an acceptable excuse to the instructor for the absence before the grades are reported will be given a mark of "0" in the examination in computing his final grade for the course.

The instructor may give the student an examination at a later date upon presentation of acceptable evidence of extenuating circumstances such as illness or family emergency.

Graduating seniors are excused from final examinations in Institute of Technology courses in which they have a grade of C or above, with the following exceptions:

(a) This rule does not apply to graduate classes or classes which contain a substantial percentage of graduate students.

(b) This rule does not apply to graduates of the 4-year bachelor of science program.

(c) The School of Chemistry and the School of Physics do not excuse students.

Grading System—Four passing grades, A (highest), B, C, and D (lowest), are given. They are all acceptable for the completion of a single course. Work completed with the grade D is counted toward graduation when combined with work of A or B grade in other courses. The grade C indicates work of the quality required for graduation; the grades B and A are given for work of higher excellence.

The temporary designation I may not be given except in emergency and unless the student has completed with a passing grade all but a small part of the terminal work of the quarter. A student who receives an I is required to complete the work of the course by the end of the sixth week of his next quarter in residence, except the Summer Session, or the I will change to an F. For absence from an examination see section on Examinations.

The grade of F (failure) is given for work which is of such poor quality as to make it necessary, in the opinion of the instructor, for the student to repeat the course if credit is desired, or (a) if a student cancels after the sixth week of classes with a failing grade, or (b) if a student officially registers and then does not attend at all or disappears at any time during the course.

The grade W is used to record the fact that the course was canceled without grade in the first 6 weeks of the quarter or was canceled after the 6 weeks and the student was passing.

Grade Point Average—The quality of work is indicated by the number of grade points. Each credit with the grade of A carries 4 grade points; each credit with the grade of B, 3 grade points; each credit with the grade of C, 2 grade points; each credit with the grade D, 1 grade point; and the grade of F carries no grade points.

The grade point average for determining probationary status is defined as the total number of earned grade points divided by the total number of credits earned and failed. Only credits and grade points earned while registered at the University of Minnesota and which are accepted for graduation from the Institute of Technology are used in calculating the grade point average. For example, assume that the following grades were received 1 quarter:

5 credits of A—$5 \times 4 =$	20 grade points
3 credits of B—$3 \times 3 =$	9 grade points
3 credits of C—$3 \times 2 =$	6 grade points
2 credits of D—$2 \times 1 =$	2 grade points
3 credits of F—$3 \times 0 =$	0 grade points
16 credits	37 grade points

The grade point average would be: $\frac{37}{16} = 2.31$

When a course which has been failed is repeated, the credits for the failed course and for the repetition will both count in the grade point average.

A student may not repeat a course for credit in which a passing grade has been received. With permission a student may audit a course in which a passing grade has been obtained.

Requirements for Graduation—The Bachelor's degree with departmental designation will be recommended for those students with grade point averages of 2.00 or better who have completed all of the required work and have the total number of credits specified in their curriculums.

The student who has completed the requirements for his degree except that his grade point average is below the specified 2.00 may attain needed grade points by taking additional courses. Approval must be given by the Scholastic Standards Committee. If the deficiency in grade points is no greater than 6, additional grade points may be earned in the Extension Division or Correspondence Study Department.

Students having a grade point average of 3.50 or better for their undergraduate work (excepting their last quarter's work) will be granted their degree "with high distinction."

Students having a grade point average between 3.00 and 3.49 for their undergraduate work (excepting their last quarter's work) will be granted their degree "with distinction."

Students who enter with advanced standing from other colleges or universities must spend at least a year in regular daily work at the University, of which 2 quarters must be in their senior year (if they have only 1 year of residence, it must be their senior year).

Combined Program with the Graduate School—In all 5-year curriculums the bachelor of science degree will be awarded at the end of the fourth year to those students who show genuine aptitude and desire to continue with graduate work. The requirements are:

(a) Grade point average of 2.80 or better.
(b) Completion of the first 4 years of the curriculum including the proportional part of the nontechnical electives (37 credits, including English).
(c) Approval of petition made to the Scholastic Standards Committee in the third quarter of the fourth year.
(d) Recommendation of the departmental faculty.
(e) Certificate of acceptance by any recognized graduate school.

Certificate in Science—If students so desire, they may apply for a certificate in science upon completion of most of the course work in the Lower Division. However, a student does not need a certificate in science in order to be admitted to the Upper Division. The certificate in science is available to any regularly admitted student of the Lower Division who applies for it and who meets the following requirements:

1. He must have a minimum of 96 quarter credits.
2. He must have a grade point average of not less than 1.80.
3. He must have satisfactorily completed the following:
   a. The first year of the stated curriculum to which he has been admitted.
   b. Math 24A, 25A.
   c. InCh 14-15 (or its equivalent) or OrCh 61-62.
   d. Phys 14 or Phys 7-8-9.

Students must complete the work of the Lower Division within 8 quarters. If a student transfers to the Institute of Technology with advanced standing, he must take a minimum of 45 quarter credits in residence at the University of Minnesota in order to qualify for the certificate.

Probation and Exclusion—*Lower Division*—A grade point average of 2.00 is required for admission to the Upper Division. Students whose cumulative G.P.A. is less than 2.00 are placed on probation. A student who is on probation will be excluded from college when his G.P.A. falls below a specified exclusion level. He may appeal the exclusion action by appearing before the Scholastic Standards Committee of his department. Failure to appeal will mean automatic exclusion.

The exclusion level for the College of Engineering and for most units in the Institute of Technology follows the schedule indicated below. However, the exclusion level may be specified separately by each unit. For example, the School of Chemistry requires a minimum G.P.A. of 2.00 at all times.

Year	Completed Credits (earned and failed)	Tolerated Grade Point Deficiency	Corresponding Accumulative Grade Point Average
1	16	10	1.38
1	33	16	1.51
1	49	20	1.59
2	66	20	1.70
2	83	20	1.76
2	100	20	1.80

Upper Division—A grade point average of 2.00 is required for graduation. Students whose cumulative grade point average is less than 2.00 are placed on probation. For most units in the Institute of Technology the minimum level for the Upper Division is the cumulative grade point average of 2.00 including the Lower Division work. The School of Physics specifies for students in its Upper Division that the minimum grade point average is 2.00, based on the cumulative work in the Upper Division only.

Procedures for Exclusion and Appeal—A list of the students who are due to be excluded is posted in the hall of Main Engineering as soon as the grades are available following the fall and winter quarters. Students who are on probation should check this list very carefully. Notification by letter will be given following the spring quarter.

If a student's name appears on the above-mentioned list and he desires to appeal the exclusion action, he should make an appointment to see his departmental Scholastic Committee and complete the "Exclusion Action Appeal" form. The fact that he may be registered and attending classes does not relieve him of the necessity of making the appeal if he desires to remain in college.

A student who is handicapped by conditions with which he is, at the time, unable to cope may be discontinued until the committee is satisfied that the conditions have changed or that the student can face them successfully. When discontinuation takes place during a quarter, the committee may direct that the grade record show "canceled without grade" if conditions seem to justify this action.

A student may be discontinued even though he is not on probation.

A student who is doing unsatisfactory work but who seems capable of succeeding in another program, on the basis of counseling interviews, test scores, and other information, may wish to consider transfer to another college.

Readmission of Excluded Students—An excluded student may be readmitted when the Scholastic Standards Committee is convinced that he has a reasonable chance of removing his deficiency and continuing successfully. A student shall have the right to have his application for readmission considered at least yearly. Usually, however, a student is excluded for a period of 3 quarters. At the end of that period, he is eligible to re-enter the college. He re-enters *on probation* and may be excluded a second time if the quality of his work has not improved sufficiently.

A student who has been excluded for low scholarship the second time shall not be readmitted except with the approval of the Scholastic Standards Committee.

A student may be discontinued for cause at any time. A discontinued student may be readmitted if and when the Scholastic Standards Committee is satisfied that the conditions which limited achievement have been changed sufficiently to permit success. Students who return to college under this provision shall be admitted on probation.

If, while excluded or discontinued, a student earns credits in another college or by evening or correspondence study, the credits need not be accepted toward a degree by his college unless the arrangement was agreed to in advance.

Quality Credits in the School of Chemistry—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.

Graduate Programs

Programs of Graduate Study—Graduate study in engineering and science, leading to the master of science and the doctor of philosophy degrees, may be pursued in the Graduate School. The major fields of study include aeronautics and

engineering mechanics, agricultural engineering, architecture, chemical engineering, chemistry, civil engineering, electrical engineering, fluid mechanics, industrial engineering, mathematics, mechanical engineering, mechanics and materials, metallurgy, mineral engineering, and physics. For a complete description of graduate work in the Institute and a statement of regulations, consult the *Bulletin of the Graduate School.*

Graduate Credit for Undergraduates—If at the beginning of a quarter not more than 9 undergraduate credits are lacking for graduation (taking into account required and sequence courses), an undergraduate may carry a limited amount of graduate work (approved courses numbered 100 and above) for graduate credit. Such credit is not applicable toward an undergraduate degree. Transfer of credit must be arranged by petition to the Graduate School.

With permission of the Scholastic Standards Committee and the Graduate School, an undergraduate lacking not more than 6 credits toward graduation may register in the Graduate School while completing his requirements for the Bachelor's degree.

Graduate Fellowships and Assistantships—Numerous fellowships and assistantships in the Institute of Technology are open to graduates pursuing advanced degrees in aeronautics and engineering mechanics, agricultural engineering, chemical engineering, chemistry, civil engineering, electrical engineering, industrial engineering, mathematics, mechanics and materials, mechanical engineering, mines and metallurgy, and physics. Fellowships carry stipends from $1,400 to $2,700 and assistantships have stipends of $2,115 for one-half positions.

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.

Professional Degree—A professional degree in engineering may be conferred upon a candidate who has obtained a Bachelor's or an advanced degree from the Institute of Technology provided he has practiced his profession for at least 8 years with at least 4 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.

Student Personnel Services

Faculty Adviser—Every new student is assigned a faculty adviser from the department in which he seeks his degree at the time of registration in the Institute of Technology. If he has not chosen this department, he is assigned an adviser from the Institute of Technology mathematics staff. If a student has been overlooked and has not been assigned an adviser, he should make that fact known at his college office, and he will be given an assignment.

At the beginning of his second year the student makes out his program of studies for the year in consultation with his adviser. Any changes in the program must also be made in consultation with the adviser and will be accepted for registration only when they have been signed by the adviser.

If there is any question, the case may be brought to the attention of the Scholastic Standards Committee and final agreement reached by consultation.

Students are urged to consult their adviser on any aspect of their college work or on any other problem upon which they would like advice.

All-University Personnel Services—In addition to the counseling within the college, the University provides several specialized personnel services for the student.

He may consult any of them either with or without referral from his adviser. These services are described more fully in the *Bulletin of General Information.*

Institute of Technology Placement Service—The Institute placement service, 133 Main Engineering, is available to assist the graduating senior or alumnus in securing employment. Assistance is also offered the undergraduate looking for summer employment. Without assuming the responsibility of getting a job for the graduate, every effort is made to help him find the opening best suited to his aptitudes, training, and interests.

Student Activities

Professional 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 Mining and Metallurgical Engineers, American Institute of Physics, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Agricultural Engineers, and the Institute of the Aerospace Sciences. In addition there are the Architectural Society, the School of Mines and Metallurgy Society, and the University of Minnesota Flying Club.

Honorary Scholastic Fraternities—The honorary scholastic fraternities in the Institute of Technology promote the high standards of the engineering profession by conferring memberships, awards, and other honors on undergraduates distinguished for scholastic achievement and for character. Of these honorary fraternities, only Tau Beta Pi selects its members from students in all undergraduate departments of the Institute of Technology. The others confine their membership to students from one department: Chi Epsilon (Civil Engineering); Eta Kappa Nu (Electrical Engineering); Phi Lambda Upsilon (Chemistry); Pi Tau Sigma (Mechanical Engineering); and Sigma Gamma Tau (Aeronautics and Engineering Mechanics). These fraternities normally elect their undergraduate members from the fourth- and fifth-year class on the basis of scholarship as measured by class rank and of character as judged by fellow students and faculty.

Plumb Bob—Plumb Bob is a senior honorary leadership and service fraternity. Its 14 members serve during their senior year, but their names are not announced until Engineers Day. Plumb Bob works to create and maintain a spirit of fellowship and co-operation among the students of the Institute of Technology and to further the interests of the Institute and the University. Its members are chosen for their character, leadership, and service by a committee of students and faculty.

Technical Commission—The Technical Commission is the executive body of the Technical Association to which all students in the Institute of Technology belong. The association enables the students to act as a unit in matters affecting the general interests of the Institute and the University. The Technical Commission, composed of the presidents of the recognized departmental societies and three members at large, has general supervision and responsibility for Engineers Day and other student activities in the Institute of Technology.

Minnesota Technolog and Technolog Board—The *Minnesota Technolog* is the undergraduate technical magazine of the Institute of Technology. It is a monthly publication produced by the students under the direction of an editorial and business staff selected from the student body. The policies of the magazine are determined by the Technolog Board of 14 members, 11 students and 3 faculty members. The Technolog Board selects the manager-editor, editor in chief, and business manager and assists them in their work. The *Minnesota Technolog* is a member of the En-

gineering Colleges Magazine Association, a national organization which is constantly working toward high quality in the technical magazines of our leading engineering colleges.

All-University Student Activities—For information on cultural and recreational opportunities, individual and intramural sports, and intercollegiate athletics, refer to the *Bulletin of General Information.*

Employment Services and Financial Assistance for Students

University Undergraduate Placement Service and Student Loans—Information on University undergraduate services and student loans may be obtained from the *Bulletin of General Information.*

Job Opportunities in Institute of Technology Research Facilities—Opportunities for both graduate and undergraduate research are available in several Institute research laboratories, and part-time employment is in many cases available to qualified and interested students. Since complete listing of these facilities and opportunities is not possible, students should inquire at the individual departments for further information.

Undergraduate Scholarships and Awards—The following scholarships and awards are available to students in the Institute of Technology. Information regarding these and other scholarships available in competition with students of other colleges in the University may be obtained from the Bureau of Student Loans and Scholarships, 201 Eddy Hall, after 2 quarters of attendance.

For description of scholarships herewith, see those under individual departments and schools as well as those under "All Divisions." Unless otherwise noted, one award is made each year.

ALL DIVISIONS

Alcoa Foundation Scholarships: For undergraduates who have completed at least 1 year in college and are working toward a degree in agricultural, chemical, civil, mechanical engineering; or metallurgy; or equally qualified candidate in other engineering majors. Amount is $625. One award in each field annually.

Associated General Contractors of Minnesota Scholarships: For undergraduate students who have bona fide interests in construction and contracting work. Candidates must have been residents of Minnesota prior to attending the University of Minnesota. Amount varies from $150-$300. Entering freshmen given special consideration.

Babcock and Wilcox Company Scholarships: For undergraduate students in the Institute of Technology. Amount is $100-$200. Two awards annually.

Boeing Airplane Company Scholarship: For aeronautical, electrical, mechanical, and civil engineering students for use in the second, third, and fourth years. Amount is $250. Four awards annually.

Collins Radio Company Scholarship: For graduates or undergraduates in the Institute of Technology—preference to majors in electrical or mechanical engineering. Amount is up to $500.

Ellerbe and Company Engineering Scholarships: For undergraduates with majors in civil, electrical, and mechanical engineering. Preference given to entering freshmen or students with advanced standing who are in the upper 10 per cent of their classes. Amount is $300. Three awards annually.

Hamilton Watch Award: For a graduating senior in the division of engineering who most successfully combined proficiency in his major field of study with achievements—either academic, extracurricular or combination of both—in the social sciences or humanities.

IT Alumni Association Scholarship: For undergraduates in any department of the Institute of Technology. Amount is $200-$400.

Minneapolis Gas Company Engineering Scholarship: To aid and encourage students in engineering, especially chemical, mechanical, and civil engineering. Entering freshmen, qualified transfer students, and students with advanced standing are eligible. Usually covers tuition for at least 1 quarter.

Minneapolis-Honeywell Award in Engineering and Science: For distinguished performance of third-, fourth-, and fifth-year student in engineering and science. Amount is $250-$300.

Harlow C. Richardson Scholarship: For undergraduates in the Institute of Technology with demonstrated interest in the humanities. Amount is minimum of tuition and incidental fees. Ten or more awards annually.

Sigma Xi Scholarship (Minnesota Chapter, University of Minnesota): For undergraduate with aptitude and proficiency in some field of scientific endeavor. Amount is $300.

Alfred P. Sloan Foundation Scholarships: For male sophomore in physical science, mathematics, physics, engineering and business administration, to use in third and fourth years. Demonstrable leadership, community mindedness, or administrative capacity required, along with superior scholarship. Amount is $200-$700. Five awards annually.

John Torrence Tate Memorial Scholarship (memorial gifts from friends of the late Professor John T. Tate): For students with advanced standing in astronomy, chemistry, engineering, mathematics, or physics. Amount is $200-$250. Two awards annually.

Texaco Company Scholarship: For any science student whose training will qualify him for work in the petroleum industry. At least 1 recipient must use the award in his senior year; other recipients must have completed 2 years of college. Amount varies.

Nellie S. Trufant Memorial Scholarship in Engineering: For the use of any qualified student in the Institute of Technology in his third or fourth year. Amount is $150-$200 annually.

Twin Cities Chapter of the American Society of Tool Engineers (Louis Walton Memorial) Scholarship: For fifth-year Institute of Technology students majoring in a phase of engineering leading to a career in tool engineering. Amount is $100.

Western Electric Scholarship: For undergraduates in engineering. Award is $800 to be used for tuition, fees, and books. Two awards annually.

William H. Ziegler and Zeco Company Scholarships: For advanced students in civil, mechanical, and mining engineering. Amount is $500.

AERONAUTICS AND ENGINEERING MECHANICS

Aero-Alumni Scholarship: For students majoring in aeronautics and engineering mechanics. Amount is tuition and fees.

James B. Burroughs Memorial Scholarship in Aeronautics and Engineering Mechanics: For aeronautics and engineering mechanics student with advanced standing. Amount varies.

Douglas Aircraft Scholarship: For senior or fifth-year student in aeronautical, electrical, or mechanical engineering (in this order of preference) and who is a citizen of the United States. Amount is $750.

AGRICULTURAL ENGINEERING

William Boss Agricultural Engineering Scholarship (Specialty Manufacturing Company, St. Paul): For entering freshman in agricultural engineering. Amount is $400.

Green Giant Agricultural Engineering Scholarship: For entering freshman in agricultural engineering. Amount is $400.

Northern States Power Company Agricultural Engineering Scholarship: For entering freshman or undergraduate in agricultural engineering. Amount is $300.

Rilco Laminated Products Agricultural Engineering Scholarship: For entering freshman in agricultural engineering. Amount is $300.

ARCHITECTURE

Ellerbe and Company Architecture Scholarship: For students entering or already in architecture. Amount is $150-$200. Three awards annually.

Flour City Architectural Education Scholarships (Flour City Architectural Metals Division, Hupp Corporation, Minneapolis): For undergraduates with advanced standing in architecture. Amount varies.

Mankato Stone Company Education Scholarships (administered by the School of Architecture): For undergraduates with advanced standing in architecture. Amount varies.

Minnesota Lathing and Plastering Bureau Scholarship Fund: For students in the School of Architecture. Amount is $200.

A. C. Ochs Brick and Tile Company Scholarship (Springfield, Minnesota): For advanced students in architecture. Amount is $250.

Setter, Leach & Lindstrom, Incorporated, Scholarship: For advanced students in architecture. Amount is $200.

Tile Council of America, Inc., Scholarship: For third-, fourth-, or fifth-year students in the School of Architecture who are citizens of the United States. Amount is $100-$200.

Albinson, Inc., Prize: Bruning drafting machine or equivalent supplies for a junior student in the School of Architecture. One award each quarter.

Cherne Design Award in Architecture Fund: Administered by the faculty. Amount varies.

Rollin B. Child, Inc., Education Fund: For students in the School of Architecture. Amount is $250.

Thomas F. Ellerbe Prize or Scholarship (sponsored by the Co-operative Foundation): For excellence in study of buildings for co-operatives. Amount is $200. Three awards annually.

Gargoyle Club Prize (Gargoyle Club, St. Paul): For best theses submitted during academic year. Amount is $200 (in books).

Illuminating Engineering Society Prizes (Twin City Section): For best work in design problem involving study of lighting. One award of $85 and five awards of society membership annually.

George B. Melcher Prize (Flour City Architectural Metals Division, Hupp Corporation, Minneapolis): For best work in design problem involving use of metal. Amount is $100.

Minneapolis Gas Company Prize Award: For undergraduates in the School of Architecture. Amount is $150-$175. Two to three awards annually.

Alpha Rho Chi Medal: For architectural ability and student leadership.

American Institute of Architects Medal: For highest scholastic standing in graduating class during academic year.

CHEMICAL ENGINEERING and CHEMISTRY

Archer-Daniels-Midland Company Scholarship: For use of senior students in organic chemistry. Amount is $250. Two awards annually.

John P. Fridley Foundation Scholarship: For undergraduate students in engineering with preference to those in chemical engineering. Amount is $100-$300. One or more awards annually.

Twin Cities Chemical and Allied Trades Association, Inc., Scholarship Fund: For chemistry or chemical engineering student who has completed at least 1 quarter at the University. Amount is $200.

Twin City Testing and Engineering Laboratory, Inc., Scholarship: For chemistry major who works and has financial need. Amount is $250. Two awards annually.

Universal Oil Products Company Scholarships: For fourth- or fifth-year students in chemical or petroleum engineering. Amount is $300-$500. Two or three awards annually.

George T. Walker Fund: To aid deserving students in the Department of Chemistry. Amount varies.

CIVIL ENGINEERING

Associated General Contractors Scholarship: See description under All Divisions.

Borchert-Ingersoll, Incorporated, Scholarship: For students in civil engineering with emphasis on highway engineering. Amount is $400.

Minnesota Surveyors and Engineers Society Highway Engineering Scholarships: For undergraduates in civil engineering with emphasis on highway engineering. Students must have completed 2 years in the Institute of Technology. Students may apply to Personnel Office, State Highway Department, for summer employment. Amount is $250, $300, $350, respectively, for third-, fourth-, and fifth-year students.

ELECTRICAL ENGINEERING

Collins Radio Company Scholarships: See description under All Divisions.

Crossley Associates, Incorporated Scholarship: For junior students studying electronics or physics. Amount is $250 offered fall of 1961-62 and alternate years.

Douglas Aircraft Scholarship: See description under Aeronautics and Engineering Mechanics scholarships.

Perry Peterson Memorial Scholarships (Control Corporation, Minneapolis): For undergraduates in electrical engineering. Amount is $500. One award annually.

Radio Corporation of America Scholarships: For undergraduates, with advanced standing, in any field of engineering, mathematics, or physics. Preference to those in electrical engineering specializing in radio or electronics. Amount is $400. Two awards annually.

MECHANICAL ENGINEERING

American Institute of Industrial Engineers—Twin City Chapter: For qualified undergraduate in industrial engineering who is a member of A.I.I.E. Amount is $100.

American Society for Quality Control—Minnesota Section Scholarship: For undergraduate in industrial engineering. Amount is $200.

Collins Radio Company Scholarships: See description under All Divisions.

Continental Oil Company Scholarship in Mechanical Engineering: Amount is $500.

Douglas Aircraft Scholarship: See description under Aeronautics and Engineering Mechanics scholarships.

Ladish Company Scholarships in Metallurgy and Mechanical Engineering: See description under Mining, Metallurgical Engineering; Metallurgy (School of Chemistry) scholarships.

Maytag Scholarship in Engineering: For a male undergraduate in mechanical or industrial engineering, the scholarship to be used during senior year. Amount is $300.

Pfeifer and Schultz Scholarship in Mechanical Engineering: For resident high school graduates and junior college graduates wanting to major in mechanical engineering who are in the upper 10 per cent of their class and who without financial assistance will not be able to further their education. Amount is $400.

Pioneer Engineering Division of Poor and Company, Incorporated, Scholarship: For resident high school graduates and junior college graduates wanting to major in mechanical engineering who are in the upper 10 per cent of their class and who without financial assistance will not be able to further their education. Amount is $500.

Standard Oil Company of California Scholarship: For undergraduate in mechanical engineering. Amount is $750.

Wickes Boiler Division of the Wickes Corporation Scholarship: For resident high school graduates and junior college graduates wanting to major in mechanical engineering who are in the upper 10 per cent of their class and who without financial assistance will not be able to further their education. Amount is $300.

MINING, METALLURGICAL ENGINEERING; METALLURGY (School of Chemistry)

American Institute of Mining, Metallurgical, and Petroleum Engineers, Minnesota Section, Scholarship: For undergraduates in the School of Mines and Metallurgy. Amount is $500.

American Society for Metals, Minnesota Chapter, Scholarship: For a sophomore interested in metallurgy. Amount is $350.

American Society for Metals Foundation for Education and Research Scholarship (Cambridge, Massachusetts): For students having 2 years of engineering and acceptance for advanced work in metallurgy. Amount is $500.

California Exploration Company Scholarship: For fourth- and fifth-year students interested in careers in petroleum and mining industry. Amount is $750.

Cleveland-Cliffs Iron Company Scholarships: For entering freshmen in mining engineering, metal engineering, geological engineering, and geophysics; renewable for second year. Amount is $500. Two freshman awards annually; 2 sophomore awards annually.

Dow Chemical Company—Department of Metallurgy Scholarship: For Upper Division students in the Department of Metallurgy. Amount is $500.

M. A. Hanna Company Scholarships: For Hanna Company employees, their sons, or relatives who wish to attend the University on the Minneapolis Campus, or Michigan College of Technology, Houghton, Michigan. Preference given to those enrolled in mineral technology (School of Mines), but students in mechanical, electrical, chemical, or civil engineering are also eligible. Amount is $500. Entering students apply through their high school by February 1 each year. Two awards each year, renewable if student maintains at least a 2.8 grade point average.

Independent Iron Ore Producers Association Scholarships (Independent Iron Ore Producers Association of Minnesota): For undergraduates in the School of Mines and Metallurgy. Amount is $200-$300.

International Nickel Company Scholarship: For entering freshmen in engineering, with preference to mining and geological engineering and metallurgy. Renewable annually. Amount is $300 plus tuition and fees.

Iron Mining Industry Scholarships (various mining companies of Minnesota): For undergraduates in the School of Mines and Metallurgy. Amount is $100-$300.

Ladish Co. Scholarships in Metallurgy and Mechanical Engineering (Ladish Co., Cudahy, Wisconsin): For entering freshmen in metallurgy or mechanical engineering, with preference to metallurgists, who are willing to accept summer employment in Milwaukee; renewable annually. Amount is $300 for first 3 years, $350 for senior year. Two new awards annually.

E. J. Longyear Memorial Scholarships (E. J. Longyear Company, Longyear Holding Company, Sargent Land Company, Percy W. Donovan, Mrs. R. D. Longyear; Minneapolis): For undergraduates in the fields of metallurgical engineering, mineral engineering, geology, and other earth sciences. Amount is $300-$400. Three awards annually.

Mesabi Tire Scholarships: For students in the School of Mines and Metallurgy or geological engineering who are from the Minnesota Iron Range, including Duluth. Amount is $250. Two or more awards annually.

Pickands Mather Scholarships in Mineral or Metallurgical Engineering: For freshmen or entering transfer students in mining and metallurgical engineering. Amount is $350. Three awards annually.

School of Mines and Metallurgy General Scholarship Fund: For students in the School of Mines and Metallurgy.

Sigma Rho Alumni Association, Beta Chapter, Scholarship: For undergraduates in the School of Mines and Metallurgy, or high school graduates who wish to enroll in the School of Mines and Metallurgy. Amount is up to $300.

Louis Ware Scholarship Fund (International Minerals and Chemical Corporation): For an outstanding student who is completing his third year and will take his B.S. degree at the end of the fourth year, or for a fourth-year student who will receive a degree in the School of Mines and Metallurgy at the end of the fifth year. A student admitted to the Graduate School to work for a doctoral degree will be eligible to compete for a $300 per year fellowship which may be renewed for up to 3 years. Amount is $1,000.

PHYSICS

Crossley Associates, Incorporated, Scholarship: See description under Electrical Engineering scholarships.

John Torrence Tate Memorial Scholarship: See description under All Divisions.

General Notes

Changes in Bulletin—The faculties of the Institute of Technology reserve the right to change their curriculums 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.

II. GENERAL CURRICULAR REQUIREMENTS

In all units of the Institute of Technology, except the School of Architecture, the undergraduate curriculums are separated into a Lower Division and an Upper Division. The Lower Division consists of the first 2 years of work and the Upper Division consists of the remaining years of work required. In the School of Architecture the 5-year curriculum in the Institute of Technology consists of 1 year of prearchitecture followed by 4 years in the School of Architecture.

The basic curriculum of the first year in the Institute of Technology is the same for all divisions except that in the Departments of Chemistry and Chemical Engineering the student enrolls in a year course in chemistry rather than a year course in physics. Also, the requirements in EG 14, 15, 16 differ in the separate divisions. The students should check the curriculum of the department in which they wish to major for the specific requirements in that department.

The second year of the curriculum, with minor exceptions, is the same for the College of Engineering, School of Mines and Metallurgy, School of Physics, and the Department of Metallurgy. Some departments specify a particular course or laboratory sequence. If, however, the student changes his declared major at any time during the first 2 years, any set of laboratory requirements which are approved in the Lower Division will be accepted by all departments; transfer students may use any physical science laboratory credits or may petition to substitute other credits.

This flexibility is introduced in the program of the Lower Division in order to allow students to build a solid foundation in science and mathematics and to enable them to readily transfer from one department to another within the Institute of Technology without loss of credit. Furthermore, the emphasis on the basic sciences and mathematics together with the course work in humanities and the social sciences makes it possible for students to transfer to another college with minimum loss of credit and time, if they develop an interest in academic or professional programs other than those available in the Institute of Technology.

In the Upper Division, the student begins a more specific course of study. He should at this time have more clearly defined professional aims, because transfer of course credit from one department to another becomes progressively more difficult as the program becomes more specialized. Work in the social-humanistic area (nontechnical electives) is required throughout his program. This is intended to broaden viewpoints and to add perspective. It is important that the student be aware of the whole educational pattern of the Institute of Technology, so that he may plan an over-all program of required and elective courses which are consistent with his professional interests. The specific requirements for each degree are described in the curriculums of the department or other unit offering that degree. Before these are presented in detail, there appears below a general description of the role of elective courses in the programs of the Institute of Technology.

Electives

Students in the Institute of Technology are offered a wide selection of elective courses. These are of three general types: (a) nontechnical electives, (b) biological science electives, and (c) technical electives.

Nontechnical electives include courses in the social sciences and the humanities. A minimum of 6 credits must be selected from a recommended group of courses (Group II) in the social sciences, plus a minimum of 6 credits from a recommended group of courses (Group III) in the humanities. In each case, the 6 credits must be taken in a single course sequence.

Students *may* use selected courses (Group I) in the biological sciences as a general graduation requirement. To satisfy the group requirement, a minimum of 6

credits must be taken in a single course sequence. Some departments require a Group I sequence; in others the 6 credits may be satisfied by taking additional courses in Groups II and III. Students should refer to the curriculums of the individual departments for details.

Technical electives include courses in mathematics, in the physical sciences, and in engineering. In individual departments, they may also include biological sciences, other than those listed in Group I. For further information regarding the choice of technical electives, students should refer to the curriculum of their major department.

Elective Groups

Group I—Biological Sciences

1. Phsl 52-53
2. Biol 1A-2A

Group II—Social Sciences

1. Econ 1T-2T, may be followed by BA 52, Econ 172
2. Pol 1-2, or 5 or A-B which may be followed by 25
3. Psy 1-2, 155
4. Soc 1-2, 14 or 1-2, 104
5. SSci 1-2-3

Group III—Humanities

1. Hum 21, 22, 23, or 51, 52, 53, or 71, 72, 73
2. Hist 20, 21, 22 or 53, 54, 55 or 79, 81
3. Philosophy
4. Engl 37, 38, 39
5. Foreign language

Students who complete the program in NROTC may substitute 24 credits in naval science for an equivalent number of credits in the required nontechnical area. At least 6 credits must be taken within a sequence in 1 of the above 3 groups. The remainder of NROTC credits may be used as electives *only* by petition and if approved by the student's adviser and department head. Students who complete the program in AFROTC or ROTC may substitute 15 credits in air or military science for an equivalent number of credits in the required nontechnical area. At least 15 credits in the required nontechnical area must be completed, including 6 credits or more within a sequence in 2 of the above 3 groups. The remainder of the ROTC credits may be used as electives only if approved by the student's adviser and department head. The ROTC program applies to all divisions of the Institute of Technology. No proportional credits will be allowed for partial completion of any ROTC program.

Courses Required of All Students in I.T.

1. *Freshman English.* Students must complete a minimum of 12 credits in English. They will be advised by the Department of English with respect to the choice between Engl A-B-C, 1A-2A-3A, and 1B-2B-3B on the basis of their performance on the Freshman English examination. Students who at any time are classified exempt from Freshman English by action of the Department of English will be required to complete a total of 12 credits in the field of language or literature. They may do so by electing a year course in a foreign language, a course in literature at the sophomore level, or by taking Engl A-B-C or Engl 1A-2A-3A. Entering freshmen who are approved for advanced standing by the Department of English will receive 6 credits toward the language-literature requirement. A student who elects more than 12 credits of English may use the additional credits toward the total nontechnical requirements specified for his degree program.

A student who makes a grade of D in either 1A or 2A must register for the succeeding quarters of the 1B-2B-3B sequence unless his instructor recommends otherwise.

2. *Social Sciences and Humanities.* Students must complete a minimum of 6 credits in any 1 sequence in each of Groups II and III. (In the School of Architecture, the 6 credits must be from the departments listed but may include, with the adviser's approval, courses other than those listed.)

   The foreign language courses may not include those designed to meet technical needs of a particular scientific area; specifiically, Ger 24-25-26 will not be accepted. A year course in a foreign language is recommended as a minimum. Credits beyond the 6 credits required in Group III may be used as additional electives. In the School of Physics, a year course in German or Russian is required *in addition to* the elective requirement in Group III.

3. In addition to 6 credits each in Group II and Group III, a minimum of 6 credits must be completed in a sequence of Group I (biological science) *or* in courses listed in Groups II and III. Individual departments may specify that this requirement be met in Group I; the student should consult his department for information. In the School of Architecture this requirement is satisfied by 6 credits in art.

A general summary of the requirements in elective courses for the several curriculums is provided below.

SUMMARY (by credits)

Unit in the Institute of Technology	English[1]	Groups I, II, III	Additional required electives[2]	Other electives[3] in the Upper Division
College of Engineering (4 yr)	12	18	7	
(5 yr)	12	18	16*	↑
School of Mines and Metallurgy (4 yr)	12	18	7	
(5 yr)	12	18	16*	
Department of Chemical Engineering (4 yr)	12	18	7	See the curriculum of each individual department
(5 yr)	12	18	16*	
Department of Metallurgy (4 yr)	12	18	7	
(5 yr)	12	18	16*	
School of Architecture	12	18	See departmental curriculum	↓
Department of Chemistry	12	18	23**	
School of Physics	12	18	15-33***	

[1] If a 15-credit course in English is completed, the additional 3 credits may be computed with the additional electives.

[2] Electives from Groups I, II, III or from the Additional Electives list on next page.

[3] These electives in some departments may include both technical and nontechnical courses. These nontechnical courses need not be limited to those in Groups I, II, and III, or those in the Additional Electives list.

* Includes Engl 85-86.

** Does not include the 16 credits of required scientific electives.

*** Plus a year course in German or Russian.

In the Upper Division, the requirements in elective courses, both technical and nontechnical, will vary for the individual degree programs. The student should therefore refer to the individual curriculums for specific details. A considerable degree of freedom is available to the student in meeting some of these requirements. Individual courses may be selected from the areas or departments from the Additional Electives list given below.

Additional Electives

Anthropology	Geography	Literature	Social Science
Art	Geology	Music	Sociology
Astronomy	History	Philosophy	Speech
Botany	Humanities	Political Science	Zoology
Classics	Languages	Psychology	

For courses not described in the *Bulletin of the Institute of Technology,* see bulletin of the college concerned.

Additional Course Information

Credit for Summer Employment—Consult your department or college office regarding credit for summer employment. Approval by department must be obtained before employment.

Substitutions—Information formerly included under the topic of Substitutions has been incorporated in the course descriptions.

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

1. Evening Courses:
   InCh 4-5, 11; AnCh 100-101, 102, 102A; CE 18, 19, 20, 31, 32, 33, 130, 131, 132, 160; Hydr 103; EG 14, 15, 16; Engl 1B-2B-3B, 85-86; Geol 1-2, A-B; ITM 8, 9 (no cr for 8, 9—admission requirement), 11, 12, 13A, 24A, 25A, 26A, 90; MM 27, 28, 29, 40, 41, 127, 128; Phys 11-12-13, 14, 14A, 50, 50A; electives—Group I, II, III.
2. Correspondence Study Courses:
   CE 146; EG 14, 15, 16; Engl 1B-2B-3B; GE 70; Geol 2; ITM 8, 9 (no cr for 8, 9—admission requirement), 11, 12, 13A, 24A, 25A, 26A; MM 27, 28, 29, 40, 41, 127, 128; electives—Group I, II, III.
3. Elective courses approved by the Scholastic Standards Committee and such other courses as have been approved by the department concerned and by the dean of the Institute of Technology.

Engineering Aide—The Extension Division offers both basic and senior engineering aide certificates. For description of these programs, see the *Bulletin of Evening and Special Classes.*

III. CURRICULUMS

The objectives, program description, and detailed requirements for each of the degrees offered will now be given in the following order:

A. College of Engineering and School of Mines and Metallurgy

B. School of Architecture

C. School of Chemistry

D. School of Physics

COLLEGE OF ENGINEERING and SCHOOL OF MINES AND METALLURGY

General Description of Engineering Curriculums—It is desirable to clarify the general approach used in the various engineering curriculums before discussing specific course requirements. This approach involves the interweaving into one expanding pattern of the elements of basic science, engineering science, professional engineering work, and design.

To build the sound foundation required in all engineering work, the first 2 years of all engineering curriculums emphasize the *basic sciences* of mathematics, physics, and chemistry. Freshmen take work also in English and graphics.

A primary objective during the third year is to continue training in science, but at this level the term *engineering science* becomes more appropriate. In such courses as solid and fluid mechanics, thermodynamics, heat transfer, electrical circuits and fields, and materials, efforts are made to co-ordinate and extend the basic sciences to simplified and idealized engineering situations. In these courses the primary concern is still analysis.

Starting in the third and fourth years, the *professional engineering* viewpoints begin to appear in some of the courses. This work not only extends further the engineering science coverage, again with emphasis on analysis, but also treats the difference between the simplified-idealized conditions assumed in earlier work and the real engineering situations. Recognition of this difference and its significance is a vital part of the engineer's development.

During his fourth and fifth years, some of the courses begin to involve *design concepts*. Thus, not only is the analysis of engineering situations continued but also the idea of *synthesis*, the putting together of combinations of ideas and components, is introduced. *Creativity* in this sense is another important aspect of the engineer's development. Design work is intended also to develop *engineering maturity* through a case approach so that such important concepts as the "engineering compromise" and "increment-of-return" begin to assume meaning.

LOWER DIVISION

Basic Curriculum for First 2 Years—The curriculum for the first 2 years is, with minor exceptions, the same for all students in the College of Engineering and the School of Mines and Metallurgy. The courses included in the first 2 years are listed as follows:

First Year

	Credits—f, w, s		
EG 14, 15, 16—Engineering Graphics	3	3	3
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Phys 11-12-13—General Physics	5	5	5
Total credits	18-17	18-17	18-17

Second Year

	Credits—f, w, s		
InCh 14-15—Inorganic Chemistry	4	4	.....
OrCh 16—Carbon Compounds (or) Phys 51—Intermediate General Physics (or) InCh 11—Semimicro Qualitative Analysis	.....	.....	4
ITM 24A, 25A—Calculus II, III: Analytic Geometry and Calculus	5	5	.....
ITM 26A—Calculus IV: Differential Equations and Calculus	.....	.....	5
MM 27—Rigid-Body Mechanics I	.....	.....	3
Phys 14, 50—Intermediate General Physics	4	4	.....
Laboratory	1	1	1
Electives—Group I or II (see Index for "Elective Groups")	3-4	3-4	3-4
Total credits	17-18	17-18	16-17

General Suggestions for Selecting Electives—A review of the various third-, fourth-, and fifth-year curriculums given below shows that the student is offered a significant number of electives, both technical and nontechnical. He may thus tailor a program to suit his individual objectives. This opportunity, however, places on him increased responsibility to be well informed on the possible variations in engineering education. The student is therefore strongly urged to discuss the selection of electives with his adviser (see section on Student Personnel Services). However, to provide some preliminary background for deciding among the various electives offered, the nature of the engineer's job and its general relationship to the engineering curriculum is discussed on succeeding pages.

It is important in choosing electives to distinguish between the classification of engineering by profession fields and the classification by engineering function. Since students must select a professional field for concentration, they are familiar with such fields of engineering as aeronautical, civil, electrical, mechanical, etc. The concept of engineering function, however, although of great value in career guidance, is frequently overlooked.

From a functional point of view, engineering jobs may be classified as: research, development, design, planning, construction and production, sales, and service engineering. In recent years scientific management has also become of great interest to engineers. The order of listing is roughly from the most technical and analytical functions to those involving the greatest association with people and the business world. Jobs in all professional fields of engineering involve these and other functions. Each student should appraise his aptitudes and past performances critically in order to determine better which engineering function best matches his talents and personality. He will then be in a position to choose his electives and guide his career development more intelligently.

In general, students with excellent grades in mathematics, physics, and other analytical courses who lean toward basic scientific engineering are encouraged to direct their efforts toward the research, development, and design functions. These require a strong background in mathematics and in the basic physical sciences, and this should be reflected in the student's choice of electives. Such students should also seriously consider graduate work; in fact, work beyond the Bachelor's degree is almost essential for high-level performance in research and development. The 4-year program leading to the B.S. degree has been developed so that qualified students may start graduate work as soon as possible.

On the other hand, students with a leaning toward professional engineering practice and business will probably find that the engineering functions which interest them most are planning, construction and production, operation, sales, and service. Students interested in these functions should consider the various departmental options or one of the interdepartmental options, such as industrial engineering. Furthermore, since the functions require competence in engineering practices, business procedures, economics, and psychology, students may well take electives in these areas.

The above generalizations are oversimplified and intended as a preliminary guide only. Students are strongly urged to consult with their advisers so that the numerous individual factors of importance in deciding a program of electives may receive thorough consideration.

UPPER DIVISION

Degree Programs—Details of the Upper Division curriculums for each degree program in the College of Engineering and in the School of Mines and Metallurgy now follow alphabetically:

Aeronautics and Engineering Mechanics
Agricultural Engineering
Civil Engineering
Electrical Engineering (and Industrial Engineering Option)
Engineering and Business Administration
Geological Engineering (Mining Option and Petroleum Option)
Geophysics
Mathematics
Mechanical Engineering (and Industrial Engineering Option)
Metallurgical Engineering
Mining Engineering (Mining Option and Petroleum Option)

Aeronautics and Engineering Mechanics

The objective of the aeronautics and engineering mechanics program is to prepare students for the broad range of problems encountered in aeromechanical systems and to cope with the rapidly changing objectives which characterize an engineering field so close to the frontiers of science. The curriculum is therefore designed to emphasize a broad engineering science base rather than to develop a finished product in any specialty. Specific knowledge on specialized devices is likely to become obsolete during the student's professional life but a broad engineering science background will generally remain applicable to the solution of the ever-changing problems and new situations characteristic of modern technology. Furthermore, with a sound engineering science background students are not bound to any specialized area but have the flexibility to cross over into other fields of technology and even interdisciplinary fields.

A review of the aeronautical curriculum tabulated below indicates the following educational pattern in the required engineering courses:

First and Second Years—Emphasis on mathematics, the basic sciences of physics and chemistry, and on verbal, written, and graphic communication.

Third and Fourth Years—Emphasis on the engineering science of: (a) fluid mechanics, (b) solid mechanics, materials, and structures, (c) thermodynamics, heat transfer, power, and propulsion, (d) electrical sciences, instruments, and controls.

Fifth Year—In addition to further study in engineering sciences and analyses important in aerospace engineering, work in "design" is offered to provide training in the synthesis of various engineering sciences.

In addition to the required courses sufficient electives are offered to permit students to develop their area or functional interests as explained in the section titled Electives included after the fifth-year curriculum. Thus, students who are strongly

motivated in such engineering functions as research, development, design, production, operation, application, or management are advised to select electives to develop such individual interests.

The 5-year curriculum offered leads to the degree bachelor of aeronautical engineering, B.Aero.E. In addition to the prescribed courses sufficient approved electives must be taken to complete a minimum of 250 credits for graduation.

Special provisions are made for students with outstanding grades. A student with a grade point average of 2.80 or more may apply for the B.S. degree during his fourth year and start his graduate program in the fifth year. In addition, there are many job opportunities within the department for outstanding undergraduate and graduate students. The research program within the department is extensive and vigorous, and this not only provides good job opportunities but also excellent engineering work experience. In addition, many fourth- and fifth-year students are employed as laboratory assistants, homework correctors, and as general assistants for the professorial staff.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

The following courses are recommended for students in aeronautics and engineering mechanics:

	Credits—f, w, s		
Aero 4-5-6—Aeromechanics Survey	1	1	1
Phys 51—Intermediate General Physics (or) OrCh 16—Carbon Compounds	.....	.....	4

UPPER DIVISION

Third Year

	Credits—f, w, s		
Hydr 101—Fluid Mechanics	3	.....	.....
Aero 100A, 101A—Theoretical Aerodynamics I, II	.....	3	3
MM 28, 29—Rigid-Body Mechanics II, III	3	3	.....
MM 40, 41—Deformable-Body Mechanics I, II	3	3	.....
MM 193—Introduction to the Theory of Mechanical Vibrations	.....	.....	3
Met 56—Physical Metallurgy	.....	.....	3
ME 30-31-32—Thermodynamics	3	3	3
Electives (see statement following fifth-year curriculum)	6	6	6
Total credits	18	18	18

Fourth Year

	Credits—f, w, s		
Aero 102A—Theoretical Aerodynamics III	3	.....	.....
Aero 106A-107A—Applied Aerodynamics I, II (see statement below)	.....	3	3
MM 150—Rheology and Strength of Solids	3	.....	.....
MM 142—Experimental Mechanics	2	.....	.....
Aero 114—Analysis of Structural Components (see statement below)	.....	.....	3
ME 133—Heat Transmission	.....	3	.....
EE 36-37-38—Elements of Electrical Engineering (see statement below)	3	3	3
EE 37A-38A—Electrical Engineering Laboratory (see statement below)	.....	1	1
Electives (see statement following fifth-year curriculum)	6	6	6
Total credits	17	16	16

A qualified student who applies for the B.S. degree during his fourth year with the intention of starting graduate work in his fifth year may, with the permission of his adviser, take substitute courses in place of Aero 107A and Aero 114 (petition not required).

A student may substitute ME 199 for EE 38 and EE 38A with permission of his adviser.

Fifth Year

	Credits—f, w, s		
Aero 108—Applied Aerodynamics III	3		
Aero 110—Compressible Viscous Flow		3	
Aero 141—Experimental Aerodynamics			3
Aero 115A—Structural System Analysis I	3		
ME 146—An Introduction to Combustion	3		
ME 143—Turbomachinery (see statement below)		3	
Aero 130A-131A-132A—Aeromechanics System Design	4	4	4
Electives (see statement below)	3	3	6
Engl 85-86—Advanced Technical Communication		3	3
Total credits	16	16	16

A student may substitute ME 150 or 155 or 157 for 143 with permission of his adviser.

Electives—In the last 4 years, a total of at least 57 credits of electives are scheduled. Of these at least 28 credits must be selected in the nontechnical and biological science areas (Groups I, II, and III) and at least 24 must be technical to satisfy graduation requirements. A student should carefully consider his functional and area interests and discuss with his adviser the selection of a co-ordinated sequence of electives to develop his interests. A student should be prepared to explain to his adviser the objectives and justification for the specific courses scheduled in his technical elective program. Those who intend to take graduate work in preparation for a career in research or teaching are encouraged to consider course sequences in mathematics, physics, chemistry, mechanics, and fluid dynamics for technical electives. Students interested in business and management functions in engineering should consider course sequences in economics, industrial engineering, and business. It should be emphasized that a conglomeration of unrelated courses will generally not be acceptable in the technical elective sequence.

Agricultural Engineering

A 5-year curriculum, in co-operation 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.

The curriculum is designed to prepare the student for professional attainment in dealing with problems of agriculture. Agricultural engineering includes the design and management of machinery and equipment for efficient farm production; the design, construction, and operation of drainage, irrigation, and soil erosion control works for the development, improvement, and conservation of agricultural lands; the functional design and construction of farm buildings; and the development of procedures and design of equipment for handling and processing agricultural crops. These studies require a sound concept and knowledge of chemistry, physics, and mathematics. To become proficient in his field the agricultural engineer must also have a basic training in agriculture.

Agricultural engineering offers a variety of opportunities for work in design, development, management, research, or sales with manufacturers of machinery, equipment, building, and drainage materials; state and federal governmental agencies; educational institutions; and consulting engineers and contractors.

Students with an interest in business and management phases of engineering may petition for admission to the combined curriculum with business administration.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
AgEn 9—Laboratory		1	
AgEn 10—Laboratory			1
Phys 14A—Physics Laboratory	1		
Agro 1—Introduction to Agronomy			4
Biol 1A-2A—General Biology	3	4	

UPPER DIVISION

Third Year

	Credits—f, w, s		
AgEn 62—Farm Structures		3	
AgEn 72—Principles of Farm Machinery			3
AgEn 82—Introduction to Soil and Water Management	3		
CE 18, 20—Surveying	3		3
Econ 1T-2T—Principles of Economics		3	3
Hydr 103, 104—Fluid Mechanics		6	
ME 21—Mechanisms: Kinematic Analysis			3
ME 24—Elements of Machine Design			3
MM 28, 29—Rigid-Body Mechanics II, III	3	3	
MM 40, 41—Deformable-Body Mechanics I, II	3	3	
MM 142—Experimental Mechanics			2
Soil 19—Intermediate Soils	4		
Total credits	16	18	17

Fourth Year

	Credits—f, w, s		
AgEn 141—Agricultural Drainage	3		
AgEn 142—Erosion Control Engineering		3	
AgEn 143—Irrigation			3
AgEn 147—Design and Management of Farm Machinery		3	
AgEn 149—Radioisotope Measurements	3		
CE 37—Elementary Structural Engineering	3		
EE 36—Elements of Electrical Engineering			3
ME 30-31—Thermodynamics	3	3	
ME 121—Machine Design		3	
ME 133—Heat Transmission			3
ME 150—Internal Combustion Engines			3
Met 56—Physical Metallurgy	3		
Rhet 22—Public Speaking		3	
Technical electives (a minimum of 6 cr selected from AgEn 167, 171, 172, 176, 180, 181 required for graduation)			3
Electives—Group III (see Index for "Elective Groups")	3	3	
Total credits	18	18	15

Fifth Year

	Credits—f, w, s		
AgEn 159—Agricultural Engineering Instrumentation			3
AgEn 170—Agricultural Tractors		3	
AgEn 179—Agricultural Process Engineering		3	
EE 37—Elements of Electrical Engineering	3		
EE 37A—Electrical Engineering Laboratory	1		
Engl 85-86—Advanced Technical Communication	3	3	
GE 101—Contracts and Specifications			3
ME 160—Psychrometrics and Air Conditioning	3		
Soil 126—Soil Physics	4		
Technical electives	3	6	4
Nontechnical electives			3
Total credits	17	15	13

Civil Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of civil engineering, B.C.E. Besides the regular course a sanitary engineering option is offered.

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 Department of Civil Engineering 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.

A student may be granted a B.S. degree after 4 years and start graduate study in the fifth year if he meets the requirements outlined in the general section on Requirements for Graduation.

Students with a grade point average of 2.50 or better may petition for admission to the combined curriculum of engineering and business administration.

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
CE 1-2-3—Civil Engineering Laboratory	1	1	1
OrCh 16—Carbon Compounds	.....	.....	4

UPPER DIVISION

Third Year

	Credits—f, w, s		
CE 18, 19, 20—Surveying	3	3	3
CE 31—Elementary Structural Analysis	3	.....	.....
CE 32, 33—Elementary Structural Design	.....	3	3
CE 34—Drafting Room Practice	.....	.....	2
Geol 5-6—Geology for Engineers	3	3	.....
Hydr 103—Fluid Mechanics	.....	5	.....
Hydr 104—Fluid Mechanics Laboratory	.....	1	.....
MM 40, 41—Deformable-Body Mechanics I, II	3	3	.....
MM 28, 29—Rigid-Body Mechanics II, III	3	.....	3
MM 142—Experimental Mechanics	.....	.....	2
Electives—Group II or I (see Index for "Elective Groups")	3	.....	.....
Elective—Group I, II, or III or CE 160—Applied Hydraulics (see statement below)	.....	.....	3
Total credits	18	18	16

Students who take CE 160 should take Plan A of the 4th-year program. Those taking Group II or I should take Plan B of the 4th-year program.

Summer Camp

CE 23—Surveying Camp	9 credits

Fourth Year

	Credits—f, w, s		
CE 51-52—Highways and Pavements	3	3	.....
CE 53—Elements of Soil Mechanics	.....	.....	3
CE 130, 131, 132—Statically Indeterminate Structures; Structural Analysis; Structural Design	3	2	2
ME 30—Thermodynamics	.....	3	.....
ME 31—Thermodynamics (or) ITM 90—Elementary Engineering Statistics (or) Hydr 187—Intermediate Fluid Mechanics	.....	.....	3
Technical elective (taken in the Institute of Technology, or others by departmental approval)	.....	.....	3
Plan A:			
CE 146—Concrete and Concrete Materials	.....	.....	3
CE 161—Hydrology	3	.....	.....
CE 170, 171—Water Supply; Sewerage and Waste Water Treatment	3	3	.....
Electives—Group II or III (see Index for "Elective Groups")	3	6	3
Plan B:			
CE 146—Concrete and Concrete Materials	3	.....	.....
CE 160—Applied Hydraulics	3	.....	.....
CE 161—Hydrology	.....	3	.....
CE 170, 171—Water Supply; Sewerage and Waste Water Treatment	.....	3	3
Electives—Group III (see Index for "Elective Groups")	3	3	3
Total credits	15	17	17

Fifth Year

	Credits—f, w, s		
CE 141, 142—Reinforced Concrete; Reinforced Concrete Design	3	3	.....
CE 147—Foundations	.....	.....	3
EE 36, 40—Elements of Electrical Engineering; Electrical Engineering Survey	3	4	.....
Engl 85-86—Advanced Technical Communication	.....	3	3
GE 101—Contracts and Specifications	3	.....	.....
Electives (see Index for "Elective Groups")	3	.....	1
Technical elective (taken in the Institute of Technology, or others by departmental approval)	3	3	4
Total credits	15	13	11

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, CE 172, Micb 53, PubH 100A and 102 in the list of fifth-year courses in sanitary engineering may be substituted, upon approval, for one of the following: CE 34, 52, 146. This selection would permit a wider choice of fifth-year elective courses or early entrance to the Graduate School.

Fifth Year

	Credits—f, w, s		
CE 141—Reinforced Concrete	3	.....	.....
CE 172—Sanitary Laboratory	3	.....	.....
CE 173, 174, 175—Sanitary Engineering Problems (Water); Waste Water; Industrial Waste Disposal	3	3	3
CE 176-177-178—Sanitary Engineering Seminar	1	1	1
Micb 53—General Bacteriology	.....	5	.....
Engl 85-86—Advanced Technical Communication	.....	3	3
GE 101—Contracts and Specifications	.....	.....	3
PubH 100A—Elements of Public Health	3	.....	.....
PubH 102—Environmental Sanitation	3	.....	.....
EE 36—Elements of Electrical Engineering	.....	.....	3
Total credits	16	12	13

CE 172, Micb 53, PubH 100A and 102 may be substituted as per statement under Sanitary Engineering Option.

Combined Curriculums of Civil Engineering and Law—These curriculums enable the student to obtain 2 degrees, 1 in the Institute of Technology and 1 in the Law School, in a period of approximately 7 years. To be eligible for admission to the Law School, the students must complete the modified 4-year civil engineering program outlined as follows and qualify for the bachelor of science degree. Then the regular law program covering 10 quarters of work will be taken leading to the degree of bachelor of laws.

First Year

See first-year curriculum for College of Engineering.

Second Year

See curriculum for the second year in civil engineering, except Psy 1-2 and 155 should be taken for the nontechnical electives.

Third Year

CE 18, 19, 20, 31, 32, 33, 51, 53, 160; MM 28, 29, 40, 41, 142; Hydr 103, 104; Econ 1T-2T; Pol A-B.

Fourth Year

CE 130, 141, 146, 147, 161, 170, 171; EE 36, 40; Engl 85-86; Hist 70-71-72; Phil 2, 3; Geol 5.

Electrical Engineering

A 5-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.

The curriculum is designed to provide the technical background in mathematics, science, and electrical technology which underlies all aspects of electrical engineering. The department offers elective courses in such fields as electronics, solid state devices, control systems, electric power, communications systems, and microwaves in order to permit the student to enhance his competence in specialized areas during the final year of his undergraduate studies.

A 2-year sequence of study in electrical engineering is offered to strongly motivated and exceptionally able students (G.P.A. at least 2.80). This honors work is similar to but more intensive than that given in the regular curriculum, and class size is limited to promote a free interchange of ideas between student and instructor. In the honors program, electrical engineering courses in the regular curriculum are replaced by corresponding H-suffixed courses, and other modifications are made in the curriculum to strengthen background in mathematics and physics. Enrollment is voluntary but must have the approval of the honors course adviser. The honors program may be entered at the beginning of the junior year by students who have completed all of the requirements of the Lower Division. Transfer students are eligible as well as those previously in residence.

A student may be granted the degree of bachelor of science (B.S.) after 4 years in order to start graduate study in the fifth year if he meets the requirements out-

lined in the general section on Requirements for Graduation. Students interested in the B.S. program but not enrolled in the honors program should consult the faculty adviser for this program, preferably as early as the beginning of the third year, in order to incorporate recommended modifications in the curriculum.

A student who is eligible for the B.S. degree and otherwise satisfies the requirements for admission to the Law School may be granted the B.S. degree in order to enter Law School. A bachelor of laws degree can be obtained in approximately 3 additional years.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
EE 12-14-16—Elements of Electrical Engineering Laboratory	1	1	1
Phys 51—Intermediate General Physics	....	....	4

Students in the electrical engineering curriculum are required to complete a minimum of 6 credits in a single course sequence of biological science electives (Group I).

UPPER DIVISION

Third Year

	Credits—f, w, s		
EE 61-62-63—Introductory Circuit Theory	4	4	4
EE 71-72-73—Electromagnetic Fields and Materials	4	4	4
EE 81-82-83—Electrical Engineering Laboratory	2	2	2
MM 28, 29—Rigid-Body Mechanics II, III	3	3	....
ME 30—Thermodynamics	....	....	3
Electives—Group I, II, or III (see Index for "Elective Groups")	3	3	4
Total credits	16	16	17

Fourth Year

(First offered 1962-63)

Electrical engineering students at the fourth-year level in 1961-62 are to follow the curriculum published in the 1959-61 *Bulletin of the Institute of Technology.* Details are available at the electrical engineering departmental office.

	Credits—f, w, s		
EE 104-105-106—Electronics	4	4	4
EE 111-112-113—Circuits and Fields	3	3	3
EE 114-115-116—Electrical Engineering Laboratory	2	2	2
Technical electives (see below)	3	3	3
Electives	3	3	3
Electives—Group I, II, or III (see Index for "Elective Groups")	3	3	3
Total credits	18	18	18

Technical Electives—One sequence is to be chosen from the following list of courses:

ITM 132, 133B-134B	Introduction to Statistics and Probability; Probability with Technological Applications
ITM 147, 148, 149	Vector Analysis; Differential Equations; Determinants and Matrices

ITM 165A, 165B-C	Introduction to Programming Modern Digital Calculators; Theory and Programming of Modern Digital Calculators
Phys 107-109-111	Atomic and Nuclear Physics
Hydr 101, ME 133, MM 40	Fluid Mechanics; Heat Transmission; Deformable-Body Mechanics I
Met 153, 154, 155	Principles of Physical Metallurgy I, II, and III
PCh 101-102-103	Physical Chemistry

Students who desire to pursue a technical interest not represented in this list may request permission of the Department of Electrical Engineering to substitute an appropriate replacement.

Fifth Year

	Credits—f, w, s		
Electrical engineering electives (see below)	6	6	6
EE 187-188-189—Problems in Electrical Engineering	3	3	3
Engl 85-86—Advanced Technical Communication	.....	3	3
Electives	6	3	3
Total credits	15	15	15

Electrical Engineering Electives—A minimum of two sequences must be completed from the regular course list, except that, (a) students who receive the permission of appropriate instructors may substitute courses from the advanced course list, (b) students who have the prerequisites may request permission to substitute the stated industrial engineering list.

Regular Course List

	Credits—f, w, s		
EE 131-133-135—Electronic Circuit Design	3	3	3
EE 132-134-136—Study of Electric Machines	3	3	3
EE 138-139-140—Electric Power Control	3	3	3
EE 157-158-159—Electronic Control	3	3	3
EE 164-165-166—Communication Circuits	3	3	3

Advanced Course List

In addition to other prerequisites these sequences require consent of instructor (denoted by the symbol ♯ in the course description section).

	Credits—f, w, s		
EE 150—Dynamical Methods in Electrical Engineering	3	.....	.....
EE 151—Thermodynamic Methods in Electrical Engineering	.....	3	.....
EE 152—Statistical-Mechanical Methods in Electrical Engineering	.....	.....	3
EE 153-154-155—Introduction to the Properties of Solids	3	3	3
EE 167-168-169—Electromagnetic Theory and Application	3	3	3
EE 173-174-175—Physical Electronics	3	3	3
EE 191-192-193—Active Network Theory	3	3	3
EE 194-195-196—Servomechanisms	3	3	3
EE 197-198-199—Electrical Design of Machines I	3	3	3

Industrial Engineering List—To be eligible to substitute this group of courses, a petition is to be submitted before the end of the fourth year, and the following preparatory courses are to be completed:

Econ 1T-2T and BA 52 are recommended nontechnical electives in Group II. In the third year, add ITM 90; in the fourth year take IE 50, 153, 170, and 171 as electives.

	Credits—f, w, s		
IE 190—Industrial Engineering Seminar	.....	.....	1
IE 194—Applied Industrial Engineering	.....	.....	3
BA 55A—Elementary Accounting	4	.....	.....
BA 55C—Managerial Costs	.....	3	.....
Minimum of 9 credits from IE 154, 155, 165, 167, 173, 174, 180, 197	3	3	3

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 curriculums. To meet this need two special curriculums have been developed, the combined curriculums in engineering and business administration, and the 4-year program in engineering and business administration (industrial administration).

Combined Curriculums in Engineering and Business Administration—The combined curriculums in engineering and business administration enable the student to complete the requirements for 2 degrees, 1 in the Institute of Technology and 1 in the School of Business Administration in a period of approximately 5 years. In the Institute of Technology the Agricultural, Chemical, Civil, Geological, Metallurgical, and Mining Engineering Departments will allow business courses to be substituted for natural science, social science, humanities, Engl 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 75 credits of business subjects (as listed in the curriculum) which satisfy the requirements for the degree of bachelor of science in business. 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 Scholastic Standards Committee for the combined engineering and business curriculums, located in 133 Main Engineering building. A grade point average of 2.50 in each field, i.e., engineering and business, based on at least 2 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 2 quarters in the Institute of Technology.

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 4 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 first-year curriculum for College of Engineering.

Second Year

It is recommended that students in the combined curriculums in engineering and business administration elect the following courses in the second year in addition to those recommended by the departments in which they desire to major. These courses are in lieu of electives from Groups I, II, and III.

	Credits—f, w, s		
Econ 1T-2T—Principles of Economics	3	3	.....

Third Year

	Credits—f, w, s		
BA 55A-B—Elementary Accounting	4	4	.....
BA 5—Elements of Statistics	.....	.....	4

Fourth Year

	Credits—f, w, s		
BA 52—Modern Industrial Relations: Labor Marketing	3		
BA 58—Business Law: Contracts	3		
Econ 65—Intermediate Economic Analysis: The Firm	3		
BA 50—Production Management		3	
BA 51—Business Statistics		3	
BA 57—Principles of Marketing		3	
BA 55C—Managerial Costs			3
BA 56—Corporation Finance			3
Econ 66—Intermediate Economic Analysis: Income and Employment			3

Fifth Year

	Credits—f, w, s		
BA 53—Risk Management and Insurance	3		
BA 54—Transportation I: Principles	3		
Econ 67—Money and Banking	3		
Econ 68—Elements of Public Finance		3	
Econ 69—Government Regulation of Business		3	
BA 60—Business Policy and Management Control			3
Business and economics electives (suggested courses follow):	6	3	3
BA 197—Purchasing			
BA 116—Investments			
BA 117—Sales Management I			
BA 175A—Advanced Cost Accounting			
BA 76—Financial Management			
BA 72—Modern Industrial Relations: Manpower Management			
BA 97—Market Analysis and Research I			
BA 110—Systems and Procedures Analysis; Work Measurement			
Total credits for 2nd to 5th years			75

Credits for the program in business and economics must total 75.

Substitutions: ITM 90 for BA 5; IE 153 for BA 110; IE 50 for BA 50. Substitutions made in the Institute of Technology for business administration and economics courses must be offset by additional courses in the School of Business Administration to total 75 credits.

Master of Business Administration—Students who have received a Bachelor's degree in engineering may be admitted to graduate study in business administration provided they meet the entrance requirements of the Graduate School. The program can be completed in 1 to 2 years, depending on the candidate's undergraduate preparation.

Unless the candidate has completed satisfactory equivalent courses in his undergraduate preparation, he will be expected to take introductory graduate courses (3 credits in each of the following): managerial economics, national income and employment, money and banking, public finance, business statistics, business law, business finance, insurance, labor economics and industrial relations, marketing, production management, transportation, management and business policy, and managerial accounting (6 credits).

All programs will include:

1. Twenty-one hours in 5 basic areas: quantitative approaches to administrative problems (6 credits), policy formulation and administration (3 credits), executive leadership (3 credits), government and business enterprise (6 credits), and business research methods and techniques (3 credits);
2. Twenty-four credits selected from courses in at least 4 of the following 9 fields, with a minimum of 6 credits each in at least 2 fields and a maximum of 9 credits in any 1 field. The 9 fields are accounting, finance, industrial management and administration, industrial relations, insurance, marketing, office management, statistics, and transportation. Any department of the Graduate School may be substituted for *1* of the 9 fields in business administration.

The candidate with approval of his adviser and appropriate instructors will select three courses suitable for Plan B written reports.

All candidates will be required to take a final written examination. The graduate faculty in business administration also reserves the right to examine any candidate orally.

A foreign language is not required.

The above program may be completed satisfactorily in about 1 year provided the student has taken the following courses as an undergraduate:

Econ 1-2, 65, 66, 67, 68; BA 50, 51, 52, 53, 54, 55A-B, 56, 57, 58, and 60.

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 2 years of this curriculum is taken in the Institute of Technology. The work in the last 2 years is taken 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 95 credits including a grade point average of 2.00 is required for admission.

Elective credits earned in the Institute of Technology or any other accredited school during the first 2 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 science in business which is given by the School of Business Administration.

First Year

Same curriculum as the first year in the College of Engineering.

	Credits—f, w, s		
EG 14, 15, 16—Engineering Graphics	3	3	3
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Phys 11-12-13—General Physics	5	5	5
Total credits	18-17	18-17	18-17

Second Year

	Credits—f, w, s		
BA 5—Elements of Statistics	....	....	4
BA 55A-B—Elementary Accounting	....	4	4
Econ 1T-2T—Principles of Economics	3	3	....
Econ 67—Money and Banking	....	....	3
InCh 14-15—Inorganic Chemistry	4	4	....
ITM 24A—Calculus II: Analytic Geometry and Calculus	5	....	....
MM 92—Statics	....	4	....
Met 56—Physical Metallurgy	....	....	3
Phys 14—Intermediate General Physics	4	....	....
Total credits	16	15	14

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

The following courses constitute a core of material which must be covered by all students. Exceptions may be made in individual cases upon petition approved by the adviser and the chairman of the Committee on Student Scholastic Standing.

1. Core Group Requirements—42 credits

	Credits
BA 50—Production Management	3
BA 51—Business Statistics	3
BA 52—Modern Industrial Relations: Labor Marketing	3
BA 53—Risk Management and Insurance	3
BA 54—Transportation I: Principles	3
BA 56—Corporation Finance	3
BA 57—Principles of Marketing	3
BA 58—Business Law: Contracts	3
BA 60—Business Policy and Management Control	3
Econ 65—Intermediate Economic Analysis: The Firm	3
Econ 66—Intermediate Economic Analysis: Income and Employment	3
Econ 67—Money and Banking	3
Econ 68—Elements of Public Finance	3
Econ 69—Government Regulation of Business	3

2. Business and Economics Electives—18 credits

No more than 12 credits of electives may be taken in any 1 field of concentration in the School of Business Administration. These fields are management, statistics, industrial relations, insurance, transportation, accounting, finance, marketing, law, office management, and economics.

3. Additional Electives—30 credits

No more than 15 credits may be taken within the School of Business Administration; see statement above.

Total credits, groups 1-3—90

4. Electives Outside the School of Business Administration

No restriction is placed on the selection of non–School of Business Administration electives except the following: (a) courses numbered below 50 may not exceed 12 credits, and (b) a concentration of 9 credits in courses numbered 50 and above in a single department.

Students may take as electives courses from the Institute of Technology, the College of Agriculture, Forestry, and Home Economics, and the College of Science, Literature, and the Arts for which they have the appropriate prerequisites.

Geological Engineering

A 5-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 245 credits, exclusive of summer fields 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 for engaging 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 geologists 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 their 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 elective courses, Group I, Group II or Group III (see section on Electives).

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

The department recommends that students in geological engineering elect the following courses instead of Phys 51 or OrCh 16:

	Credits—f	w	s
InCh 11—Semimicro Qualitative Analysis	.....	.....	4
MinE 1—Mineral Engineering Laboratory	.....	.....	1
Phys 14A, 50A—Physics Laboratory	1	1	.....

Students in the geological engineering curriculum are required to complete a minimum of 6 credits in a single course sequence of biological science electives (Group I).

UPPER DIVISION

Third Year

	Credits—f	w	s
MinE 111-112—Exploration, Development, and Exploitation of Mineral Deposits (or) PetE 111, 112—Oil Field Development; Oil Field Production	3	3	.....
MinE 131—Rock Mechanics I	.....	.....	3
MinE 13—Mine Surveying	.....	.....	3
Geol 1-2—General Geology (Physical and Historical)	3	3	.....
Geol 23-24, 25—Mineralogy; Rock Study	4	4	2
CE 18, 20—Surveying	3	.....	3
Hydr 103—Fluid Mechanics	.....	.....	5

	Credits—f, w, s		
Hydr 104—Fluid Mechanics Laboratory	.....	.....	1
MM 28, 40, 142—Rigid-Body Mechanics II; Deformable-Body Mechanics I; Experimental Mechanics	3	3	2
IE 50—Elements of Industrial Engineering and Management	.....	3	.....
Total credits	16	16	19

Mining Option in Geological Engineering—For those students interested primarily in metallic and nonmetallic minerals, mining geology, and engineering geology.

Summer Field Trip

MinE 15B—Mine Surveying Field Work (3 weeks)	5 credits
Geol 100—Field Work in Northern Minnesota	3 credits

Fourth Year

	Credits—f, w, s		
Geol 106—Optical Mineralogy	3	.....	.....
Geol 107—Invertebrate Paleontology	3	.....	.....
Geol 110-111—Economic Geology	.....	3	3
Geol 125—Structural Geology	4	.....	.....
Geol 131—Petrology	.....	4	.....
MinE 16—Mine Maps	.....	.....	1
GPhy 110—Introduction to Exploration Geophysics	.....	.....	3
MetE 110, 111—Mineral Dressing	4	4	.....
PCh 101-102—Physical Chemistry	4	4	.....
Electives—Group I, II, III (see Index for "Elective Groups")	.....	.....	6
Total credits	18	15	13

Summer Field Trip

Geol 150—Field Geology (Black Hills, S.D.)	6 credits

Fifth Year

	Credits—f, w, s		
Geol 118—Geomorphology	3	.....	.....
Geol 151—Stratigraphy I	.....	3	.....
Geol 166—Mineralography	.....	3	.....
Geol 171—Geologic Report	1	.....	.....
GPhy 108—Introduction to Earth Geophysics	3	.....	.....
MinE 132—Rock Mechanics II	3	.....	.....
MinE 141—Mineral Economics	3	.....	.....
MinE 180—Geochemical Exploration	.....	3	.....
CE 53—Elements of Soil Mechanics	.....	.....	3
Engl 85-86—Advanced Technical Communication	.....	3	3
Technical elective	.....	.....	3
Electives—Group I, II, or III (see Index for "Elective Groups")	3	4	3
Total credits	16	16	12

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

IT—AnCh 57; CE 19; GE 101; IE 153, 173, 180; ME 128, 198; EE 36; MetE 12, 106, 112, 121, 122; Met 56; MinE 121, 122, 133, 142, 160; PetE 111, 112, 135; Phys 51

Business—Econ 1T-2T; BA 55A-B

SLA—Geol 101, 112, 114, 120, 121, 132, 145, 153, 161, 167

Petroleum Option in Geological Engineering—For those students interested primarily in the geology and exploitation of petroleum deposits.

Third Year Summer Field Trip

MinE 15B—Mine Surveying Field Work (3 weeks)	5 credits
Geol 100—Field Work in Northern Minnesota	3 credits

Fourth Year

	Credits—f, w, s		
Geol 106—Optical Mineralogy	3	.....	.....
Geol 107—Invertebrate Paleontology	3	.....	.....
Geol 118—Geomorphology	3	.....	.....
Geol 125—Structural Geology	4	.....	.....
Geol 131—Petrology	.....	4	.....
Geol 151, 152—Stratigraphy I, II	.....	3	3
GPhy 110—Introduction to Exploration Geophysics	.....	.....	3
MinE 16—Mine Maps	.....	.....	1
PetE 131—Reservoir Mechanics	.....	.....	3
PetE 134—Natural Gas Engineering	.....	2	.....
PCh 101-102—Physical Chemistry	4	4	.....
Electives—Group I, II, or III (see Index for "Elective Groups")	.....	3	6
Total credits	17	16	16

Summer Field Trip

Geol 150—Field Geology (Black Hills, S. D.) ..... 6 credits

Fifth Year

	Credits—f, w, s		
Geol 101—Sedimentation	3	.....	.....
Geol 112—Petroleum Geology	3	.....	.....
Geol 171—Preparation of Geologic Report	1	.....	.....
MinE 141—Mineral Economics	3	.....	.....
PetE 152-153-154—Petroleum Production Technology	3	3	3
CE 53—Elements of Soil Mechanics	.....	.....	3
Engl 85-86—Advanced Technical Communication	.....	3	3
Technical elective	3	3	.....
Electives—Group I, II, or III (see Index for "Elective Groups")	.....	4	3
Total credits	16	13	12

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

IT—AnCh 57; CE 19; GE 101; IE 153, 170, 173, 180; ME 24, 128, 198; EE 36; MetE 12, 106, 110, 111, 112; Met 56; MinE 121, 122; PetE 135, 144-145; Phys 51; MetE 132, GPhy 108

Business—Econ 1T-2T; BA 55A-B, 55C, 58, 60

SLA—Geol 102, 110-111, 121, 132, 153, 166

Geophysics

A 5-year curriculum is offered which leads to the degree of bachelor of geophysics, B.Geophys. A total of 250 credits 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. Courses in geophysics attempt to provide not only geophysical data but also the evidence on which such data are based.

Both the geophysics curriculum and individual geophysics courses place primary emphasis on basic principles and techniques. The curriculum provides a thorough background in geology, physics, and mathematics. It prepares students either for graduate work in geophysics and related fields, or for responsible posi-

tions in geophysical companies, oil or mining companies, or research institutions. The program may be taken also by students interested chiefly in a broad scientific training.

LOWER DIVISION

First Year

See first-year curriculum for the College of Engineering or School of Physics.

Second Year

Follow second-year curriculum for either College of Engineering or School of Physics. Recommended laboratory sequence is Phys 14A, 50A, and MinE 1.

UPPER DIVISION

Third Year

	Credits—f, w, s		
GPhy 125—Principles of Gravity and Magnetic Exploration	.....	.....	3
GPhy 126—Principles of Seismic Exploration	.....	3	.....
GPhy 127—Principles of Electrical Exploration	2	.....	.....
Geol 1-2—General Geology (Physical and Historical)	3	.....	3
Geol 23-24—Mineralogy	4	4	.....
Geol 25—Rock Study	.....	.....	2
ITM 147—Vector Analysis (see statement below)	3	.....	.....
ITM 148—Differential Equations	.....	3	.....
ITM 149—Determinants and Matrices	.....	.....	3
Phys 144—Electrical Measurements	4	.....	.....
Phys 146—Physics of Vacuum Tubes and Associated Circuits	.....	4	.....
Phys 148—Application of Electronic Circuits	.....	.....	4
Nontechnical elective (see Index for "Elective Groups")	.....	3	.....
Total credits	16	17	15

ITM 151, 152, 153 may be substituted for ITM 147, 148, 149.

Fourth Year

	Credits—f, w, s		
GPhy 108—Introduction to Earth Geophysics	.....	3	.....
Geol 125—Structural Geology	4	.....	.....
MM 193—Introduction to the Theory of Mechanical Vibrations (or) Geol 145—Aerial Photographs	.....	.....	3
Phys 100-102-104—Mechanics, Electricity, and Magnetism	4	4	4
Technical electives	5	7	7
Nontechnical electives (see Index for "Elective Groups")	3	3	3
Total credits	16	17	17

Summer Field Trip

Geol 150—Field Geology	6 credits
(or) GPhy 90—Industrial Employment (see statement below)	ar credits
(or) GPhy 138—Research Problems in Geophysics	ar credits

If GPhy 90 or 138 is taken in place of Geol 150, additional credits to a total of 6 must be taken from GPhy 91-92, 135-136-137, or electives. Students who elect to take a B.S. degree at the end of the fourth year (see Requirements for Graduation) will be held for Summer Field Trip.

Fifth Year

	Credits—f, w, s		
GPhy 109—Introduction to Earthquake Seismology	3	.....	.....
Engl 85-86—Advanced Technical Communication	3	.....	3
Geol 110—Economic Geology	.....	3	.....
MM 180—Introduction to Theory of Elasticity (or) Geol 112—Petroleum Geology	3	.....	.....
Phys 107-109-111—Atomic and Nuclear Physics	3	3	3
Technical electives	.....	6	8
Nontechnical electives (see Index for "Elective Groups")	3	4	.....
Total credits	15	16	14

Electives must include at least 6 credits from Geol 101, 111, 126; Phys 123-124-125, 131, 133; ITM 173, 174, 175 or (if not taken as fourth or fifth year required courses) Geol 112, 145; MM 180, 193.

Recommended technical electives are geophysics courses; ITM 165A; Ast 52; EE 131-133-135, 161; MinE 180; Phys 121, 122, 171-172-173.

Industrial Engineering

Professional training in industrial engineering is offered through industrial engineering options in mechanical and electrical engineering. These options lead to the degree of bachelor of mechanical engineering, B.M.E., or bachelor of electrical engineering, B.E.E., respectively.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of at least 250 credits for graduation. Students must submit a petition for entrance into any industrial engineering option.

The industrial engineering curriculum offers the student an opportunity to learn those scientific and engineering principles which deal with the optimum utilization of men, materials, and equipment.

The industrial engineer studies product designs to adapt them for economic production, determines an optimum system of necessary operations, selects the most economical production equipment and tooling and develops effective work methods and measurements. He must learn the fundamental concepts associated with developing inventory and production controls, establishing production standards, estimating and comparing alternative costs of new operations, and administering wage incentives and cost reduction programs. The industrial engineer is also concerned with the development and analysis of the optimum layout of industrial plants together with systems of materials handling.

Today the industrial engineer should have a knowledge of the potential usefulness of the high speed digital computer as a tool both in engineering research, industrial development and control. Industrial statistics and engineering mathematics together with engineering economics are fundamental to industrial engineering. Formulating problems, weighing the objectives, constructing mathematical models, obtaining analytical and numerical solutions, and making decisions are fast becoming the industrial engineer's responsibilities. In fact, by applying his engineering training and his appreciation of the basic managerial problems of an enterprise, the industrial engineer has become the key adviser to managers constantly faced with a variety of decisions to be made.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

See sections on Mechanical Engineering or Electrical Engineering for recommended electives.

UPPER DIVISION

Third, Fourth, and Fifth Years

See section on Mechanical Engineering or Electrical Engineering for recommended integration with other required courses.

	Credits
IE 50—Elements of Industrial Engineering and Management	3
IE 153—Methods Engineering and Work Measurement	3
IE 170—Production Planning and Control	3
IE 171—Quality Control	3
IE 190—Industrial Engineering Seminar	1
IE 194—Applied Industrial Engineering	3
Industrial Engineering Analysis (minimum of 12 credits from IE 154, 155, 163, 165, 167, 173, 174, 182, 197)	12
ITM 90—Elementary Engineering Statistics (or) ITM 132—Introduction to Statistics and Probability	3
BA 55A—Accounting	4
BA 55C—Managerial Costs	3
Electives—Group II and III (see Index for "Elective Groups") (Econ 1T-2T, and BA 52 are recommended for Group II)	

Master of Science in Industrial Engineering—A student in any industrial engineering option may be granted a B.S. degree after 4 years and start graduate study in the fifth year if he meets the requirements outlined in the general section on Requirements for Graduation.

Students who have received a bachelor of science degree in any engineering area may be admitted to graduate study majoring in industrial engineering provided they meet the entrance requirements of the Graduate School. Candidates will be expected to complete, either as undergraduates or as graduate students, adequate preparation in undergraduate subjects and in the sciences fundamental to industrial engineering. The M.S. degree in industrial engineering is offered under both Plan A and Plan B.

Mathematics

A 4-year curriculum is offered which leads to the degree of bachelor of mathematics, B.Math.

In addition to the prescribed courses, a student must meet the nontechnical requirement of 37 credits, including 12 credits of Freshman English, and have sufficient approved electives to complete a total of 200 credits for graduation.

This course of study is designed to prepare the student for positions in industry and government research as well as for college teaching. In addition to a thorough training in mathematics, the student will be provided with fundamental knowledge in physics and chemistry and he may also obtain an introduction to some field of engineering on an elective basis. The curriculum is flexible enough to provide for some specialization such as statistics, mechanics, or numerical analysis. Yet it is broad enough to provide a sound foundation for graduate study leading to a professional career in either pure or applied mathematics. A careful selection of electives and options should provide for the individual's special interests.

A combined 5-year curriculum is offered also in co-operation with the College of Education leading to the 2 degrees, bachelor of mathematics and master of education.

LOWER DIVISION

First Year

	Credits—f, w, s		
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
EG 14—Engineering Graphics (see statement below)	3	.....	.....
Engl 1B-2B-3B or 1A-2A-3A or A-B-C—Freshman English	4	4	4
Phys 11-12-13—General Physics	5	5	5
Electives (see statement below)	.....	3	3
Total credits	17	17	17

Students may substitute an elective for EG 14 by petition. However, students who are not certain whether to major in mathematics or engineering should take EG 14, 15, 16 which are required in engineering.

Second Year

ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
ITM 14—Laboratory	.....	.....	1
InCh 14-15—Inorganic Chemistry	4	4	.....
MM 27—Rigid-Body Mechanics I (or) OrCh 16—Carbon Compounds (or) Elective — see statement below	.....	.....	3
Phys 14, 50, 51—Intermediate General Physics	4	4	4
Phys 14A, 50A—Physics Laboratory	1	1	...
Electives—Groups I, II, or III (see Index for "Elective Groups")	3	3	3
Total credits	17	17	16

Students who are not certain whether to major in mathematics or engineering or who plan to take MM 28, 29, 40 in the third year should take MM 27 which is required in engineering.

UPPER DIVISION

Third Year

	Credits—f, w, s		
ITM 132—Introduction to Statistics and Probability	3	.....	.....
ITM 133-134—Statistical Theory with Applications (see statement below)	.....	3	3
ITM 151, 152, 153—Calculus V, VI, VII: Advanced Calculus	3	3	3
Phys 100-102-104—Mechanics, Electricity, and Magnetism (or) MM 28, 29, 40—Rigid-Body Mechanics II, III; Deformable-Body Mechanics I	4-3	4-3	4-3
Technical elective (see statement below)	3	3	3
Electives—Groups I, II, or III (see Index for "Elective Groups")	3	3	3
Electives	1-2	1-2	1-2
Total credits	17	17	17

ITM 133A-134A may be substituted for ITM 133-134.

The technical elective can be selected from any IT department. It must be a sequence of 9 credits or more.

Fourth Year

	Credits—f, w, s		
ITM 99—Mathematical Problem Seminar	3	.....	.....
ITM 150—Ordinary Differential Equations	.....	3	.....
ITM 149—Determinants and Matrices (or) ITM 168B—Applications of Complex Variables (or) ITM 169—Mathematical Theory of Fluid Flow (or) ITM 192—Theory of Approximation in Numerical Analysis (see statement below)	.....	.....	3
ITM 173—Elementary Partial Differential Equations	3	.....	.....
ITM 174—Elementary Theory of Complex Variables	.....	3	.....
ITM 175—Integral Transforms	.....	.....	3
Mathematics option (see below)	3	3	3
Electives—Groups I, II, or III (see Index for "Elective Groups")	3	3	3
Electives	4	4	4
Total credits	16	16	16

Students who do *not* select 142-143, 180 as the mathematics option must take ITM 149. Those who take 142-143, 180 must take 1 of the other 3.

Any student planning on entering the Graduate School should take a foreign language. A language course can be included as part of the nontechnical requirements or part of the electives.

A minimum of 25 credits must be taken in the nontechnical electives. Engl 85-86 may be used for 6 of these credits.

A minimum of 200 credits are required for the degree, bachelor of mathematics.

Mathematics Option—One of the following sequences must be completed:

ITM 142-143, 180—Vector and Matrix Theory; Finite Groups
ITM 161-162-163—Analytical Dynamics
ITM 165A, B-C—Theory and Programming of Modern Digital Calculators
ITM 184, 185-186—Numerical Analysis
ITM 190A-B-C—Combinatorial Topology
ITM 193A, B, C—Introduction to Higher Geometry: Axiomatic, Projective, and Differential Geometry

Combined Mathematics and Education Curriculum—The combined 5-year curriculum between mathematics and the College of Education leads to the 2 degrees, bachelor of mathematics, B.Math., and master of education, M.Ed.

A student may apply for this curriculum during the third quarter of his junior year. He must have at least a C average (2.00) in all courses and a C+ average (2.50) in mathematics. In addition, he must complete the speech, health, and psychological examinations and interviews required by the College of Education and secure the approval of his major adviser in mathematics in the Institute of Technology and the Admission Committee of the College of Education.

The student carriers courses in both colleges concurrently during the fourth and fifth years and is awarded both degrees when he meets the following requirements. He must complete the prescribed courses in both colleges and a total of 245 credits. These must include 45 credits of graduate level courses (numbered 100 or higher) in mathematics and education (maximum of 12 in education) with a B (3.00) average. He must also have satisfactory scores on the master of education comprehensive examinations.

First Year

See first-year curriculum for bachelor of mathematics degree.

Second Year

	Credits—f, w, s		
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
ITM 14—Laboratory	....	....	1
InCh 14-15—Inorganic Chemistry	4	4	....
OrCh 16—Carbon Compounds	....	....	4
MM 27—Rigid-Body Mechanics I (or) Phys 51—Intermediate General Physics (or) Elective (see statement below)	....	....	3
Phys 14, 50—Intermediate General Physics	4	4	....
Phys 14A, 50A—Physics Laboratory	1	1	....
Psy 1-2—General Psychology	3	3	....
Psy 70—Principles of Psychological Measurement	....	....	3
Total credits	17	17	16

Students who plan to take MM 28, 29, 40 in the third year or who are not certain about majoring in mathematics should take MM 27 which is required in engineering.

Third Year

	Credits—f, w, s		
ITM 132—Introduction to Statistics and Probability	3	....	....
ITM 133-134—Statistical Theory with Applications (see statement below)	....	3	3
ITM 151, 152, 153—Calculus V, VI, VII: Advanced Calculus	3	3	3
Phys 100-102-104—Mechanics, Electricity, and Magnetism (or) MM 28,29, 40—Rigid-Body Mechanics II, III; Deformable-Body Mechanics I	4-3	4-3	4-3
PCh 107-108—Elementary Physical Chemistry	3	3	....
Physical education	1	1	1
Electives—Groups I or II (see Index for "Elective Groups")	3	3	3
Elective	0-1	0-1	3-4
Total credits	17	17	17

ITM 133A-134A may be substituted for ITM 133-134.

Fourth Year

	Credits—f, w, s		
ITM 99—Mathematical Problem Seminar	3	....	....
ITM 150—Ordinary Differential Equations	....	3	....
ITM 149—Determinants and Matrices (or) ITM 168B—Applications of Complex Variables (or) ITM 169—Mathematical Theory of Fluid Flow (or) ITM 192—Theory of Approximation in Numerical Analysis (see statement below)	....	....	3
Mathematics option (see Mathematics Option in mathematics curriculum)	3	3	3
CD 132—Adolescent Psychology	....	....	3
EPsy 193—Psychology of Human Learning	3	....	....
EdT 67A-B-C—Teaching Secondary School Mathematics	3	1	1
EdT 67—Student Teaching in Mathematics	1	1	1
French, German, or Russian	3	3	3
Electives	1	6	3
Total credits	17	17	17

Students who do *not* select ITM 142-143, 180 as the mathematics option must take ITM 149. Those who take 142-143, 180 must take 1 of the other 3.

Fifth Year

		Credits—f, w, s		
ITM 165A—Introduction to Programming Modern Digital Calculators ITM 184—Elementary Numerical Analysis in Engineering ITM 193A—Axiomatic Geometry ITM 193B—Elementary Projective Geometry	Two courses required	3	3	.....
EdCI 113—High School Curriculum		3	.....	.....
EdT 67—Student Teaching in Mathematics (see statement below)		3-0	0-3	.....
EdT 68M or A—Teaching Secondary School Science		3	.....	.....
EPsy 117—Basic Principles of Measurement		.....	3	.....
EPsy 208—Methods in Educational Research		.....	3	.....
HEd 180—The School and Society		.....	3	.....
PubH 50—Personal and Community Health		3	.....	.....
EdCI 199E—Internship		.....	.....	12
Elective		0-3	3-0	.....
	Total credits	15	15	12

EdT 67 may be taken either fall or winter allowing 3 elective credits in the other quarter.

Mechanical Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of mechanical engineering, B.M.E.

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

A student may be granted a B.S. degree after 4 years and start graduate study in the fifth year if he meets the requirements outlined in the general section on Requirements for Graduation.

The mechanical engineering department offers work in the following areas: thermodynamics, heat transmission, heating and air conditioning, refrigeration, internal combustion engines, turbomachinery, steam and nuclear power generation, design of machines, instrumentation and automatic controls, operation of industrial plants, and production and manufacturing methods. A student may specialize in any of these areas by taking the appropriate senior design courses and electives. Research activities are conducted in all areas.

An industrial engineering option in mechanical engineering is available to students who wish to concentrate in this area.

Co-operative work-study curriculums in mechanical engineering are available to qualified students.

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
OrCh 16—Carbon Compounds	.....	.....	4
OrCh 17—Carbon Compounds Laboratory	.....	.....	1
Phys 14A, 50A—Physics Laboratory	1	1	.....

Phys 51A is recommended as a substitute for OrCh 17 for those students who have elected Phys 51.

Students in the mechanical engineering curriculum are required to complete a minimum of 6 credits in a single course sequence of biological science electives (Group I).

UPPER DIVISION

Third Year

	Credits—f, w, s		
ME 21—Mechanisms: Kinematic Analysis	....	....	3
ME 30-31-32—Thermodynamics	3	3	3
ME 33—Mechanical Engineering Laboratory I	2	....	....
ME 34—Mechanical Engineering Laboratory II	....	....	2
ITM 90—Elementary Engineering Statistics IE 50—Elements of Industrial Engineering and Management	3	3	....
MM 28—Rigid-Body Mechanics II	3	....	....
MM 29—Rigid-Body Mechanics III	....	3	....
MM 40—Deformable-Body Mechanics I	3	....	....
MM 41—Deformable-Body Mechanics II MM 142—Experimental Mechanics Hydr 103—Fluid Mechanics Hydr 104—Fluid Mechanics Laboratory (all required)	....	5-6	5-6
Electives—Group II or I (see Index for "Elective Groups")	3	3	3
Total credits	17	17-18	16-17

Fourth Year

	Credits—f, w, s		
ME 15—Casting, Working, and Welding of Engineering Materials ME 16—Cold Processing of Materials	....	3	3
ME 22—Mechanisms: Dynamic Analysis	3	....	....
ME 23—Mechanisms: Components and Synthesis	....	3	....
ME 133—Heat Transmission ME 134—Thermodynamics of Fluid Flow	3	3	....
ME 24—Elements of Machine Design ME 146—An Introduction to Combustion ME 160—Psychrometrics and Air Conditioning	3	3	3
ME 121—Machine Design ME 143—Turbomachinery ME 180—Mechanical Refrigeration (one course required)	....	....	3
Met 56—Physical Metallurgy	3	....	....
EE 36—Elements of Electrical Engineering	....	....	3
Technical electives (see statement below)	....	3	3
Electives—Group III (see Index for "Elective Groups")	3	3	3
Total credits	15	18	18

Fifth Year

	Credits—f, w, s		
ME 125—Machine Design Laboratory ME 159—Heat Power Laboratory ME 169—Air Conditioning and Refrigeration Laboratory	2	2	2
ME 121—Machine Design ME 143—Turbomachinery ME 180—Mechanical Refrigeration (two courses required)	6	....	....
ME 198—Industrial Instrumentation and Automatic Control	....	3	....
Engineering design group (minimum of 3 credits from ME 122, 147, 161, IE 163)	....	....	3
EE 37-38—Elements of Electrical Engineering	3	3	....
EE 37A-38A—Electrical Engineering Laboratory	1	1	....
Engl 85-86—Advanced Technical Communication	3	3	....
Technical electives (see statement below)	3	3	3
Electives—Group I, II, or III (see Index for "Elective Groups")	....	....	3
Electives (sufficient to complete a total of at least 250 credits for graduation	....	....	5
Total credits	18	15	16

Technical electives should be chosen from courses numbered 100 or above in the Institute of Technology or in the physical sciences. Senior level technical courses numbered 99 or below may be petitioned for departmental approval.

Industrial Engineering Option—Mechanical engineering training with specialization in industrial engineering is provided by this option. Students who follow this option are also eligible to apply for the bachelor of science degree or for the cooperative work-study program. For further descriptive information, see Industrial Engineering section.

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

Third Year

See third-year curriculum for Mechanical Engineering.
Econ 1T-2T and BA 52 are recommended for Group II of the electives.

Fourth Year

	Credits—f, w, s		
ME 15—Casting, Working, and Welding of Engineering Materials }			
ME 16—Cold Processing of Materials }		3	3
ME 22—Mechanisms: Dynamic Analysis	3		
ME 24—Elements of Machine Design		3	
ME 133—Heat Transmission		3	
ME 134—Thermodynamics of Fluid Flow ME 143—Turbomachinery ME 146—An Introduction to Combustion ME 160—Psychrometrics and Air Conditioning ME 180—Mechanical Refrigeration } one course required			3
Met 56—Physical Metallurgy	3		
EE 36—Elements of Electrical Engineering			3
IE 153—Methods Engineering and Work Measurement	3		
IE 170—Production Planning and Control		3	
IE 171—Quality Control			3
BA 55A—Elementary Accounting	4		
BA 55C—Managerial Costs		3	
Electives—Group III (see Index for "Elective Groups")	3	3	3
Total credits	16	18	15

Fifth Year

	Credits—f, w, s		
ME 121—Machine Design		3	
ME 198—Industrial Instrumentation and Automatic Control			3
ME 134—Thermodynamics of Fluid Flow ME 143—Turbomachinery ME 146—An Introduction to Combustion ME 160—Psychrometrics and Air Conditioning ME 180—Mechanical Refrigeration } two courses required	3		3
IE 190—Industrial Engineering Seminar		1	
IE 194—Applied Industrial Engineering			3
Engineering analysis group (minimum of 12 credits from IE 154, 155, 163, 165, 167, 173, 174, 182, 197)	6	3	3
EE 37-38—Elements of Electrical Engineering	3	3	
EE 37A-38A—Electrical Engineering Laboratory	1	1	
Engl 85-86—Advanced Technical Communication	3	3	
Electives—(see Index for "Elective Groups"; Soc 146 recommended)			3
Electives (sufficient to complete a total of at least 250 credits for graduation)		3	3
Total credits	16	17	18

Co-operative Work-Study Curriculum—A 5-year work-study curriculum designed to provide both theoretical and practical training is offered in co-operation with industry. The program is available to all qualified students registered in the mechanical engineering curriculum and leads to the degree of bachelor of mechanical engineering. Students registered in mechanical engineering who have completed the first 3 years of the regular program with a grade point average of 2.00 or better are eligible at the end of the spring quarter of their third year. Application should be filed by February 1 preceding the completion of the first 3 years' work.

The first industrial assignment is made during the summer or fall term following the completion of the first 3 years' 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 a B.M.E. will require the satisfactory completion of all the basic required University work as designated in the regular 5-year mechanical engineering curriculum including 4 alternate quarters of supervised industrial experience.

Students in mechanical engineering should contact the director of the work-study program for information. Candidates will be selected on the basis of scholastic ability, financial need, personal qualifications, and fitness for work.

Combined Curriculums of Mechanical Engineering and Law—These curriculums enable the student to obtain 2 degrees, 1 in the Institute of Technology and 1 in the Law School, in a period of approximately 7 years. To be eligible for admission to the Law School, the student must complete a modified 4-year mechanical engineering program and qualify for the bachelor of science degree. Then the regular law program covering 10 quarters of work will be followed. This leads to the degree of bachelor of laws.

Information on this program can be obtained in the mechanical engineering office.

Metallurgical Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of metallurgical engineering, B.Met.E.

A total of 250 credits is required for graduation.

Metallurgical engineering is the co-ordinated application of scientific and engineering principles to the beneficiation of ores (mineral dressing), and to the extraction of metals from ores and beneficiated products and the subsequent stages of metal refining (process or chemical metallurgy). In process metallurgy, intermediate products and metals are formed from ores and are refined by high temperature reactions (pyrometallurgy); are chemically leached from ores (hydrometallurgy); and are recovered by electrolytic and electrothermal procedures (electrometallurgy).

In general, the past exploitation of rich ores has left only low-grade material from which it is difficult to extract the contained metals efficiently and at a profit. The high demand for metals in the modern world dictates that all sources of metals be developed and utilized so far as is economically feasible.

The mineral dressing engineer devises and applies various methods, based upon the mineralogical, chemical, and physical properties of the ore, to segregate the valuable metal-bearing minerals from the waste material. Similar methods are used in coal processing and in the recovery of many important industrial minerals.

The extraction of metals from ores and concentrates, and the refining of these metals, involve processes which are necessarily chemical in nature. As such processes encompass a wide variety of chemical reactions, the metallurgical engineer must be familiar with the fundamentals of chemical reaction between solids, liquids and gases, and with the driving forces which make these reactions possible. In

industrial operations, large quantities of material must be processed, so that the metallurgical engineer is required to apply both scientific and engineering principles.

As economic conditions change, the mineral dressing engineer and the metallurgical engineer must work together to find efficient and economical methods to treat the material available.

Students taking the combined course with business administration may substitute business courses for electives Group II and Group III (see section on Electives).

A student may be granted a B.S. degree after 4 years and start graduate study in the fifth year if he meets the requirements outlined in the general section on Requirements for Graduation.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

The division recommends that students in metallurgical engineering elect InCh 11 instead of Phys 51 or OrCh 16. This course is a prerequisite for AnCh 57 in the third year.

For the laboratory sequence, the following courses are recommended:

	Credits—f, w, s		
Phys 14A, 50A—Physics Laboratory	1	1	.....
MetE 1—Metallurgical Engineering Laboratory	.....	.....	1

UPPER DIVISION

Third Year

	Credits—f, w, s		
MetE 11—Elements of Metallurgical Engineering	3	.....	.....
MetE 106, 107, 108—Principles of Process Metallurgy	3	4	4
Geol 23-24—Mineralogy	4	4	.....
PCh 101-102-103—Physical Chemistry	4	4	4
AnCh 57—Quantitative Analysis	4	.....	.....
OrCh 16—Carbon Compounds	.....	.....	4
Nontechnical electives (see Index for "Elective Groups")	.....	3	3
Total credits	18	15	15

Fourth Year

	Credits—f, w, s		
MetE 110, 111, 112—Mineral Dressing	4	4	4
ChEn 101, 102—Principles of Chemical Engineering	5	5	.....
Met 153, 154, 155—Principles of Physical Metallurgy I, II, III	3	3	3
ITM 90—Elementary Engineering Statistics	.....	.....	3
MM 28—Rigid-Body Mechanics II	3	.....	.....
MM 40, 142—Deformable-Body Mechanics I; Experimental Mechanics	.....	3	2
Technical elective	3	.....	.....
Nontechnical electives (see Index for "Elective Groups")	.....	3	3
Total credits	18	18	15

Field Trip

MetE 75—Metallurgical Engineering Inspection Trip (offered during 4th or 5th year) ..... 2 credits

Fifth Year

	Credits—f, w, s		
MetE 121—Iron Ore Beneficiation	3	.....	.....
MetE 122, 123—Hydrometallurgy	.....	3	3
MetE 134, 135, 136—Metallurgical Unit Processes	3	3	3

	Credits—f, w, s		
EE 36-37-38—Elements of Electrical Engineering	3	3	3
EE 37A-38A—Electrical Engineering Laboratory	.....	1	1
Engl 85-86—Advanced Technical Communication	.....	3	3
MinE 141—Mineral Economics (or) Geol 106—Optical Mineralogy	3	.....	.....
Technical elective (see statement below)	.....	.....	3
Nontechnical electives (see Index for "Elective Groups")	4	3	.....
Total credits	16	16	16

Credits beyond the curriculum requirements may be taken by special permission.

Recommended Technical Electives—ChE 119-120; MetE 138, 144; MinE 122, 124; Met 180-181-182.

Other Electives—MetE 124-125-126, 141-142-143; Phys 107-109-111, 144; InCh 112; ChEn 111, 112; GE 101; IE 50; ME 198; ITM 150, 151, 152.

Co-operative Work-Study Curriculum—A 5-year work-study curriculum designed to provide both theoretical and practical training is offered in co-operation with industry. The program is available to all qualified students registered in the metallurgical engineering curriculum and leads to the degree of bachelor of metallurgical engineering. Students who will complete their first 2 years of Lower Division studies (or the equivalent) in the Institute of Technology, or other college having a co-ordinated program, with a grade point average of 2.00 or better are eligible. Applications should be filed preferably by February 1 preceding the completion of the second year's work, but no later than the beginning of the fall quarter of the third year. Those students whose applications are received by February 1 may work on an industrial assignment in the summer between their second and third years. This period of work is not mandatory, though desirable. The regular work-study program starts at the beginning of the fall quarter of the third year.

The first required industrial assignment is made during the summer following the completion of the third year. The remaining 2 work quarters will be taken during the fourth and fifth school year for all students registered in the work-study program. 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 a B.Met.E. will require the satisfactory completion of all the basic required University work as designated in the 5-year metallurgical engineering work-study curriculum, including a minimum of 3 quarters of supervised industrial experience. In addition to the prescribed courses, sufficient electives must be taken to complete a total of at least 250 credits, including field trips, for graduation.

Students in metallurgical engineering should contact the head of the School of Mines and Metallurgy (or the director of the work-study program, Institute of Technology) for information. Candidates will be selected on the basis of scholastic ability, financial need, personal qualifications, and fitness for work.

Any student on the work-study program who wishes to obtain a B.S. degree after 4 years should consult with the head of the School of Mines and Metallurgy.

Mining Engineering

A 5-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 245 credits, exclusive of summer field trips, is required for graduation.

The 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 Division of Mineral Engineering 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.

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 division 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.

Additional geophysics courses are recommended to supplement these curriculums. 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, may be substituted for prescribed credits.

Students taking the combined curriculum with business administration may substitute business courses for electives Group II, Group III (see section on Electives).

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

The department recommends that students in mining engineering elect the following courses instead of Phys 51 or OrCh 16:

	Credits—f, w, s		
InCh 11—Semimicro Qualitative Analysis	.....	.....	4
MinE 1—Mineral Engineering Laboratory	.....	.....	1
Phys 14A, 50A—Physics Laboratory	1	1	.....

UPPER DIVISION

Third Year

	Credits—f, w, s		
MinE 111-112—Exploration, Development, Exploitation of Mineral Deposits (or) PetE 111, 112—Oil Field Development; Oil Field Production	3	3	.....
MinE 131—Rock Mechanics I	.....	.....	3

MinE 13—Mine Surveying	.....	.....	3
Geol 1-2—General Geology (Physical and Historical)	3	3	.....
Geol 23-24, 25—Mineralogy; Rock Study	4	4	2
CE 18, 20—Surveying	3	.....	3
Hydr 103—Fluid Mechanics	.....	.....	5
Hydr 104—Fluid Mechanics Laboratory	.....	.....	1
MM 28, 40, 142—Rigid-Body Mechanics II; Deformable-Body Mechanics I; Experimental Mechanics	3	3	2
IE 50—Elements of Industrial Engineering and Management	.....	3	.....
Total credits	16	16	19

Mining Option in Mining Engineering—For those students interested primarily in the engineering, valuation, and exploitation of metallic and nonmetallic minerals. The curriculum is designed to prepare the graduate for responsible positions in the field of mining.

Summer Field Trip

MinE 15A—Mine Surveying Field Work (4 weeks) ..... 6 credits

Fourth Year

	Credits—f, w, s		
MinE 16—Mine Maps	.....	.....	1
MinE 121—Mine and Petroleum Plant Engineering	.....	.....	3
MinE 132—Rock Mechanics II	3	.....	.....
MetE 110, 111—Mineral Dressing	4	4	.....
Geol 110-111—Economic Geology	.....	3	3
Geol 125—Structural Geology	4	.....	.....
EE 36, 40—Elements of Electrical Engineering; Electrical Engineering Survey	3	4	.....
ME 30—Thermodynamics (see statement below)	3	.....	.....
Technical electives (see statement below)	.....	3	6
Nontechnical electives—Group II or Group III (see Index for "Elective Groups")	.....	3	3
Total credits	17	17	16

Technical Electives—Technical electives must be selected from the following list:

MinE 123—Mine Air Conditioning
MinE 133—Rock Mechanics III
MinE 142—Surface Mine Engineering
MetE 12—Metallurgical Processes
MetE 112—Mineral Dressing
MetE 121—Iron Ore Beneficiation
GPhy 110—Introduction to Exploration Geophysics
CE 37—Elementary Structural Engineering
ME 31—Thermodynamics
IE 153—Methods of Engineering and Work Measurement
IE 155—Industrial Wage Administration
IE 165—Industrial Plants
IE 170—Production Planning and Control
IE 173—Engineering Economic Analysis

The student has the choice of the following as a substitute for ME 30 and one of the above-listed courses.

PCh 101-102—Physical Chemistry	4	4	.....

Nontechnical Electives—Recommended courses are in Group II: Econ 1T-2T; BA 52, 55A, 55C, 58, 60.

Summer Field Trip

MinE 139—Inspection trip (study of mining operations, mine plants, and metallurgical plants in several mining areas) (2 weeks) ..... 3 credits

Fifth Year

	Credits—f, w, s		
MinE 122—Mine Plant Engineering	3	.....	.....
MinE 141—Mineral Economics	3	.....	.....
MinE 144-145—Advanced Mining Engineering	.....	2	4
Engl 85-86—Advanced Technical Communications	3	3	.....
Technical electives (see statement below)	3	6	3
Nontechnical electives—Group II or Group III (see Index for "Elective Groups")	3	4	3
Total credits	15	15	10

Technical courses must be selected from the list shown under fourth year.
Recommended courses for nontechnical electives—see list under fourth year.

Petroleum Option in Mining Engineering—For those students interested primarily in the engineering, valuation, and exploitation of petroleum. The curriculum is designed to prepare the graduate for positions in the field of petroleum production.

Third Year Summer Field Trip

MinE 15A—Mine Surveying Field Work (4 weeks) ..... 6 credits

Options: Either Geol 150 or MinE 15A. MinE 15A must be followed by MinE 16 (1 credit) which may be used to satisfy Institute of Technology elective requirements.

Fourth Year

	Credits—f, w, s		
PetE 131—Reservoir Mechanics	.....	.....	3
PetE 134—Natural Gas Engineering	.....	2	.....
MinE 121—Mine and Petroleum Plant Engineering	.....	.....	3
Geol 101—Sedimentation	3	.....	.....
Geol 112—Petroleum Geology	3	.....	.....
Geol 125—Structural Geology	4	.....	.....
Geol 153—Subsurface Stratigraphy	.....	.....	2
EE 36, 40—Elements of Electrical Engineering; Electrical Engineering Survey	3	4	.....
ME 30-31—Thermodynamics	.....	3	3
PCh 101-102—Physical Chemistry	4	4	.....
Nontechnical electives (Group II or Group III)	.....	3	6
Total credits	17	16	17

Nontechnical Electives—Recommended courses are in Group II: BA 52, 55A, 55C, 58, 60; Econ 1T-2T.

Spring Field Trip

PetE 135—Inspection Trip ..... 3 credits

Fifth Year

		Credits—f, w, s		
PetE 144-145—Advanced Petroleum Engineering		.....	2	4
PetE 152-153-154—Petroleum Production Technology		3	3	3
MinE 141—Mineral Economics		3	.....	.....
Engl 85-86—Advanced Technical Communication		3	3	.....
CE 37—Elementary Structural Engineering GPhy 110—Introduction to Exploration Geophysics ME 24—Elements of Machine Design Met 56—Physical Metallurgy MinE 132—Rock Mechanics II IE 153—Methods Engineering and Work Measurement IE 155—Industrial Wage Administration IE 170—Production Planning and Control	3 courses required	3	3	3
Nontechnical electives (Group II and Group III)		3	4	.....
Total credits		15	15	10

Co-operative Work-Study Curriculum—A 5-year work-study curriculum designed to provide both theoretical and practical training is offered in co-operation with industry. The program is available to all qualified students registered in the mining engineering curriculum and leads to the degree of bachelor of mining engineering. Students who will complete their first 2 years of Lower Division studies (or the equivalent) in the Institute of Technology, or other college having a co-ordinated program, with a grade point average of 2.00 or better are eligible. Applications should be filed preferably by February 1 preceding the completion of the second year's work, but no later than the beginning of the fall quarter of the third year. Those students whose applications are received by February 1 may work on an industrial assignment in the summer between their second and third years. This period of work is not mandatory, though desirable. The regular work-study program starts at the beginning of the fall quarter of the third year.

The first required industrial assignment is made during the summer following the completion of the third year. The remaining 2 work quarters will be taken during the fourth and fifth school year for all students registered in the work-study program. 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 a B.Min.E. will require the satisfactory completion of all the basic required University work as designated in the 5-year mining engineering work-study curriculum, including a minimum of 3 quarters of supervised industrial experience. In addition to the prescribed courses, sufficient electives must be taken to complete a total of at least 254 credits, including field trips, for graduation.

Students in mining engineering should contact the head of the School of Mines and Metallurgy (or the director of the work-study program, Institute of Technology) for information. Candidates will be selected on the basis of scholastic ability, financial need, personal qualifications, and fitness for work.

Any student on the work-study program who wishes to obtain a B.S. degree after 4 years should consult with the head of the School of Mines and Metallurgy.

SCHOOL OF ARCHITECTURE

The School of Architecture offers three curriculums:

Five-Year Curriculum—Leads to the degree of bachelor of architecture, B.Arch. It normally requires 1 year of prearchitectural work followed by 4 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 Curriculum—Leads to the degree of bachelor of arts, B.A., in the College of Science, Literature, and the Arts with a major in architecture. It normally requires 2 years of prerequisite work in the Lower Division. Two additional years in the Upper Division 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 specialized fields of architecture, city planning, landscape architecture, and decorative, industrial, or interior design. With appropriate modifications, it provides the first 4 years' work of the 6-year curriculum described below. For further details, see the *Bulletin of the College of Science, Literature, and the Arts.*

Six-Year Curriculum (combined)—Leads to both degrees, B.A. and B.Arch. It normally constitutes a modification of the 4-year curriculum described above followed by 2 years in the School of Architecture to complete the requirements for the B.Arch. degree.

In addition to the above, the School of Architecture offers work on the graduate level leading to the degree of master of architecture, M.Arch. For details see *Bulletin of the Graduate School.*

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

Enrollment as a candidate for the B.Arch. and B.A. degrees in the three curriculums described requires approval by the School of Architecture. A prerequisite for such approval is completion of work as follows:

Five-year curriculum—Completion of the recommended first year of college work (see following).

Four-year curriculum—Completion of 2 years of college work required for entrance to the Upper Division of the College of Science, Literature, and the Arts as stated in its bulletin.

Six-year curriculum—Completion of the B.A. degree with a major in architecture in the College of Science, Literature, and the Arts.

Upon completion of the required prerequisite work, application shall be made to the School of Architecture for enrollment in the desired curriculum. Application forms may be obtained from the School of Architecture or from the Office of Admissions and Records. *Applications should be submitted not later than July 15 preceding the beginning of the academic year for which admission is being sought.* Entrance to beginning architectural design (Arch 81) is permitted only in the fall quarter. Approval will be based on a consideration of (a) the student's scholastic standing in previous high school and college work, (b) his maturity and experience, (c) his professional aptitude and objective, and (d) the work space and instructional facilities of the School of Architecture. Prospective students are urged to consult advisers in the School of Architecture, 110 Architecture building.

FIVE-YEAR CURRICULUM

The core of study is a sequence of 4 years of architectural design, providing cumulative experience with a large number of design problems involving an evaluation of all pertinent factors of site, climate, purpose and social setting, and providing scope for the application of the student's growing knowledge of materials and building techniques as well as his judgment and creative skill. The permanent faculty is regularly supplemented by part-time instructors active in the profession and by visiting critics. Field inspection trips are included in the course work.

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 Arch 121-122 and by choice of thesis subject in Arch 123.

Before entrance into Arch 123, the student is required to have fulfilled a minimum of 800 hours of practical experience outside of classwork, or its equivalent.

In addition to the prescribed courses, sufficient approved electives must be taken to make a minimum total of 237 credits. 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 the University and the School of Architecture.

First Year

	Credits—f, w, s		
EG 14, 15, 16—Engineering Graphics (see statement below)	3	3	3
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Phys 11-12-13—General Physics	5	5	5
Total credits	18-17	18-17	18-17

Architecture students should enroll in special session of EG 16. See spring quarter *Class Schedule.*

The first year of prearchitectural work may also be taken in the College of Science, Literature, and the Arts. This work should include Freshman English, Math T (Trigonometry), Math 15 (College Algebra), Math 49 (Analytic Geometry and Calculus I), and Phys 1-2-3, 1A-2A-3A and should total a minimum of 45 credits. In choosing electives, preference should be given to history, economics, political science, sociology, and foreign language.

A year of comparable college work taken elsewhere is also acceptable.

Second Year

	Credits—f, w, s		
Arch 81-82-83—Architectural Design I	6	6	6
Art 23A-24A-25A—Drawing and Painting I	2	2	2
ITM 24A—Calculus II: Analytic Geometry and Calculus (or) Math 53—Analytic Geometry and Calculus II	5	.....	.....
MM 92, 93—Statics; Solid Mechanics for Architects	.....	4	4
Nontechnical electives—Group II or III (see Index for "Elective Groups")	3	3	3
Total credits	16	15	15

Third Year

	Credits—f, w, s		
Arch 71-72-73—Building Technology	4	4	4
Arch 91-92-93—Architectural Design II	6	6	6
Art 60A-61A-62A—Drawing and Painting II	2	2	2
CE 38-39-41—Structural Design in Steel, Steel and Timber, Concrete	3	3	3
Nontechnical electives—Group II or III (see Index for "Elective Groups")	3	.....	.....
Total credits	18	15	15

Fourth Year

	Credits—f, w, s		
Arch 51-52-53—History of Architecture	4	4	4
Arch 74-75-76—Building Technology	4	4	4
Arch 111-112-113—Architectural Design III	8	8	8
Total credits	16	16	16

Fifth Year

	Credits—f, w, s		
Arch 104—Planning	3	.....	.....
Arch 121-122—Architectural Design IV	9	9	.....
Arch 123—Thesis	.....	.....	12
Arch 126—Professional Relations	.....	3	.....
Approved electives	3	3	3
Total credits	15	15	15

FOUR-YEAR CURRICULUM

First and Second Years

The first- and second-year work is taken in the Lower Division of the College of Science, Literature, and the Arts as outlined in its bulletin. The following requirements must be included for admission to the major in architecture in the Upper

Division: High school or college equivalents of higher algebra, solid geometry, Phys 1-2-3, 1A-2A-3A, Art 23A, 24A, 25A.

Third and Fourth Years

During the third and fourth years the student is registered in the Upper Division of the College of Science, Literature, and the Arts as a major in architecture. The major sequence of courses is as follows:

	Credits—f, w, s		
Arch 51-52-53—History of Architecture	4	4	4
Arch 81-82-83—Architectural Design I	6	6	6
Arch 91-92-93—Architectural Design II	6	6	6

See the *Bulletin of the College of Science, Literature, and the Arts* for complete Upper Division requirements.

SCHOOL OF CHEMISTRY

Three undergraduate curriculums are offered through the School of Chemistry: a 4-year program in chemistry, a 5-year program in chemical engineering, and a 5-year program in metallurgy. Each program is discussed separately below. A 4-year program is also offered to those chemical engineering and metallurgy students who are qualified and intend to pursue graduate work.

In addition to the curriculums mentioned above, a combined chemistry and education curriculum is offered leading at the end of 5 years to the Bachelor's degree in chemistry and the Master's degree in education.

Chemistry

A 4-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 203 credits.

The curriculum in chemistry more than fulfills the requirements of the American Chemical Society and also prepares the student for graduate work at any university. Included are courses to provide an adequate background in the related fields of physics and mathematics and to give wide acquaintance with the nontechnical fields. Many students are stimulated to seek graduate degrees in chemistry leading to an even broader selection of careers than is available to the holder of the Bachelor's degree. The chemistry curriculum is often selected by students who plan advanced work in biochemistry. It is also an excellent basis for many other professional careers.

The field of chemistry embraces a multitude of areas of activity from fundamental and applied research to technical sales promotion. Pharmaceutical chemistry, biochemistry, the production of paints, dyes, pigments, synthetic polymers, rubbers, leathers and textiles, fuels, metals, detergents, rocket propellants, and many other fields stem from and depend on chemistry and chemists.

Chemists have in common an interest in the fundamental chemical mechanisms of the world in which we live. Thus the chemist is essentially a research man seeking to understand and control his environment. His choice of field is enormous. He may be interested in the basic biological mechanisms of muscle, or plant photosynthesis or perhaps the development of new rocket fuels or again the chemical events in nuclear disintegrations. He may want to know exactly how molecules are made up from component atoms or he may want to know how to improve antibiotics.

Because chemistry is the basis for so many different types of activity, the holder of a degree in chemistry can choose among many careers. He may be-

come a teacher yet play an active role in advancing our knowledge of science; he may help to control important industrial processes or to develop new processes; he may choose team attack with medical scientists on the crucial problems of disease. Even if he selects a career outside the field of chemistry he may find his chemical knowledge to be of considerable value in solving problems that arise from time to time. His choice is great and his chance for a good position in his chosen area is very good. Today manufacturing chemistry is the largest of all our manufacturing industries.

LOWER DIVISION

First Year

	Credits—f, w, s		
InCh 24-25-26 or 24-25H-26H—Introduction to Chemical Principles	5	5	5
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Engl A-B-C—Freshman Literature and Composition	5	5	5
Electives	3	3	3
Total credits	18	18	18

Second Year

	Credits—f, w, s		
OrCh 61-62, 63—Elementary Organic Chemistry	4	4	3
OrCh 64—Elementary Organic Chemistry Laboratory	.....	.....	3
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Phys 7-8-9—General Physics	5	5	5
Electives	3	3	.....
Total credits	17	17	16

UPPER DIVISION

Third Year

	Credits—f, w, s		
AnCh 100-101—Quantitative Analysis	2	3	.....
AnCh 102—Laboratory in Gravimetric and Volumetric Analysis	.....	.....	4
OrCh 102—Organic Qualitative Analysis	4	.....	.....
PCh 101-102-103 or 101H-102H-103H—Physical Chemistry	4	4	4
Ger 50-51-52—Reading German	3	3	3
Electives	3	6	6
Total credits	16	16	17

Ger 1B-2B-3B or 1C-2C-3C may be taken in place of Ger 50-51-52. These courses contribute 6 credits of nonscientific electives in addition to meeting the German requirement.

Fourth Year

	Credits—f, w, s		
AnCh 111—Physicochemical Methods of Analysis	3	.....	.....
AnCh 112—Physicochemical Methods of Analysis (Laboratory)	.....	2	.....
InCh 103, 104—Atomic Structure and the Properties of the Elements Based Thereon; Chemistry of the More Representative Elements	3	3	.....
Ch 96-97-98—Senior Thesis	3	3	3
InCh 122—Advanced Inorganic Chemistry Laboratory	.....	.....	2
PCh 104-105—Physical Chemistry Laboratory	2	2	.....
Electives	6	6	12
Total credits	17	16	17

Senior Thesis may be elected by students having a grade average of B or better. PCh 106, Physical Chemistry Laboratory (2 credits), is required of students not taking Senior Thesis.

Electives—Electives total 54 credits. Of these 54 elective credits, 32 should be in nonscientific electives courses and 22 should be in scientific elective courses.

Of the 22 scientific elective credits, 6 must be in one of the sequences of Group I of the elective groups (see Index for "Elective Groups"). Sixteen more credits may be chosen from the following list:

Any IT field	Geophysics	Physical Geology
Astronomy	Mathematics	Physics
Biochemistry	Medical Technology	Physiological Chemistry
Biology	Microbiology	Physiology
Botany	Mineralogy	Plant Physiology
Geology	Natural Science	Zoology

Nonscientific electives are defined as subjects other than those listed above as scientific electives. Of the minimum of 32 nonscientific elective credits, 6 must be in one of the sequences of Group II and 6 in one of the sequences of Group III of the nontechnical electives. In so far as possible, a major fraction of the remaining nonscientific credits are to be devoted to a single cultural area.

In certain instances specialization in microbiology, biochemistry, or geology may seem desirable. Upon petition the student may request the use of a smaller minimum of nonscientific elective credits to achieve such specialization.

Combined Chemistry and Education Curriculum—A 5-year curriculum that leads to the degree of bachelor of chemistry and the degree of master of education, M.Ed., upon completion of a total of 235 credits. See general statement on page 10.

First Year

	Credits—f, w, s		
InCh 24-25-26—Introduction to Chemical Principles	5	5	5
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5

Option I

Engl A-B-C—Freshman Literature and Composition	5	5	5
Physical education (required for the master of education degree)	1	1	1

Option II

Engl 1A-2A-3A—Freshman English	4	4	4
Elective	3	3	3
Total credits (Option I)	16	16	16
Total credits (Option II)	17	17	17

Second Year

	Credits—f, w, s		
OrCh 61-62, 63—Elementary Organic Chemistry	4	4	3
OrCh 64—Elementary Organic Chemistry Laboratory	.....	.....	3
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Phys 7-8-9—General Physics	5	5	5
Psy 1-2—General Psychology	3	3	.....
Physical education (for those taking Option II; required for the master of education degree)	1	1	1
Total credits	17-18	17-18	16-17

Third Year

	Credits—f, w, s		
AnCh 100-101—Quantitative Analysis	2	3	.....
AnCh 102—Laboratory in Gravimetric and Volumetric Analysis	.....	.....	4
PCh 101-102-103 or 101H-102H-103H—Physical Chemistry	4	4	4
Ger 50-51-52—Reading German	3	3	3
Electives	6	6	6
Total credits	15	16	17

Fourth Year

	Credits—f, w, s		
PCh 104-105-106—Physical Chemistry Laboratory	2	2	2
InCh 122—Advanced Inorganic Chemistry Laboratory	...	...	2
OrCh 102—Organic Qualitative Analysis	4	...	...
Phys 50, 50A, 51, 51A—Intermediate General Physics	...	5	5
PubH 50—Personal and Community Health (required for the master of education degree)	...	...	3
EPsy 193, 116, 117—Psychology of Human Learning; Introduction to Statistical Methods; Basic Principles of Measurement	3	3	3
EdT 68—Student Teaching in Science	1	1	1
EdT 68A-B-C—Teaching of Secondary Science	3	1	1
CD 132—Adolescent Psychology	...	3	...
Electives (those taking Option II may omit these electives)	3	3	...
Total credits	16	18	17

Fifth Year

	Credits—f, w, s		
AnCh 111, 112—Physicochemical Methods of Analysis	3	2	...
InCh 103, 104—Atomic Structure and the Properties of the Elements Based Thereon; Chemistry of the More Representative Elements	3	3	...
EdCI 113—High School Curriculum	3	...	...
EdCI 199E—Teaching Internship	...	...	12
EdT 68—Student Teaching in Science	...	3	...
EdT 67M—Teaching of Secondary School Mathematics	3	...	...
EPsy 208—Methods in Educational Research	...	3	...
HEd 180—The School and Society	3	...	...
Total credits	15	11	12

Chemical Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of chemical engineering, B.Chem.E. Qualified students are eligible for a bachelor of science degree if they enter the graduate school at the University of Minnesota (or elsewhere) at the beginning of the fifth year. Students who are interested in the 4-year B.S. degree should consult with their advisers or the department head as early as possible so that the proper program of study can be planned.

In addition to the prescribed courses, sufficient approved electives must be taken to complete a total of 255 credits. Students are urged to consult with their advisers when making out programs of study in order that their best interests may be served.

Chemical engineering is based on the application of an exceptionally broad base of engineering science and of basic chemistry, physics, and mathematics as well as economics. The chemical engineer is therefore particularly well suited to engage in a very wide variety of industries and activities in research, in development of new processes, in manufacturing, or in marketing. Chemical engineering deals in particular with the unit operations such as crushing and grinding, mixing, fluid mechanics and heat transfer, filtration, drying, distillation absorption, extraction, crystallization as well as chemical processing. These operations are vital in making an industry based on a chemical or physical transformation a commercial success. The field of chemical engineering is a rapidly developing one and the chemical engineer is often engaged in basic and applied research on new products or processes. 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 physiochemical, chemical, or microbiological and engineering principles on which they are based. The study of such principles constitutes that branch of engineering known as chemical engineering. The chemical engineer is primarily a producer and it is his province to develop a process from the laboratory stage through semi-works equipment to the production stage.

Because many industries are based on some chemical or physical process involving the transformation of matter, the chemical engineer is much in demand. He may be engaged in the manufacture of inorganic products—acids, alkalies, ammonia, paint pigments, fertilizers; in the organic industries—dyes, explosives, textiles, fibers, rubber, rocket fuels, solvents, plastics, agricultural chemicals, pharmaceuticals, or petroleum products; in the manufacture of gases—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; in the food industries involving the processing of various food products; and even in the fermentation industry for production of chemicals such as antibiotics, feed supplements, and the like. There are many other products such as petroleum, nuclear materials, paper, glass, and cement.

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

The chemical engineer may also enter into the field of nuclear engineering which encompasses the processing, separation, development, and testing of materials for nuclear reactors; the design and operation of nuclear reactors for research, isotope production, breeding, heat and power generation; and the utilization as well as the disposal of radionuclides and fission products. He may also enter the field of biochemical engineering which involves the treatment of products of biological origin. For this purpose, he must have a sound background in microbiology and biochemistry. The curriculum provides opportunities for the student to choose directions of particular interest to him.

LOWER DIVISION

First Year

	Credits—f, w, s		
InCh 24-25-26—Introduction to Chemical Principles	5	5	5
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Calculus I: Analytic Geometry and Calculus	5	5	5
Electives—Group I or II (see Index for "Elective Groups")	3	3	3
Total credits	18-17	18-17	18-17

Second Year

	Credits—f, w, s		
OrCh 61-62, 63—Elementary Organic Chemistry	4	4	3
OrCh 64—Elementary Organic Chemistry Laboratory	.....	.....	3
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Phys 7-8-9—General Physics	5	5	5
Electives—Group II or I (see Index for "Elective Groups")	3	3	3
Total credits	17	17	19

Students in the chemical engineering curriculum are required to complete a minimum of 6 credits in a single course sequence of biological science electives (Group I).

UPPER DIVISION

Third Year

	Credits—f, w, s		
ChEn 100—Chemical Engineering Stoichiometry	3	.....	.....
ChEn 101, 102, 103—Principles of Chemical Engineering	5	5	3
ChEn 119-120—Chemical Engineering Thermodynamics	.....	3	3
AnCh 100-101—Quantitative Analysis	2	3	.....
AnCh 102A—Laboratory in Gravimetric and Volumetric Analysis	.....	.....	3
PCh 101-102-103—Physical Chemistry	4	4	4
Electives (consult adviser)	3	3	3
Total credits	17	18	16

Students who choose the biochemical engineering option should take Micb 53 (5 credits) in the fall quarter of the third year. MM 27 and 28 may be taken out of sequence since these are offered every quarter.

Fourth Year

	Credits—f, w, s		
ChEn 111, 112, 113—Chemical Engineering Laboratory	2	2	2
ChEn 131-132—Chemical Reactor Analysis	....	3	3
PCh 104-105-106—Physical Chemistry Laboratory	2	2	2
PCh 109—Physical Chemistry	4	....	....
MM 27, 28, 40—Rigid-Body Mechanics I and II; Deformable-Body Mechanics I	3	3	3
Technical electives (consult adviser)	3	3	3
Electives—Group III (see Index for "Elective Groups")	4	4	4
Total credits	18	17	17

Biochemical Engineering Option—It is possible in the fourth year to choose courses ChEn 122, Biochemical Engineering, and ChEn 123, Biochemical Engineering Laboratory, which together with Micb 53 make up the option in biochemical engineering. Students should consult with Professor Tsuchiya.

Fifth Year

	Credits—f, w, s		
ChEn 116-117-118—Process Evaluation and Design	3	3	3
ChEn 171-172—Process Control	3	3	....
EE 36-37-38—Elements of Electrical Engineering	3	3	3
EE 37A-38A—Electrical Engineering Laboratory	....	1	1
Engl 85-86—Advanced Technical Communication	....	3	3
Met 60—Physical Metallurgy	3	....	....
Met 161—Corrosion of Metals	....	....	2
Electives	3	5-2	3
Total credits	15	18-15	15

Chemical Engineering Advisers for Seniors—Professors Amundson, Ceaglske, Isbin, Piret, Ranz, Madden, Preckshot, Tsuchiya, Aris, Dahler, Fredrickson, Scriven.

Metallurgy

A 5-year curriculum is offered which leads to the degree of bachelor of metallurgy, B.Met.

A total of 249 credits is required for graduation.

Metallurgy is the application of scientific principles to the purification of metals (chemical metallurgy), and to the effective utilization of metals and alloys based upon the control of their properties (physical metallurgy).

Metallurgy is founded on the basic sciences of physics and chemistry. Therefore these subjects form a large part of the metallurgical curriculum. Considerable emphasis is also placed upon the structure of crystalline solids and the relation of structure to the properties of matter.

Chemical metallurgy involves application of the principles of physical chemistry, particularly of thermodynamics, and a basic knowledge of the procedures of chemical engineering. Physical metallurgy combines the disciplines of physics, physical chemistry, and mechanics concentrating particularly on the theory of solids and the structure of crystals.

The recent technological advances in such fields as nuclear energy, jet propulsion, and rocketry have created demands for materials with properties heretofore not available. To meet this demand, metallurgists are constantly engaged in research on the nature and properties of metals in order to develop suitable alloys.

Because of the importance of metallurgy to modern technology, metallurgists are in demand not only in the metal producing industries but in the metal consuming industries as well where they find work in plant operation, research, and management.

Students interested in business and engineering administration may elect a combined curriculum of metallurgy and business administration by substituting with the approval of the Department of Metallurgy business courses satisfactory to the School of Business Administration for certain nontechnical electives and engineering electives.

A student may be granted a B.S. degree after 4 years and start graduate study in the fifth year if he meets the requirements outlined in the general section on Requirements for Graduation.

LOWER DIVISION

First Year

See first-year curriculum for the College of Engineering.

Second Year

See second-year curriculum for the College of Engineering.

The department recommends that students in metallurgy substitute Phys 51 for MM 27 and elect the following courses:

	Credits—f, w, s		
Met 1—Metallurgy Laboratory	.....	.....	1
InCh 11—Semimicro Qualitative Analysis	.....	.....	4
Phys 14A, 50A—Physics Laboratory	1	1	.....

UPPER DIVISION

Before the beginning of the third year, it is recommended students obtain departmental approval of their complete elective program. Recommended technical electives follow the fifth year curriculum. Others may be taken with departmental approval.

Third Year

	Credits—f, w, s		
PCh 101-102-103—Physical Chemistry	4	4	4
Met 153, 154, 155—Principles of Physical Metallurgy I, II, III	3	3	3
Met 153A, 154A, 155A—Laboratory in Physical Metallurgy	2	2	2
MM 27, 40, 28—Rigid-Body Mechanics I; Deformable-Body Mechanics I; Rigid-Body Mechanics II	3	3	3
MM 142—Experimental Mechanics	.....	.....	2
Electives—Group I, II, or III (see Index for "Elective Groups")	3-4	3-4	3-4
Total credits	15-16	15-16	17-18

Fourth Year

	Credits—f, w, s		
Met 180-181-182—Thermodynamics and Kinetics of the Solid State	3	3	3
EE 36-37-38—Elements of Electrical Engineering	3	3	3
Technical electives	6	6	6
Electives—Group I, II, or III (see Index for "Electives Groups")	3	3	3
Total credits	15	15	15

Field Trip

MetE 75—Metallurgical Engineering Inspection Trip (offered during 4th or 5th year) ..... 2 credits

Met 90 and 91 together, 2 credits each, may be substituted for field trip, if both are completed before the field trip is offered.

Fifth Year

	Credits—f, w, s		
Met 173,174,175—Crystalline Properties of Metals; Modern Theory of Metals and Alloys; Imperfections in Metals	3	3	3
Engl 85-86—Advanced Technical Communication	3	3	.....
Technical electives	6	6	6
Electives—Group I, II, or III (see Index for "Elective Groups")	3	3	3
Total credits	15	15	15

Recommended Technical Electives—ChEn 161-162-163; OrCh 16, 61-62, 63; PCh 104, 109, 117, 118; GE 101; EE 37A-38A; ITM 147, 148, 149; Met 57, 161, 162, 162A, 167, 168, 169, 170-171-172; MetE 106, 107, 108, 134, 135, 136, 138, 141-142-143; Phys 107-109-111, 126-127-128.

SCHOOL OF PHYSICS

Major undergraduate study in the School of Physics is offered in the Institute of Technology and in the College of Science, Literature, and the Arts. While both avenues serve the function of preprofessional training in physics, the IT physics curriculum permits greater technical specialization while a major in physics in SLA permits greater curriculum flexibility in choice of arts and science courses. For details of the SLA physics program, consult the *Bulletin of the College of Science, Literature, and the Arts.*

In the Institute of Technology a 4-year curriculum is offered which leads to the degree of bachelor of physics, B.Phys. (A 5-year curriculum, offered jointly by the School of Physics and the College of Education, leads to the degrees of bachelor of physics and master of education, both conferred at the end of 5 years. For details of this curriculum, see page 74 of the IT bulletin.) A grade point average of 2.00 or higher earned for work in the Lower Division is required for admission into the Upper Division. Further, a minimum G.P.A. of 2.00 in Upper Division work must be maintained for continuation.

The curriculum is intended to be sufficiently broad in scope to provide for the needs of those who desire to prepare for industrial and governmental research fields as well as those intending to pursue the study of physics in graduate school. To encourage flexibility, the curriculum may be modified by petition to the Scholastic Standards Committee of the School of Physics.

In addition to the following prescribed courses, 60 credits of electives must be selected to complete a total of 200 credits required for the bachelor of physics degree. The electives selected must include:

1. Nine credits chosen from Ph 148, 124, 125, 108A, 110A, 112A, 126, 131, 133A, 134, 136, 165, 166, 167, 181, 183, 185.

2. Not more than 18 additional credits in the areas of mathematics, engineering, and the physical sciences (physics, chemistry, astronomy, geology). These electives are to supplement the required physics curriculum and when possible should be from the Upper Division offerings in these areas. A year of graphics, if taken during the first year, is an acceptable technical elective.

3. Not less than 33 credits chosen in the areas of biological sciences (Group I), social sciences (Group II), and humanities (Group III), or from the Additional Electives list (see Index for Additional Electives). A 6-credit sequence in *each* of Groups II and III plus 6 credits in a sequence of Group I or in courses listed in Groups II and III must be selected.

LOWER DIVISION

First Year

	Credits—f, w, s		
Phys 11-12-13—General Physics (Phys 7-8-9, requiring more advanced mathematics prerequisites, substitutes directly for Phys 11, 12, 13, 14, 14A and should be elected by adequately prepared students)	5	5	5
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Electives	3	3	3
Total credits	18-17	18-17	18-17

Second Year

	Credits—f, w, s		
Phys 14, 50, 51—Intermediate General Physics	4	4	4
Phys 14A, 50A, 51A—Physics Laboratory	1	1	1
InCh 14-15—Inorganic Chemistry	4	4	.....
OrCh 41—Elementary Organic Chemistry	.....	.....	4
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Electives	3	3	3
Total credits	17	17	17

UPPER DIVISION

Third Year

	Credits—f, w, s		
Phys 100A-101A-102A—Introduction to Analytic Mechanics	3	3	3
Phys 144—Electrical Measurements	4	.....	.....
Phys 146—Physics of Vacuum Tubes and Associated Circuits	.....	4	.....
ITM 151, 152, 153—Calculus V, VI, VII: Advanced Calculus	3	3	3
Ger 50-51-52—Reading German for Juniors and Seniors (with the adviser's consent, the entire sequence Ger 1-2-3 or Russ 1-2-3 may be substituted for Ger 50-51-52. The 6 extra credits so earned may be applied toward the elective requirements)	3	3	3
Electives	3	6	9
Total credits	16	19	18

Fourth Year

	Credits—f, w, s		
Phys 103A-104A-105A—Introduction to Electric and Magnetic Fields	3	3	3
Phys 123—Thermodynamics	3	.....	.....
Advanced Laboratory—Any 2 quarters of Phys 120, 121, 122 are required	3	3	.....
Phys 133—Physical Optics	.....	.....	3
Electives	6	6	9
Total credits	15	15	15

Combined Physics and Education Curriculum—A 5-year curriculum is offered by the School of Physics and the College of Education leading to the degrees of bachelor of physics and master of education conferred at the end of 5 years. Application for admission to this program is to be made early in the third quarter of the third year. Admission requirements, registration procedure, and graduation requirements for this program are discussed in the *Bulletin of the College of Education.*

First Year

	Credits—f, w, s		
Phys 11-12-13—General Physics	5	5	5
EG 14—Engineering Graphics	3	.....	.....
Engl A-B-C—Freshman Literature and Composition (or) Engl 1A-2A-3A—Freshman English (or) Engl 1B-2B-3B—Freshman English	5-4	5-4	5-4
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Electives—Group II (see Index for "Elective Groups")	.....	3	3
Total credits	18-17	18-17	18-17

Second Year

	Credits—f, w, s		
Phys 14, 50, 51—Intermediate General Physics	4	4	4
Phys 14A, 50A, 51A—Physics Laboratory	1	1	1
InCh 14-15—Inorganic Chemistry	4	4	.....
OrCh 41—Elementary Organic Chemistry	.....	.....	4
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Psy 1, 2—General Psychology	.....	3	3
PubH 50—Personal and Community Health	3	.....	.....
Total credits	17	17	17

Third Year

	Credits—f, w, s		
Phys 100-102-104—Mechanics, Electricity, and Magnetism	4	4	4
Phys 144—Electrical Measurements	4	.....	.....
Phys 146—Physics of Vacuum Tubes and Associated Circuits	.....	4	.....
Phys 133, 133A—Physical Optics, Physical Optics Laboratory	.....	.....	4
ITM 151, 152, 153—Calculus V, VI, VII: Advanced Calculus	3	3	3
Electives—Group II (see Index for "Elective Groups")	3	3	3
Electives—Group III (see Index for "Elective Groups") (or) Ger 50-51-52—Reading German for Juniors and Seniors	3	3	3
Total credits	17	17	17

Fourth Year

	Credits—f, w, s		
Phys 107-109-111—Atomic and Nuclear Physics	3	3	3
OrCh 62, 63—Elementary Organic Chemistry	.....	4	4
PCh 107-108—Elementary Physical Chemistry (or) PCh 101-102-103—Physical Chemistry	3-4	3-4	0-4
Physical education	1	1	1
EPsy 193—Psychology of Human Learning	3	.....	.....
EdT 68—Student Teaching in Science	1	1	1
EdT 68A-B-C—Teaching Secondary School Science	3	1	1
CD 132—Adolescent Psychology	.....	.....	3
EdCI 113—High School Curriculum	3	.....	.....
EPsy 116, 117—Introduction to Statistical Methods; Basic Principles of Measurement	.....	3	3
Total credits	17-18	16-17	16-20

Fifth Year

	Credits—f, w, s		
Physics elective	6	6	.....
Mathematics elective	3	3	.....
EdT 67M—Teaching Secondary School Mathematics	3	.....	.....
EdT 68—Student Teaching in Science	.....	3	.....
EPsy 208—Methods in Educational Research	.....	3	.....
HEd 180—The School and Society	3	.....	.....
EdCI 199E—Internship	.....	.....	12
Elective	3	.....	.....
Total credits	18	15	12

IV. COURSE DESCRIPTIONS

See the *Bulletin of the Graduate School* for descriptions of courses numbered 200 and above.

Aeronautics and Engineering Mechanics

Aeronautics (Aero)

4-5-6. Aeromechanics Survey. History and technical review of aerospace vehicles. Principles of flight, stability, and control. Power plant arrangements. Review of wind tunnels and related laboratory facilities. (1 cr per qtr)

20-21-22. Flying: Theory and Practice. Consists of 12 hours of ground instructions and 10 hours of flying. (1 cr per qtr; 1 lect hr and about 1 flying hr per wk; lab fee by ar) Staloch

46. Link Instrument Flying. Lectures and practice on Link Trainer. (No cr; prereq ♯; twelve 2-hr periods) Staloch

100A. Theoretical Aerodynamics I. Kinematics of fluid field including continuity equation, vorticity, circulation, velocity potential, source, and doublet. Co-ordinate systems. Euler's equation of motion. Bernoulli's equation. (3 cr; prereq ITM 26A and Hydr 101; 3 rec hrs per wk)

101A. Theoretical Aerodynamics II. Flow about a body. Kutta-Joukowski's momentum theorem. Thin airfoil theory. Stress and strain rate. Navier-Stokes' equations. Boundary layer equation and solution along a plate. Von Karman momentum integral. Pohlhausen method. Turbulent boundary layer. (3 cr; prereq 100A; 3 rec hrs per wk)

102A. Theoretical Aerodynamics III. Review of thermodynamics. One-dimensional steady isentropic flow. Laval nozzle. Normal and oblique shock waves and reflections. Prandtl-Meyer flow. Thin airfoil theory. Similarity rule. (3 cr; prereq 101A; 3 rec hrs per wk)

103-104-105. Dynamic Stability and Control in Flight. Dynamics of rigid-body flight. Methods of solution. Longitudinal and lateral stability. Flap control. Measurements of aerodynamic derivatives. (3 cr per qtr; prereq 108; 3 lect hrs per wk)

106A. Applied Aerodynamics I. Standard atmosphere and outer atmosphere. Aerodynamics of subsonic, transonic, and supersonic airfoils. Wing theory. Interference effects of body, wing, and tail planes. Propellers. (3 cr; prereq 102A; 3 lect hrs per wk)

107A. Applied Aerodynamics II. Dynamic equations of aircraft and missiles. Power balance for different propulsion systems. Take-off, landing, climb, ceiling, range, and endurance. Missile trajectories. (3 cr; prereq 106A; 3 lect hrs per wk)

108. Applied Aerodynamics III. Longitudinal and lateral stability and control of rigid aircraft and missiles. Power, dihedral and steady state aeroelasticity effects. (3 cr; prereq 107A; 3 lect hrs per wk)

110. Compressible Viscous Flow. Navier-Stokes' equation of compressible viscous fluid. Energy equation. Dynamic and thermodynamic similarity. Thermal and velocity boundary layer equations. Karman-Tsien solution. Momentum and energy integrals. Turbulent boundary layer. Shock wave boundary layer interaction. (3 cr; prereq 102A; 3 lect hrs per wk)

114. Analysis of Structural Components. Load factors for aerospace vehicles. Identification of structural types. Analyses of flexural members, torsional members, columns, beam-columns, ties and connections. Introduction to shear flow. Thin-shell members. (3 cr; prereq MM 41, 150; 3 rec hrs per wk)

115A. Structural System Analysis I. Semi-monocoque structures. Shear flow. Torsion of multicellular structures. Energy methods. Rings. Redundant trusses. Natural frequencies. Moment distribution. (3 cr; prereq 114, MM 193; 3 rec hrs per wk)

116A. Structural System Analysis II. Problems in aerospace frame analysis. Moment distribution considering sidesway and beam-columns. Muller-Breslau principle of influence lines. Energy method of analysis. (3 cr; prereq 115A; 2 rec hrs and 2 lab hrs per wk)

117A. Analysis of Load-Carrying Surfaces. Thin plates and membranes. Buckling of plates. Flexure of cylindrical shells. Membrane analysis of shells. (3 cr; prereq 115A; 3 rec hrs per wk)

130A-131A-132A. Aeromechanics System Design. Aerodynamics, performance, static stability and stress analysis related to a selected type of aerospace system. (4 cr per qtr; prereq ¶108 and ¶115A; 2 lect and 4 lab hrs per wk)

135. Testing of Aircraft Structures and Models. Static and dynamic testing of components, subassemblies, and complete assemblies. (3 cr; prereq 114, MM 142; 2 rec and 3 lab hrs per wk)

138-139. Summer Engineering Employment. Written report based on summer work in an engineering field (not less than 360 hours per summer). (1-3 cr per qtr; prereq ♯, completion of 3rd yr and approval of instructor prior to regis)

141. Experimental Aerodynamics. Flow visualization techniques; surface wave in water table. Pressure and temperature measurements of a model. Boundary layer measurements in subsonic wind tunnel. Experiments in duct and plasma jet. (3 cr; prereq 102A; 2 lect and 4 lab hrs per wk)

150. Aeroelasticity I. Static aeroelastic phenomena, closed form and approximate solutions for torsional divergence and aileron reversal. Simple harmonic and arbitrary motion for irrotational incompressible and compressible flow. The gust and flutter problems. (3 cr; prereq 102A and MM 193)

159. Aerodynamic Retardation. Aerodynamics of subsonic and supersonic retardation devices. Wake and interference effects. Trajectory calculations, re-entry problems and recovery systems. (3 cr; prereq 107A or 102A or ♯)

160. Aerodynamic Analysis of Aerospace Vehicles. Steady flight boundary conditions. Optimum body configurations and area rule. Plan forms. Thickness and aspect ratio. (3 cr; prereq 107A; 3 rec hrs per wk)

161. Vtol and Stol Vehicles. Vertical and short take-off and landing vehicles. Rotor theories. Boundary layer control. Jet deflection. (3 cr; prereq 107A; 3 lect hrs per wk)

180. Flight Trajectory in Atmosphere and Space. Mechanical and aerodynamic forces on rocket. Dynamic equations of flight. Simplified vertical trajectory. Performance and trajectory of single- and multi-stage rocket. Optimization in trajectory and orbit altitude. Trajectory of re-entering body into atmosphere. Satellite orbits. Lunar flight. Interplanetary operations. (3 cr; prereq 102A or ♯; 3 lect hrs per wk)

184. Intermediate Gas Dynamics. One-dimensional channel flow with friction and heat addition. One-dimensional wave motion. Flow in ducts and wind tunnels. Two-dimensional and axially symmetric characteristics method. Supersonic source integration method for wing and body of revolution. Piston theory. (3 cr; prereq 102A)

185. Rarefied Gas Dynamics. Flow regimes, free molecular flow, slip flow and transition. Dynamics of dissociated gas and ionized gas. Magnetogasdynamics. (3 cr; prereq 110 or ♯; 3 lect hrs per wk)

193-194-195.*‡ Problems in Aeromechanics. Investigation of approved problems. Undergraduate thesis. (2-6 cr; prereq ♯; faculty sponsor required before regis)

For Graduate Students Only

201-202-203. Aerodynamics of Compressible Fluid

204. Supersonic Aerodynamics Laboratory

205-206-207. Viscous Fluid Flow and Boundary Layer Theory

210-211-212.‡ Selected Topics in Gas Dynamics

215-216-217. Theory of Turbulence

220. Astronautics

221. Astronautics and Hypersonic Re-entry Problems

230. Aerodynamics of Supersonic Inlet Diffusers

231, 232. Aerodynamics and Flight Performance of Supersonic Missiles

240, 241. Dynamics of Aircraft Structures

250-251-252. Magneto-Fluid Dynamics

272-273-274.*‡ Research in Aeromechanics

Mechanics and Materials (MM)

27. Rigid-Body Mechanics I. Vector algebra. Application of the equations of equilibrium to the analysis of simple engineering structures and machines. Nature and influence of friction. Elementary theory of statically determinate framed structures. (3 cr; prereq ITM 25A and Phys 14; 3 lect hrs per wk)

28. Rigid-Body Mechanics II. Application of the principles of particle motion. Kinematics. Impulse-momentum and work-energy principles. Potential and potential energy, motion in a central force field. Introduction to forced and free mechanical vibrations. (3 cr; prereq 27 and ITM 26A; 3 lect hrs per wk)

29. Rigid-Body Mechanics III. Dynamics of rigid-body motions. Extension of the principles of impulse-momentum and work-energy. Euler's equations of motion. The gyroscope. Virtual work. Stability. (3 cr, §Phys 100; prereq 28; 3 lect hrs per wk)

40. Deformable-Body Mechanics I. Stress and strain. Applications to tension and torsion members, beams, columns, and joints. Design considerations. Statically indeterminate members. (3 cr; prereq 27; 3 rec hrs per wk)

41. Deformable-Body Mechanics II. Stress, strain, and deformation analysis of beams, columns, rings, and cylindrical pressure vessels. (3 cr; prereq 40; 3 rec hrs per wk)

92. Statics. (Architects and Combined Engineering-Business) Resolution of force systems. Equilibrium of rigid bodies and analysis of framed structures. Centroids and moments of inertia. (4 cr; prereq ITM 24A; 4 rec hrs per wk; 27 may be substituted for 92)

93. Solid Mechanics for Architects. Introduction to static strength properties of structural materials. Stress and strain. Applications to tension and torsion members, beams, columns, and joints. Design considerations. Material testing. (4 cr; prereq 92; 3 rec and 1 lab hrs per wk; 40 may be substituted for 93)

142. Experimental Mechanics. Assumptions and limitations of theory; role of experimental mechanics. Mechanical, electrical, optical, and other gauges for measurement of static and dynamic strain. Photoelasticity, brittle coating, model analysis. Verification of equations of solid mechanics. Tests of axial, torsional, and transverse-loaded members. Dimensional analysis. (2 cr; prereq 40)

150. Rheology and Strength of Solids. Structure of solids, mechanical models, equation of state. Stress-strain-time and fracture properties under static and dynamic loading. Design significance of creep, relaxation, fatigue, impact, and damping properties. Multi-axial stress and theories of failure. Metallic and nonmetallic structural materials. (3 cr; prereq 41 and Met 56; two 2-hr sessions per wk)

151. Fatigue of Materials and Structures. Submicro- and micromechanisms of fatigue. Crack initiation and propagation. Statistical aspects. Random loading. Fatigue environment of aerospace structures, its analysis and simulation. Elevated temperature problems. Thermal fatigue. Resonance and acoustic fatigue. (3 cr; prereq 150; two 2-hr sessions per wk)

164-165-166.*‡ Problems in Mechanics and Materials. Short duration individual research problems, literature studies, and reports. (3 cr per qtr; faculty sponsor required before regis; prereq ‡)

180. Introduction to the Theory of Elasticity. General analysis of stress and strain in 2 and 3 dimensions. Stress-strain relationships for linearly elastic crystals and isotropic materials, plastic and viscoelastic materials. Emphasis on principles of continuum mechanics illustrated by application to typical problems of stress analysis. (3 cr; prereq 40 and ¶ITM 147 or equiv) Graduate staff

181. Deformable-Body Mechanics III. Stress analysis of structural elements. Flexure of beams on elastic subgrades. Unsymmetrical bending and shear centers. Application of energy methods to statically indeterminate structures. Buckling of columns and frames. (3 cr; prereq 41 or 180)

182. Deformable-Body Mechanics IV. Stress analysis of machine members. Torsion of members of noncircular cross section. Curved beams. Stress analysis of thick cylinders and shrink-fit assemblies. Stress concentrations and concentrated loads. (3 cr; prereq 41 or 180)

183. Applied Plasticity. Plastic analysis of structures. Load carrying capacity. Limit analysis theorems. Shakedown and plastic collapse. Applications to trusses, beams, and frames. (3 cr; prereq 28, 41)

187. Theory of Linear Viscoelasticity. Linear viscoelastic behavior; linear viscoelastic laws; method of viscoelastic analysis; applications to simple quasi-static viscoelastic problems. (3 cr; prereq 41, ITM 148 or 150A)

193. Introduction to the Theory of Mechanical Vibrations. Vibrations of linear lumped-parameter systems. Transient and steady state behavior of linear systems having a single degree of freedom. Influence of damping. Vibration isolation. Introduction to vibrations of multiple degree of freedom linear discrete systems. (3 cr; prereq 29)

194. Theory of Vibrations of Linear Discrete Systems. Lagrange's equations of motion for holonomic discrete dynamical systems for motions in the neighborhood of static stable equilibrium. Multiple degree of freedom systems. Transformation to principal co-ordinates. Free and forced motions. Advanced topics. (3 cr; prereq 193 or grad)

196. Problems in Advanced Rigid-Body Dynamics. Fundamental theory; three-dimensional kinematics, Euler's angles, matrix representation of rigid-body rotations; Lagrange's and Euler's equations. Application to selected problems chosen to develop facility in the analysis and interpretation of the dynamical behavior of mechanical systems. Topics will include impulsive motion, nutation and precession of gyroscopes, effects of earth's rotation, the marine gyrocompass. (3 cr; prereq 193 or ITM 162 or EE 150 or Phys 102 or equiv; 3 hrs per wk)

199. Thermal Stresses. Analysis of thermal stresses in various types of structures such as aerospace components, pressure vessels, and nuclear reactors. Inelastic thermal stresses. (3 cr; prereq 180 and ME 133; 3 lect hrs per wk)

For Graduate Students Only

202. Gyroscopic Instruments and Other Applications of Advanced Dynamics

211, 212. Theory of Vibrations I and II

213. Advanced Topics in the Theory of Nonlinear Vibrating Systems

222-223. Theory of Plasticity

227. Introduction to Structural Instability

235-236-237. Theory of Mechanical Behavior of Solids with Applications

241-242.‡ Theory of Viscoelasticity

264-265-266.*‡ Advanced Topics in Mechanics and Materials

290. Theory of Plates and Shells

291. Advanced Theory of Shells

295-296. Theory of Elasticity with Engineering Applications

297-298-299.* Mechanics and Materials Seminar

Agricultural Engineering (AgEn)

(College of Agriculture, Forestry, and Home Economics)

9. Laboratory. Engineering units and materials, their characteristics and use. (1 cr; 2 lab hrs per wk)

10. Laboratory. Introduction to agricultural engineering applications. (1 cr; 3 lab hrs per wk)

62. Farm Structures. Functional requirements of farm animal shelters, storage, and service buildings. Selection of materials and methods of construction. Design in wood. (3 cr; prereq MM 41 or ¶MM 41, 2 lect and 3 lab hrs per wk) Otis or Pomroy

72. Principles of Farm Machinery. Functional design, operating characteristics, and field performance of farm machines. Machine mechanisms, hitching, and force systems. (3 cr; prereq ME 24 or ¶ME 24; 2 lect and 3 lab hrs per wk) Flikke

82. Introduction to Soil and Water Management. The hydrologic cycle and its component parts—precipitation, transpiration, evaporation, infiltration, and runoff. Basic principles of drainage, irrigation, and erosion control. (3 cr; 3 lect hrs per wk) Manson

101-102. Summer Employment I and II. (2 cr per qtr; prereq completion of 3rd yr work and △)

125. Topics in Agricultural Physics. An advanced study of the essential physical principles involved in the utilization of electricity in agriculture. (3 cr; prereq Phys 50 or integral calculus and MeAg 25 or equiv) Hustrulid

141. Agricultural Drainage. Soil-water-plant relationships. Design, cost, and construction of tile drainage and open ditch systems. Economics and legal aspects of drainage. (3 cr; prereq 82, Hydr 103, Soil 19; 3 lect hrs per wk) Manson

142. Erosion Control Engineering. Design and construction of terraces, diversions, grass waterways, and earth dams. Hydraulic design of drop spillways, chutes, culverts, and conduit spillways. (3 cr; prereq 82, Hydr 103, Soil 19; 3 lect hrs per wk) Larson

143. Irrigation. Principles and practices of irrigation in arid and humid regions. Plant water requirements, water supply development, theory and operation of irrigation pumps. Design, cost, and construction of irrigation systems and structures. (3 cr; prereq 82, Hydr 103, Soil 19; 3 lect hrs per wk) Allred

147. Design and Management of Farm Machinery. Principles of operation and performance characteristics of farm machinery. Design of machine elements and assemblies. Management of machinery. (3 cr; prereq 72; 2 lect and 3 lab hrs per wk)

149. Radioisotope Measurements. Properties of nuclear radiation. Geiger-Müller, proportional, and scintillation detectors. Gamma ray spectrometer. Statistics of nuclear radiation measurement. Applications of radioisotope measurements in agricultural engineering. (3 cr; prereq Phys 50, ITM 26A; 2 lect and 3 lab hrs per wk) Hustrulid

159. Agricultural Engineering Instrumentation. Application of basic electrical instruments to measurement and control. Controls and control circuits. Pyrometry, psychrometry, and pressure measurement and control. Physical measurements relating to soils and crops. Radioactive and tracer instrumentation. (3 cr; prereq EE 37; 2 lect and 3 lab hrs per wk) Hustrulid

167. Advanced Farm Structures. Design of structural members and assemblies for farm buildings. Wind resistant construction. Insulation and ventilation. Building equipment. Cost estimating. (3 cr; prereq ME 160, CE 37; 2 lect and 3 lab hrs per wk) Otis

170. Agricultural Tractors. Tractor engines, transmissions, and final drives. Auxiliary drive systems. Chassis mechanics and tractor stability. Hitches and hydraulic systems. Tractor performance and tests. (3 cr; prereq ME 121, 150; 2 lect and 3 lab hrs per wk) Strait

171. Design of Agricultural Machinery. Operating principles and problems. (3 cr; prereq 147, ME 121; 1 lect and 6 lab hrs per wk) Strait

172. Agricultural Machine Analysis. Advanced design problems. Application of the principles of dynamics to the design of agricultural machinery. Experimental measurement of working forces and stresses. Motion analysis. (3 cr; prereq 171, MM 142; 1 lect and 6 lab hrs per wk) Strait

176. Management of Power and Machinery. Principles. (3 cr; prereq 147; 2 lect and 3 lab hrs per wk) Schwantes

179. Agricultural Process Engineering. Size reduction, cleaning, and sorting of agricultural products. Principles of materials handling. Refrigeration theory and application. Steam generation and use. Heating, cooling, drying, and concentrating processes. Fans and pumps. Process control, flow diagrams, plant design, and cost analysis. (3 cr; prereq ME 160; 2 lect and 3 lab hrs per wk)

180. Agricultural Hydrology and Flood Control. Runoff measurements and estimation of runoff. Hydrograph analysis. Water storage, detention, and flood routing. Floods, flood damage, and flood control in agricultural areas. (3 cr; prereq 142 or ¶142; 3 lect hrs per wk) Larson

181. Field Problems in Soil-Water Management. Survey, design, and layout of drainage, erosion control, and irrigation systems and structures for the management and conservation of soil and water. (3 cr; prereq 141, 142, 143 or ¶143; 2 lect and 6 lab hrs per wk) Allred, Larson

191-192-193.‡ Problems in Agricultural Engineering. Special problems in (S) soil moisture, (P) power and machinery, (F) farmstead equipment and operations. (2-6 cr per qtr; prereq #)

For Graduate Students Only

200. Seminar

211-212-213.‡ Advanced Problems and Research

Agronomy and Plant Genetics (Agro)

(College of Agriculture, Forestry, and Home Economics)

1. Introduction to Agronomy. Principles of field crop development, adaptation and distribution as they apply to the production, use, and improvement of major groups of economic plants. Lecture and laboratory. (4 cr)

Air Science (Air)

(Department of Air Science)

Air Force Reserve Officers Training Corps is a 4-year elective course open to all regularly enrolled male students who meet physical, moral, age, and citizenship requirements. The course is designed to meet University educational standards and to train the student in military subjects so that he may qualify for a Reserve commission in the United States Air Force.

The student will not specialize in any one military career field but instead will take subjects aimed at giving a well-rounded course of study which provides a complete background of officer training. He will be given an Air Force specialty classification that corresponds to his University academic major. Every effort is made by the Air Force classification and assignment system to utilize this specialty training.

The Air Force ROTC student is not in the military service and is therefore not subject to the Uniform Code of Military Justice.

For further information see the *Bulletin of the Army-Navy-Air Force ROTC.*

Air 31, 32, and 36 are noncredit air science courses requiring the substitution of University courses of two 5-hour credit courses with the continuing requirement of 1 hour per week attendance at AFROTC Leadership Laboratory. For further information, IT students should consult their advisers and the *Bulletin of the Army-Navy-Air Force ROTC.*

Air Force ROTC credits may be substituted for humanities credits in the Institute of Technology.

31. Leadership Laboratory. Survey of Department of Defense and USAF mission. Role of Air Force ROTC in defense. Air Force customs and courtesies. Implications of the concept of aerospace defense. Military skills including wear of the uniform and individual drill movements. (No cr [substitute course cr of 2-5 hrs required]; 1 hr per wk)

32. Leadership Laboratory. Demonstration, performance, and critiquing of group drill including: voice of command, supplementary commands, forming and aligning the squadron, inspection of squadron and group, and manual of the guidon. Extensive practice in organizational positions of squad leader, flight guide, flight sergeant, and guidon bearer. (No cr [substitute course cr of 2-5 hrs required]; 1 hr per wk)

33. Foundations of Air Power I. Nature of air power: elements and potentials of world military air powers. Elements of aerodynamics and aircraft, subsonic to supersonic system, B-70, F-106, Tiros, Atlas, Saturn. Conventional and exotic propulsion systems. Subspace navigation and astrogation. Weapons systems: air-to-ground, ground-to-air. Implications of space flight. Professional opportunities in the United States Air Force. (2 cr)

34. Foundations of Air Power II. A study of the development of aerial warfare from conception to modern application. Includes: military history from Alexander the Great through the Civil War; Von Klausewitz' principles; aerial warfare in World War I; U. S. air doctrine, 1919-1941; theories of Douhet, Trenchard, Mitchell, De Seversky; aerial warfare since 1941. Modern Air Force basic doctrine. (2 cr; prereq 33)

35. Foundations of Air Power II. (Continuation of 34) Elements of aerial warfare: targets, including tactical and strategic targets, target complex, target systems, and intelligence; weapons, conventional and nuclear. Delivery vehicles: Mace, Snark, Atlas, Titan, Minuteman, B-52, and B-58. Employment of forces to include Strategic, Tactical, Air Research and Development Commands. A summation of current space programs including Mercury, Dyna-soar, Saturn, and lunar probes. (2 cr; prereq 34)

36. Leadership Laboratory. Exercises in forming the squadron in line, column and mass; squadron inspection; elements of parade; exercise of command bearing, voice, and posture in noncommissioned officer positions: squad leader, flight guide, flight sergeant, first sergeant, and guidon bearer. (No cr [substitute course cr of 2-5 hrs required; 1 hr per wk]; prereq 35)

131. Leadership Theory and Application I. Philosophy and methodology of the creative approach to problems: brainstorming, identification of causes and effects, bias, fallacy, statistical validity, fundamentals of research. The staff study. Military justice: history of military justice in the West, military law as a function of command; article 15 UCMJ, summary, special and general courts-martial, trial, and pretrial investigations, appellate review. (3 cr; prereq 36)

132. Air Force Communicating and Instructing. Principles of learning, planning instruction. Methods: lecture, discussion, demonstration-performance. Instructional aids, characteristics of effective evaluation. Air Force communication includes: nature of communication, barriers to effective communication; observation and perception; techniques of study and communication. Air Force writing, format and factors of effective reports. Effective speaking. (3 cr; prereq 131)

133. Leadership Theory and Application II. Basic principles of leadership psychology; problems in leadership and management; theory including biology of behavior, personality development, nature of intense motivation, American attitudes and values. Leadership practice, problems, and exercises. (3 cr; prereq 132)

134. Aerial Navigation and Meteorology. Navigational and meteorological aspects of airmanship, such as Air Weather Service, the earth and space, circulation and wind patterns, temperature and heat transfer, pressure standards and scales, absolute and relative humidity, pseudoadiabatic charts, air mass weather and source regions, frontal weather, thunderstorm structure, fog formation, icing, world weather, classification of projections, earth's surface and maps, dead reckoning navigation, aircraft instruments, wind triangle, circular slide rule, radio compass, loran, omnirange, radar navigation, celestial navigation, polar and high speed navigation. (3 cr; prereq 133)

135. Military Aspects of World Political Geography. Military aspects of world political geography includes studies in areas, such as factors influencing the power of states, geography of climate, global strategic views, political and military geography, Latin America, arctic regions, the U.S.S.R., Eastern Europe, Western Europe, Middle East, Africa, Asia, Communist China, Japan, Taiwan and Korea, Australia and Antarctica. (3 cr; prereq 134)

136. International Relations and the Air Force Officer. Major factors underlying international tensions, nations and nationalism, national goals, imperialism and communism. Attempts to alleviate world tensions—balance of power concepts, League of Nations, United Nations, and regional security organizations. Rise of the two superpowers—United States and U.S.S.R. Also, study of material to help cadet make a rapid effective adjustment to active duty as an officer in the United States Air Force. (3 cr; prereq 135)

Architecture (Arch)

1. Introduction to Architecture. The philosophy and principles of architecture as an art, a science, and a profession. (1 cr; 1 lect hr per wk)

50. Japanese Architecture. History and development of Japanese residential architecture and its relation to contemporary planning. (1 cr) Engel

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 cr per qtr; prereq 2nd yr for IT students or 3rd yr for SLA students; 4 lect hrs per wk)

71-72-73. Building Technology. Principles, techniques, materials, and equipment involved in building. (4 cr per qtr; prereq 2nd yr; 4 lect hrs per wk)

74-75-76. Building Technology. Principles, techniques, materials, and equipment involved in building. (4 cr per qtr; prereq 73; 4 lect hrs per wk)

81-82-83.† Architectural Design I. Basic exercises in composition of line, form, proportion, color, and texture. Elements of architectural design. Architectural drawing. Model making. (18 cr, normally 6 cr per qtr; prereq 2nd yr for IT students, jr for SLA students and △; 18 lab hrs per wk; entrance fall qtr only)

91-92-93.† Architectural Design II. Continuation of design principles with emphasis on development of structures as an integral part of design. Research techniques. (18 cr, normally 6 cr per qtr; prereq 83; 18 lab hrs per wk)

101-102-103. Tutorial Work in History of Architecture. Reading and written reports on special historical problems. (2 cr per qtr; prereq 53; 1 conf and 5 research hrs per wk)

104. Planning. (Same as Econ 110, Pol 123, Soc 106) Social, economic, political, geographic, and technical phases of modern city planning. (3 cr; prereq 4th yr; 3 lect hrs per wk)

105. Planning. Techniques of planning. (3 cr; prereq 104) Vivrett

106. Planning. Housing. (3 cr; prereq 104) Vivrett

110. Planning. Field and laboratory work in planning. (Cr ar; not open to candidates for degree of bachelor of architecture; prereq 105)

111-112-113.†°° Architectural Design III. Advanced architectural problems involving city planning, detailed study of buildings, interiors, mechanical and electrical equipment. Individual effort and group collaboration. (24 cr, normally 8 cr per qtr; prereq 93 and MM 93; 24 lab hrs per wk)

121-122.†°° Architectural Design IV. Advanced architectural and planning problems of complex requirements involving thorough study and detailed solution. Individual effort and group collaboration. (18 cr, normally 9 cr per qtr; prereq 113 and CE 41; 27 lab hrs per wk)

123.°° Architectural Thesis. Individual choice, study, and solution of an architectural problem to demonstrate proficiency in all phases of design. (12 cr; prereq 122; 36 lab hrs per wk)

126. Professional Relations. Relations of the architect to clients, contractors, and fellow practitioners; procedures of architectural practice. (3 cr; prereq 4th yr; two 2-hr seminars per wk)

For Graduate Students Only

201.° Special Research in Architectural History

231-232-233.° Planning

251-252-253.° Architectural Design VI

For related courses required of architectural students (listed under architectural curriculums) see respective department announcements for detailed information.

Astronomy (Ast)

(College of Science, Literature, and the Arts)

51. General Astronomy. Gives a brief survey of the known facts about our solar system with special emphasis on the basic laws that govern the motions of the planets and some additional discussions of special phenomena such as eclipses, formation of tides. Slightly more mathematical than Ast 11. (3 cr, §11; prereq Math T or ITM 12)

°° Before entrance into Arch 123, the student is required to have fulfilled a minimum of 800 hours of practical experience outside of classwork, or its equivalent.

52. Astrophysics. Deals mainly with the physical characteristics of the stars and the manner in which these are derived from present-day observations, mainly of a spectroscopic nature. Treating the sun in more detail, it gives a derivation of the luminosities, temperatures, masses, and densities of the stars with a brief summary of the thermonuclear processes going on in the stars and the probable course of stellar evolution. (4 cr; prereq Math 53 and Phys 50 or 9 with ‡)

53. Stellar Astronomy. (Continuation of Ast 52) Treats especially the statistical and dynamical picture of our stellar system, double stars, variable stars, and the structure of the galactic system. As much observation with the telescope as weather conditions permit. (3 cr; prereq Math 53 and Ast 11 or Phys 9)

104. Celestial Mechanics. Central orbit theory. The two-body problem. Computation of an ephemeris. The determination of an orbit from observations. (3 cr; prereq Math 59)

105. Celestial Mechanics. The restricted three-body problem. The gravitational field of the earth. Numerical methods applicable to the computations of special perturbations. First order theories of the motion of the moon and of the motion of a satellite of an oblate planet. Drag perturbed orbits. (3 cr; prereq 104)

106. Celestial Mechanics. Applications of contact transformations and the Hamilton-Jacobi equation to the computation of general perturbations. The Delaunay and Hill-Brown theories of the motion of the moon. The motion of a satellite of an oblate planet. (3 cr; prereq 105)

Biology (Biol)

(College of Science, Literature, and the Arts)

1A-2A. General Biology. Introduction to living things, both plant and animal, and to the major biological concepts. (7 cr, †1A-2A; not open to students who have taken Zool 1-2-3, 14-15, Bot 1-2-3, or NSci 7-8-9)

Chemical Engineering (ChEn)

100. Chemical Engineering Stoichiometry. Energy and material balances. (3 cr; prereq 3rd yr; 3 lect and rec hrs per wk) Madden

101. Principles of Chemical Engineering. Fluid dynamics and its application to chemical engineering unit operations. (5 cr; prereq 3rd yr and ¶PCh 101; 3 lect and 3 rec hrs per wk) Scriven

102. Principles of Chemical Engineering. Heat and mass transfer and its application to chemical engineering unit operations. (5 cr; prereq 101; 3 lect and 3 rec hrs per wk) Ranz

103. Principles of Chemical Engineering. Equilibrium stage separations applied to chemical engineering unit operations. (3 cr; prereq 102; 2 lect and 2 rec hrs per wk) Isbin

104. Principles of Chemical Engineering. Primarily for undergraduates to include topics sparsely covered or not considered in 101, 102, 103. (3 cr; prereq 103; 3 lect and rec hrs per wk)

111. Chemical Engineering Laboratory. Applications of unit operations principles in fluid flow, heat and mass transfer experiments, with reports. (2 cr; prereq 101; 4 lab hrs and ½ lab conf hr per wk) Fredrickson

112. Chemical Engineering Laboratory. (See ChEn 111) (2 cr; prereq 102; 4 lab hrs and ½ lab conf hr per wk) Fredrickson

113. Chemical Engineering Laboratory. (See ChEn 111) (2 cr; prereq 103; 4 lab hrs and ½ lab conf hr per wk) Fredrickson

116-117-118. Process Evaluation and Design. Dynamics of chemical engineering industries, economics of process evaluation, bases for cost estimations, and expansion of activities considered. Plant designs prepared and compared with actual installations. Special applications of unit operations, reaction kinetics, and thermodynamics. (3 cr per qtr; prereq 103; 3 lect hrs per wk for 116, 4 lect and lab hrs per wk for 117 and 118) Preckshot

119-120. Chemical Engineering Thermodynamics. Three principles of thermodynamics applied to batch and particularly to flow systems. Generalized law of corresponding states and fugacity applied in practical problems of physical and chemical equilibriums. (3 cr per qtr; prereq PCh 101; 2 lect and 2 rec hrs per wk) Dahler

122. Biochemical Engineering. Application of biochemical and microbiological principles to industrial processes. (3 cr; prereq 103, Micb 53 or ♯; 3 lect hrs per wk) Tsuchiya

123. Biochemical Engineering Laboratory. Application of chemical engineering, microbiological and biochemical principles to fermentations, food processing, waste stabilization, etc. (3 cr; prereq 122, Micb 53; 9 lab hrs per wk ar) Tsuchiya

131-132. Chemical Reactor Analysis. Principles of reactor design for homogeneous and heterogeneous reactions. Analysis of the chemical reactor from a kinetic and thermodynamic point of view. Applications to some specific processes. (3 cr per qtr; prereq 120, PCh 109; 3 lect hrs per wk) Aris

152. Chemical Process Laboratory. Applications of principles covered in 131-132 in pilot or semiplant laboratory. (2 cr; prereq 103, 132) Madden

153-154-155-156.‡ Special Problems. Investigations in chemical engineering. Library or laboratory research. (Cr ar; 1 conf hr per wk, lab hrs ar) Staff

161-162-163. Nuclear Reactor Design. An engineering approach to the development and application of nuclear reactor theory, including basic nuclear chemistry and physics, mathematical developments and special techniques, design, operation, and control of homogeneous and heterogeneous reactors, and nuclear reactor economics. Laboratory credit available. (3 cr per qtr; prereq ♯; 3 lect hrs per wk) Isbin

171-172. Process Control. Theory and application of instrumentation and control with particular emphasis on application to the chemical industry, including analytical methods. (3 cr per qtr; prereq 4th or 5th yr or ♯; 3 lect and rec hrs per wk for 171, 2 lect and 3 lab hrs per wk for 172) Ceaglske

173. Advanced Process Control. (Continuation of ChEn 171-172) Additional methods such as the root-locus and Guillemin's for the analysis and design of process control systems are covered. (3 cr; prereq 172; 3 lect and rec hrs per wk) Ceaglske

For Graduate Students Only

201-202-203.‡ Seminar

205-206-207.‡ Physical Rate Processes and the Transfer Operations

208-209-210. Physical Rate Processes and the Transfer Operations

211-212-213. Molecular Theory of Transport Processes

214-215-216. Advanced Mathematics for Chemical Engineers and Chemists

217. Analysis of Chemical Engineering Problems

218. Advanced Topics in Chemical Engineering

219-220. Advanced Chemical Engineering Thermodynamics

221-222-223.‡ Chemical Rate Processes and Reactor Design Principles

225-226-227. Fluid Mechanics and Related Topics

264. General Survey of Chemical Engineering

301-302-303. Research in Chemical Engineering

Chemistry

Analytical Chemistry (AnCh)

57. Quantitative Analysis. Introductory course covering the general principles and methods of gravimetric and volumetric analysis. Typical problems are assigned and attention is given to proper laboratory practice. (4 cr; primarily for premed students; prereq InCh 11 or 26) Herr

96-97-98.‡ Senior Thesis. (Cr ar; prereq 4th yr) Kolthoff, Sandell, Meehan, Bruckenstein

100-101. Quantitative Analysis. Introductory lecture courses covering the general principles and theoretical foundations of quantitative analysis. 100: Gravimetric analysis. 101: Volumetric analysis. (2 cr for 100, 3 cr for 101; prereq InCh 26 for 100, 100 for 101) Meehan

102. Laboratory in Gravimetric and Volumetric Analysis. (4 cr; prereq 101) Meehan

102A. Laboratory in Gravimetric and Volumetric Analysis. (3 cr; for chemical engineers; prereq 101)

103. Quantitative Inorganic Microanalysis. Representative methods of micro- and semimicro analysis, gravimetric, volumetric, and colorimetric. (3 cr; limited to 16; prereq 100, 101, 102 or 102A) 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 cr; prereq 100, 101, 102 or 102A) Sandell

105. Polarizing Microscope. Its use and application to chemistry. Identification of substances. (3 cr; limited to 16; prereq PCh 101) 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 cr per qtr; prereq 100, 101, 102 or 102A) Sandell

111. Physicochemical Methods of Analysis. Lecture. Optical and electrochemical methods and methods of separation. (3 cr; prereq 102 or 102A, PCh 103) Kolthoff and staff

112. Physicochemical Methods of Analysis. Laboratory course. Quantitative application of electrochemical, optical, and other physical techniques. (2 cr; prereq 111) Bruckenstein

122. Advanced Analytical Chemistry. Condensed review of fundamentals of gravimetric and volumetric analysis. (2 cr; prereq 100, 101, 102 or 102A) Meehan

123.* Analysis of Complex Materials. Literature study, critical selection and application of fundamentals of analysis to complex materials. (1-3 cr; prereq 112) Kolthoff

127.* Optical Methods of Analysis. Lecture. (2 cr; prereq PCh 103; offered 1961-62 and alt yrs) Meehan

131.* Solution Equilibria. Lecture. Systematic treatment of acid-base and related equilibria. (2 cr; prereq PCh 103) Bruckenstein

132-133.* Electrochemical Methods of Analysis. Lecture. Potentiometric, coulometric, polarographic, and other electrical methods. (2 cr per qtr; prereq PCh 103) Bruckenstein

134-135. Electrochemical Methods of Analysis. Laboratory course. (1-2 cr per qtr; prereq 132 or ¶132 for 134 and 133 or ¶133 for 135) Bruckenstein

138. Advanced Volumetric Analysis. (3 cr; prereq 131) Kolthoff

140. Water Analysis. Analysis of potable water with interpretation of results. (2 cr; prereq 100, 101, 102 or 102A) Sandell

141-142-143.*† Seminar: Modern Problems in Analytical Chemistry. (1 cr per qtr; prereq 100, 101, 102 or 102A and PCh 103) Kolthoff

For Graduate Students Only

201-202-203.† Selected Topics in Analytical Chemistry

235-236-237.† Research Seminar in Analytical Chemistry

262. General Survey of Analytical Chemistry

301-302-303.† Research in Quantitative Analysis

Inorganic Chemistry (InCh)

4-5.† General Inorganic Chemistry. An introduction to chemistry from the standpoint of atomic structure; periodic properties of the elements and compounds derivable from structural considerations; a study of the laws governing the behavior of matter,

theories of solutions, acids, bases, and equilibrium. (5 cr per qtr; prereq a first course in high school algebra; 3 lect, 1 quiz, 1 rec, and 3 lab hrs per wk) Brasted and staff

11. Semimicro Qualitative Analysis. Laboratory work in systematic qualitative analysis of cations with lectures on solutions, ionization, chemical and physical equilibriums, oxidation and reduction, etc. (4 cr; prereq 5 or 15 or 25; 3 lect and 4 lab hrs per wk) Brasted and staff

14-15.† Inorganic Chemistry. Fundamental principles and survey of inorganic chemistry. (4 cr per qtr; limited to College of Engineering students; prereq Phys 11, 12 or consent of chief of Division of Inorganic Chemistry; 3 lect, 1 rec, 1 quiz, and 3 lab hrs per wk) O'Connor and staff

24-25†-26. Introduction to Chemical Principles. The lecture material deals primarily with the basic theories of chemistry: atomic structure, kinetic theory, chemical stoichiometry, the chemical bond, oxidation-reduction, solution theory, chemical equilibrium. Examples are drawn from all fields of chemistry. A considerable portion of the laboratory program involves qualitative analysis, including cation and anion analysis. (5 cr per qtr; for students whose major is chemistry or chemical engineering; 3 lect, 1 quiz, 1 rec, and 5 lab hrs per wk) O'Connor and staff

25H-26H. Honors Course: Chemical Principles. (5 cr per qtr; prereq 24 for 25H, 25 or 25H for 26H)

96-97-98.‡ Senior Thesis. (Cr ar; prereq 4th yr)

103.° Atomic Structure and the Properties of the Elements Based Thereon. Nature of atomic and molecular electronic systems and the properties of various elements, including the transition elements. (3 cr; prereq PCh 103; 3 lect hrs per wk) Reynolds

104.° Chemistry of the More Representative Elements. A detailed discussion of the preparation, reactions, and chemical properties of the regular group elements and their compounds. (3 cr; prereq 103 or ♯; 3 lect hrs per wk) Brasted

107.° Oxidation-Reduction Systematics. Application of tabulated thermodynamic data, including potential diagrams, to the prediction of chemical reactions. (3 cr; prereq PCh 101; 3 lect hrs per wk; offered 1962-63 and alt yrs) Hugus

111.° Silicon and Related Elements. Review of current studies on silicon, germanium, tin and lead, with emphasis on recent silicon chemistry. (3 cr; prereq OrCh 62; 3 lect hrs per wk; offered 1961-62 and alt yrs) Johnson

112.° Radioactivity and Nuclear Chemistry. The properties of nuclei, disintegration, properties of radiation; natural and artificial radioactivity; modern views of nuclear structure. (3 cr; prereq PCh 103; 3 lect hrs per wk; offered 1961-62 and alt yrs) O'Connor

113.° Mechanisms of Inorganic Reactions. A discussion of the prevalent ideas concerning the mechanisms of inorganic oxidation-reduction and substitution reactions. (3 cr; prereq PCh 103; 3 lect hrs per wk; offered 1961-62 and alt yrs) Reynolds

122. Advanced Inorganic Chemistry Laboratory. Measurements of the equilibria and kinetics of selected inorganic reactions, and advanced synthetic methods. (2 cr; prereq AnCh 100, 101, 102 or 102A and PCh 103) Hugus, Reynolds, Britton

134-135-136.‡ Seminar: Modern Problems in Inorganic Chemistry. (1 cr per qtr; prereq PCh 103) Staff

For Graduate Students Only

203. Atomic Structure and the Chemical Bond

204. Advanced Inorganic Chemistry

205. Advanced Inorganic Chemistry

211-212-213.‡ Selected Topics in Inorganic Chemistry

220-221-222.† Advanced Inorganic Chemistry Laboratory Methods

260. General Survey of Inorganic Chemistry

301-302-303.† Research in Inorganic Chemistry

Organic Chemistry (OrCh)

16. Carbon Compounds. (Engineers, except ChemE and MinE) 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 cr; prereq InCh 15; 4 lect hrs per wk; this course cannot be substituted for OrCh 61 or 62) Leete

17. Carbon Compounds Laboratory. A laboratory course to accompany OrCh 16. (1 cr; prereq 16 or ¶16) Leete

41-42. Elementary Organic Chemistry. (AFHE) Discussion of important classes of organic compounds, both aliphatic and aromatic together with some heterocyclic compounds. Laboratory work includes preparation of typical substances. (4 cr per qtr; prereq InCh 4 and 5 or equiv; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk) Leete, Lauer

61-62.† Elementary Organic Chemistry. (Chem, ChemE, 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 cr per qtr; prereq 12-15 cr in chemistry; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk) Dodson, Koelsch, Kreevoy

63. Elementary Organic Chemistry. (Continuation of OrCh 61-62) Lecture course. (3 cr; prereq 42 or 62; this course is prerequisite to all other advanced courses in organic chemistry; 3 lect and 1 quiz hr per wk) Parham, Noland

64. Elementary Organic Chemistry Laboratory. (3 cr; prereq 63 or ¶63; this course is prerequisite to all advanced courses in organic chemistry; 6 lab hrs and 1 conf hr per wk) Dodson

96-97-98.‡ Senior Thesis. (Cr ar; prereq 4th yr) Any staff member of Division of Organic Chemistry

101. Intermediate Organic Chemistry. Survey course which considers important modern topics: organic theory, unusual types of aliphatic, aromatic, and heterocyclic compounds. (3 cr; prereq 63, 64 or equiv) Lauer

102. Organic Qualitative Analysis. Elementary course. Reactions of typical functional groups and introduction to methods of organic qualitative analysis. (4 cr; prereq 63, 64 or equiv) Fenton

130. Organic Quantitative Analysis. Methods of proximate and ultimate analysis of organic compounds, with attention to semimicro methods. (3 cr; prereq 63 and 64, AnCh 100, 101, 102 or 102A and ♯) Lauer

139. Advanced Organic Chemistry Laboratory Work. Selected laboratory synthetic problems, which may include original work. Includes considerable individual instruction. (2-5 cr; prereq 64 or equiv; 6-15 hrs lab work ar) Noland

142. Chemistry of Natural Products. Including alkaloids, biogenesis. (3 cr; prereq 63 and 64; offered 1961-62 and alt yrs) Leete

143. Chemistry of Natural Products. Hormones both steroidal and polypeptide, their isolation, proof of structure, synthesis, and action. (3 cr; prereq 63 and 64) Dodson

144. Heterocyclic Compounds. Typical classes of heterocyclic compounds, their chemical and physical properties and uses, synthesis. (3 cr; prereq 63 and 64; offered 1962-63 and alt yrs) Leete

For Graduate Students Only

201-202-203.‡ Organic Chemistry Seminar

220. Survey

221. Survey

222. Survey

223. Stereochemistry

224. Theoretical Organic Chemistry

238. Introduction to Research

239-240. Introduction to Research

246. Organic Instrumental Analysis

250. Theoretical Organic Chemistry

261. General Survey of Organic Chemistry

301-302-303.‡ Research in Organic Chemistry

Physical Chemistry (PCh)

96-97-98.‡ Senior Thesis. (Cr ar; prereq 4th yr)

101-102-103. Physical Chemistry. General survey of the subject. (4 cr per qtr; prereq 1 yr college chemistry, Phys 9 or ¶Phys 9 with △, ITM 25A or Math 53) Livingston

101H-102H-103H. Honors Course: Physical Chemistry. General survey of the subject. For students with GPA greater than 2.75 in mathematics, physics, and chemistry. (4 cr per qtr; prereq 1 yr college chemistry, Phys 9 or ¶Phys 9 with △, ITM 25A or Math 53) Prager

104-105-106. Physical Chemistry Laboratory. (1 or 2 cr per qtr; prereq 101 or ¶101 for 104...102 or ¶102 for 105...103 or ¶103 for 106) Lipsky

107-108.† Elementary Physical Chemistry. Primarily for premedical students. (3 cr per qtr; prereq 1 yr college chemistry, 1 yr college physics, Math 40) Lumry

109.° Physical Chemistry. Elementary atomic and molecular structure, wave mechanics, nuclear chemistry, photochemistry. (4 cr; prereq 103) McCartin

110. Thermodynamics and Chemistry. Principles of classical thermodynamics; their application to physical and chemical phenomena. (4 cr; prereq 103 and calculus) Wertz

111. Thermodynamics. Application of principles of thermodynamics to chemical phenomena including those occurring in solutions of electrolytes. (2 cr; prereq 110) Wertz

112. Atomic and Molecular Structure. An experimental viewpoint. (3 cr; prereq 103) Wertz

113. Quantum Mechanics. Applications to molecular structure. Theory of the chemical bond. (3 cr; prereq 112 or equiv) Wertz

117. Fundamentals of Reaction Kinetics. Empirical analysis of rate measurements, collision theory, transition state theory, chain reactions. (3 cr; prereq 103) McCartin

118.° Introduction to Quantum Theory. Fundamentals of quantum mechanics and their application to simple physical and chemical problems. (3 cr; prereq 103 and calculus) Overend

119.° Introduction to Molecular Structure. Methods of determining molecular structure with simple applications. Chemical and physical properties in terms of nature of chemical bonds. (3 cr; prereq 103) Crawford

128. Colloid and Surface Chemistry. Fundamental principles of colloid chemistry, surface chemistry, electrokinetic phenomena, lyophobic and lyophilic colloids. (3 cr; prereq 103) Lumry

175.° Photochemistry. General survey, including discussion of spectroscopy, with particular reference to visible and ultraviolet absorption spectra of molecular gases. (3 cr; prereq 103 and Phys 9; offered 1962-63 and alt yrs) Livingston

For Graduate Students Only

204-205-206. Atomistics

211. Introduction to Statistical Mechanics

212. Statistical Mechanics and Kinetic Theory

214. Kinetics and Mechanism of Enzymic Reactions

215. Physical Chemistry of Proteins

216. Physical Chemistry of Polymers

221-222-223.‡ Seminar in Radiation Chemistry

250-251-252.‡ Physical Chemistry Seminar

253-254-255.‡ Seminar in Molecular Spectroscopy

256-257-258.‡ Seminar in Theoretical Chemistry
259-260-261.‡ Seminar in Chemical Kinetics
263. General Survey of Physical Chemistry
265-266-267.‡ Seminar in Magnetochemistry
268-269-270.‡ Seminar in Statistical Mechanics
271-272-273.‡ Seminar in Physical Chemistry of Biological Systems
274-275-276.‡ Seminar in Quantum Mechanics
290-291-292.‡ Selected Topics in Physical Chemistry
301-302-303.‡ Research in Physical Chemistry

Civil Engineering (CE)

General: CE 1, 2, 3, 124, 169, 280-281-282.
Highway Engineering and Soil Mechanics: CE 51-52, 53, 146, 148, 151, 152, 153, 154, 156, 158, 159, 251-252.
Hydraulic Engineering: CE 160, 161, 164, 166, 263.
Sanitary Engineering: CE 170, 171, 172, 173, 174, 175, 176-177-178, 179, 261-262, 264, 276, 277.
Structural Engineering: CE 31, 32, 33, 34, 37, 38, 39, 41, 130, 131, 132, 136, 137, 141, 142, 143, 144, 145, 147, 234-235, 236, 240-241-242, 243, 244, 247-248-249.
Surveying: CE 18, 19, 20, 23, 109, 111, 112.

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 cr per qtr; 3 lab hrs per wk; recommended in 2nd yr)

18. Surveying. Theory and practice in length, angle, and elevation measurements; transit and level adjustments and use. Astronomic observations for azimuth. Field problems in traverses and level circuits. Adjustments of traverses, triangulation and level circuits. (3 cr; prereq ITM 13A or equiv or ♯; 2 lect and 4 lab hrs per wk)

19. Surveying. Simple, compound, and spiral horizontal curves; vertical curves; elements of route surveying, grades, curvature, rise and fall, mass diagram, and earthwork volume calculations. (3 cr; prereq 18; 2 lect and 4 lab hrs per wk)

20. Surveying. Property and design surveys including land surveys, topographic surveys, design computations and methods, and construction surveys. Field problems in survey staking, slope staking, cross sectioning, and stadia mapping. (3 cr; prereq 18; 2 lect and 4 lab hrs per wk)

23. Surveying Camp. Applied problems and lectures in mapping, route surveying, hydrographic surveying, control surveys, traverses, triangulation, leveling, and engineering astronomy. (9 cr; prereq 20; offered first term Summer Session in the field at summer camp)

31. Elementary Structural Analysis. Algebraic and graphical analysis of structural framework, influence lines. Equivalent loads. (3 cr; prereq EG 16, MM 27; 3 lect and 3 lab hrs per wk)

32. Elementary Structural Design. Design principles and methods of selecting members and connections. (3 cr; prereq 31, ¶MM 41; 3 lect and 3 lab hrs per wk)

33. Elementary Structural Design. Design of timber and steel members and connections. (3 cr; prereq 32; 3 lect and 3 lab hrs per wk)

34. Drafting Room Practice. Detailing, drafting, and estimating of structural steel and timber. (2 cr; prereq ¶33; 1 lect and 3 lab hrs per wk)

37. Elementary Structural Engineering. (AgE, MinE, MechE, EE) Elementary structural analysis and design in wood, steel, and reinforced concrete. (3 cr; prereq MM 40; 2 lect and 2 lab hrs per wk)

38. Elementary Structural Design (Steel). (Arch) Elementary structural analysis and design of frame buildings. (3 cr; prereq MM 93; 3 lect hrs per wk)

39. Elementary Structural Design (Steel and Timber). (Arch) Elementary structural analysis and design of frame buildings. (3 cr; prereq 38; 3 lect hrs per wk)

41. Elementary Structural Design (Concrete). (Arch) Elementary structural analysis and design of reinforced concrete for buildings and foundations. (3 cr; prereq 39; 3 lect hrs per wk)

51-52. Highways and Pavements. Elements of highway planning, economics, location, design, construction, and maintenance. Field trips and laboratory testing of materials. (3 cr per qtr; prereq ¶MM 40; 2 lect and 3 lab hrs per wk) Thomas

53. Elements of Soil Mechanics. Physical properties of soils; soil profiles; stress distribution; shearing strength. Laboratory identification and compaction tests. (3 cr; prereq 52 [no prereq for Min and GeolEng]; 2 lect and 3 lab hrs per wk) Kersten

109. Geodetic Surveying. First-order triangulation, traverse, and level nets. Least squares adjustments of survey nets. Computations and use of state-wide co-ordinate grids. Geodetic astronomy. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk) Fant

111. Land Surveying. Study of Minnesota Public Land Survey and proper methods of resurveys. Subdivision design and computations. Preparation of standard plats and descriptions. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk) Fant

112. Aerial Surveying and Photogrammetry. Theory and methods of making planimetric and topographic maps from aerial and terrestrial photographs. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk) Fant

124. Railway Engineering. Design, construction, and maintenance of railway roadbed, track, and structures. Economic principles of railway transportation. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk)

130. Statically Indeterminate Structures. Method of moment area. Williot diagram. Slope-deflection method. (3 cr; prereq 33; 2 lect and 2 lab hrs per wk) Andersen

131. Structural Analysis. Moment distribution method. (2 cr; prereq 130; 1 lect and 3 lab hrs per wk) Andersen

132. Structural Design. Continuous structures of steel and concrete. (2 cr; prereq 131; 1 lect and 3 lab hrs per wk) Andersen

136. Advanced Structural Analysis. Wind bracing for buildings. Space structures. Secondary stresses. (3 cr; prereq 132; 3 lect hrs per wk) Graves

137. Structural Laboratory. Theoretical and experimental study of structural members, structural models, and strain gauges. Lectures and demonstrations on photoelasticity and dynamic strain measurements. (3 cr; prereq 141 and ¶131; 2 lect and 3 lab hrs per wk) Self

141. Reinforced Concrete. Principles of reinforced concrete. Design of beams, slabs, columns, and footings. Analysis of continuous beams and rigid frames by moment distribution. (3 cr; prereq 33; 2 lect and 3 lab hrs per wk) Graves

142. Reinforced Concrete Design. (Continuation of CE 141) Application of principles of design of complete building frames, footings, and retaining walls. (3 cr; prereq 130, 141; 2 lect and 2 lab hrs per wk) Graves

143. Arch Analysis and Design. Analysis and design of steel and reinforced concrete arches. (3 cr; prereq ♯; 3 lect hrs per wk) Andersen

144. Prestressed Reinforced Concrete. Principles of design and analysis for pretensioned and posttensioned construction. Methods of prestressing and fabrication. Design of buildings and bridges using prestressed reinforced concrete. (3 cr; prereq 142; 3 lect hrs per wk) Graves, Self

145. Structural Design by the Ultimate Load Theory. Methods of limit load analysis. Ultimate strength design of reinforced concrete. Plastic design of structural steel. Yield line theory for slabs. Selection of load factors and application to continuous beams, rigid frames, and shell structures. (3 cr; prereq 142) Graves

146. Concrete and Concrete Materials. Design and control of concrete mixtures, air-entrained concrete, properties of concrete, and constitution of cement. (3 cr; prereq 51 or ¶51; 2 lect and 4 lab hrs per wk) Thomas

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 cr; prereq 141; 3 lect hrs per wk) Andersen

148.* Special Problems in Concrete. Short research problems. (2-3 cr; prereq 146) Thomas

151.* Advanced Highway Laboratory. Special experimental studies of highway materials. (3 cr; prereq 52; 8 lab hrs per wk) Thomas

152.* Highway Design. Geometric design of rural highways. Design of intersections, interchanges, and freeways. (3 cr; prereq 52; 3 lect hrs per wk) Thomas

153. Soils in Highway Engineering. Classification, soil maps, frost action, surveys, physical tests, compaction, design of graded mixes, and soil stabilization. (3 cr; prereq 53; 3 lect hrs per wk) Kersten

154. Design of Highway and Airport Pavements. Advanced studies of theories and practices in the design of rigid and flexible pavements. Strength tests of subgrades and base courses. Pavement evaluation. (3 cr; prereq 53; 3 lect hrs per wk) Kersten

156. Highway Traffic Engineering. Characteristics of vehicle and driver. Traffic volumes and traffic surveys. Regulations and control of traffic; parking solutions. Accidents and their relation to design. (3 cr; prereq 52; 2 lect and 3 lab hrs per wk) Thomas

158. Airport Design. Field layout, capacity, drainage, and studies of bases and surfaces for aprons, runways, and taxiways. (3 cr; prereq 52; 3 lect hrs per wk) Kersten

159. Soil Mechanics. Seepage, consolidation, strength theory. Settlement analysis; stability of slopes; bearing capacity. (3 cr; prereq 53; 3 lect hrs per wk) Kersten

160. Applied Hydraulics. Pipe flow, compound pipe systems, network analysis. Characteristics and applications of centrifugal pumps. Uniform and varied flow in open channels and spillways. Analysis of flow in culverts on mild and steep slopes. (3 cr; prereq Hydr 103 and 104; 2 lect and 3 lab hrs per wk)

161. Hydrology. A study of basic data and methods available for analysis of precipitation and runoff, including stream flow, groundwater infiltration, unit graphs, flood frequencies, flood routing, and probable maximum floods. (3 cr; prereq Hydr 101 or 103; 2 lect and 3 lab hrs per wk)

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 cr; prereq 161 or ♯)

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 cr; recommended for srs in sanitary engineering; prereq 161; 2 lect and 4 lab hrs per wk)

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. Reponsibilities of the engineer. Typical problems. (3 cr; prereq 52)

170. Water Supply. Sources of water supply; quality of water, collection, distribution, and water purification; test methods. Laboratory problems in analysis and design. Inspection trips. (3 cr; prereq 160; 3 lect and 3 lab hrs per wk) Johnson

171. Sewerage and Waste Water Treatment. Sources and quantities of waste water; sanitary, storm, and combined sewer systems; materials and methods of construction; physical, chemical, and biological characteristics of waste water. Disposal by dilution. Domestic and industrial waste treatment. Laboratory problems in analysis and design. Inspection trips. (3 cr; prereq 161, 170; 3 lect and 3 lab hrs per wk) Johnson

172. Sanitary Laboratory. Biological, bacteriological, physical, and chemical analyses of water, waste water, air, coagulant chemicals, disinfectants, waste water sludge, etc. (3 cr; prereq 5th yr or grad; 8 lab hrs per wk) Johnson

173.* Sanitary Engineering Problems (Water). (Supplements CE 170) Investigations of problems in water supply. Collection, distribution, and purification. Economic studies. (3 cr; prereq 170; 3 lect hrs per wk) Schroepfer

174.* Sanitary Engineering Problems (Waste Water). (Supplements CE 171) Investigations of problems in waste water treatment and industrial waste disposal. Stream pollution, stream standards, economic studies of various types and degrees of treatment. (3 cr; prereq 171; 3 lect hrs per wk) Schroepfer

175.* Industrial Waste Disposal. Investigation of various types of industrial wastes and methods of disposal. Economic studies. (3 cr; prereq 174; 3 lect hrs per wk) Schroepfer

176-177-178.‡ Sanitary Engineering Seminar. Reports and discussions on assigned topics in the field of sanitary engineering with occasional talks by practicing sanitary engineers. (1 cr per qtr; required of grad and 5th yr students in sanitary option; prereq 5th yr or grad; 1 rec hr per wk) Schroepfer

For Graduate Students Only

234-235.*‡ Advanced Theory of Structures

236.* Shell Structures

240-241-242. Advanced Structural Laboratory

243.* Dynamics of Structures

244.* Dynamics of Structures Laboratory

247*-248-249. Seminar in Structures

251-252.* Advanced Soil Mechanics Laboratory

261.* Water Plant Design

262.* Waste Water Plant Design

263. Advanced Hydraulic Engineering Problems

264. Sanitary Engineering Unit Operations

276.* Advanced Sanitary Engineering (Water)

277.* Advanced Sanitary Engineering (Waste Water)

280-281-282.* Civil Engineering Research

Economics and Business Administration

(School of Business Administration)

Economics (Econ)

1T-2T. Principles of Economics. (Open to IT students). The principles underlying economic activity and the way these principles work out through our economic institutions. 1: Demand and supply, competition and monopoly, and the distribution of income. 2: National income, money and banking, business cycles, and international trade. Econ 1-2 or equivalent are prerequisite for most advanced courses in business administration and economics. (3 cr each qtr, §1-2, §C, §50A-B; prereq 3rd qtr fr for 1, 1 for 2)

1-2. Principles of Economics. Same as Econ 1T-2T

65. Intermediate Economic Analysis: The Firm. Behavior of firms under competitive and monopolistic conditions; factors influencing the firm's decisions regarding production, output, and prices. (3 cr, §165; prereq 2 or equiv)

66. Intermediate Economic Analysis: Income and Employment. Determinants of national income, employment, and price level, with particular attention to aggregate consumption and investment. (3 cr, §166; prereq 2 or equiv or ♯)

67. Money and Banking. Historical development, present pattern, and economic role of financial institutions, with special emphasis on commercial banks, the money supply, and the Federal Reserve System. (3 cr; prereq 2 or equiv)

68. Elements of Public Finance. Survey of government expenditures, budgeting, fiscal policy, debts, and taxes in terms of fiscal institutions, impact on business and the economy, and policy issues. Condensed course given especially for School of Business Administration students. (3 cr, §168, §178A-B; prereq 2 or equiv)

69. Government Regulation of Business. Economic aspects of public policy affecting the market process. Relations between market structure and economic efficiency and welfare; economic origins of monopoly and other business limitations on free com-

petition; and purposes and effect of antitrust laws and laws relating to "unfair business practices." (3 cr, §169; prereq 65 or 165 for business or economics majors, suitable background in law or political science for others or ♯)

172. Public Policy: Labor Relations. Employer-employee-union relationships and their social control; legislative, executive, and judicial attempts to deal with these issues; economic and social implications. (3 cr; prereq BA 52 or 152)

Business Administration (BA)

1. Business and the American Economy. Descriptive survey of the American economy with emphasis on the business segment. Functions performed by any economic system and typical businesses; kinds of decisions to be made and examples of information needed for making selected decisions. (3 cr; prereq fr or soph with no previous BA, or social studies majors in education with no previous BA)

5. Elements of Statistics. Sources and collection of data; tabular and graphic presentation; frequency distributions; probability; sampling; introduction to statistical estimation and decision-making. (4 cr, §151, §Soc 45; prereq Math 10 or equiv)

50. Production Management. The techniques, the managerial problems, and the decision-making processes in planning and controlling the production activity. Production as a function of the enterprise rather than as a strictly manufacturing activity. Research and development, the role of standards, physical facilities, systems and procedures analysis, work measurement, materials control, quality control, and production planning and control. (3 cr, §150, §IE 50; prereq Econ 2 or equiv)

51. Business Statistics. Basic concepts of regression and correlation; statistical estimation and decision-making, applications to survey sampling, acceptance sampling and statistical quality control; time series analysis and index numbers. (3 cr, §161; prereq soph with ♯, 5 or equiv)

52. Modern Industrial Relations: Labor Marketing. An introduction to current employment relationships; an economic approach and analysis. The application and conservation of human resources in employment, related social and economic problems. Labor marketing, collective bargaining, unions and employer associations, industrial unrest and conflict, employment and unemployment, wage problems. (3 cr, §152; prereq Econ 2 or equiv)

53. Risk Management and Insurance. Recognition, measurement, and evaluation of insurable personal, property, and liability risks of economic units. Tools of risk management; assumption, loss prevention, transfer, and others with emphasis on insurance. Design and implementation of the optimum risk management program. Government regulation of insurance. (3 cr, §153; prereq Econ 2 or equiv)

54. Transportation I: Principles. Roles, interests, and relationships of users of the service, carriers, and regulatory agencies in the transportation field; national transportation policy approach. Organization of the transportation industry and administration of the transportation function by users of the service in their business activities. Economic aspects of railway, highway, pipeline, water, and air transportation. Current transportation problems; national transportation policy. (3 cr, §154; prereq Econ 2 or equiv)

55A-B. Elementary Accounting. The equivalent of BA 24-25-26 (Principles of Accounting) for School of Business Administration students and for 5-year combined engineering and business students. (4 cr per qtr, §24-25-26; counts as Lower Division course when transferred to SLA)

55C. Managerial Costs. General survey of cost accounting from point of view of the executive who must use cost information in conduct of his business. (3 cr, §115A, §115B, §265A; prereq 26 or equiv)

56. Corporation Finance. Principles governing the planning, raising, and control of short- and long-term funds for a business enterprise. Cash-flow, valuation, capital structures, investment banking, dividend policy, mergers, and reorganization. (3 cr, §156; prereq 26)

57. Principles of Marketing. Marketing functions and institutions. Channels of distribution. Retail and wholesale trade. Pricing policies and practices. Marketing policies and methods for consumers' goods, producers' goods, and raw materials. (3 cr, §157; prereq Econ 2 or equiv)

58. Business Law: Contracts. Law of contracts. Case method used in BA 58, 78, 88, 98. (3 cr, §158; prereq Econ 2 or equiv)

60. Business Policy and Management Control. Managerial authority and responsibilities, organizational relationships, and effective executive action. Managerial problems of policy formulation involving decisions based upon a knowledge of all the major functions in the firm. (3 cr, §260; prereq 3rd qtr sr)

Electrical Engineering (EE)

12-14-16. Elements of Electrical Engineering Laboratory. Principles, materials, instruments, elementary circuit calculations, laboratory techniques, safety, orientation. (1 cr per qtr; prereq ITM 13A; 2 lab hrs per wk)

36-37-38. Elements of Electrical Engineering. (Aero, AgE, CE, ChemE, ME, Met, MinE) Basic concepts of direct-current and alternating-current circuits, electric and magnetic fields. Analysis of electron devices and their associated circuitry, semiconductors. Electromechanical energy conversion. Regulating systems, instrumentation. (3 cr per qtr; prereq ITM 26A; 3 lect and 2 prob session hrs per wk for 36, 3 lect hrs per wk for 37 and 38)

37A-38A. Electrical Engineering Laboratory. Supporting laboratory for EE 37-38. Experimental study of electric circuits and devices with emphasis on instrumentation and measurement techniques. (1 cr per qtr; prereq ¶37-38; 2 lab hrs per wk)

40. Electrical Engineering Survey. (CE, MinE) Principles of operation of electric machines. Type study of transformers, motors, generators, and their application in electrical systems. (4 cr; prereq 36; 3 lect hrs and 2 lab hrs per wk)

61-62-63. Introductory Circuit Theory. Analysis of linear circuits excited by constant, exponential, and sinusoidal sources. Time and frequency analysis of the forced and free response of circuits and the concepts of power and energy in lumped constant elements. (4 cr per qtr; prereq ITM 26A, Phys 14; 3 lect and 2 rec hrs per wk)

61H-62H-63H. Honors Course: Introductory Circuit Theory. A more intensive treatment of the topics of EE 61-62-63. (4 cr per qtr; prereq ITM 26A, Phys 14, ¶71H-72H-73H, ¶81H-82H-83H, △; 3 lect and 2 rec hrs per wk)

71-72-73. Electromagnetic Fields and Materials. Properties and behavior of electromagnetic fields under static and time-varying conditions based upon the experimental laws of electromagnetism leading to Maxwell's equations; interaction of fields and matter; energy concepts; conductive, dielectric, and magnetic properties of materials. (4 cr per qtr; prereq MM 27, ITM 26A, Phys 50; 3 lect and 2 rec hrs per wk)

71H-72H-73H. Honors Course: Electromagnetic Fields and Materials. A more intensive treatment of the topics of EE 71-72-73. (4 cr per qtr; prereq ITM 26A, MM 27, Phys 50, ¶61H-62H-63H, ¶81H-82H-83H, △; 3 lect and 2 rec hrs per wk)

81-82-83. Electrical Engineering Laboratory. Experimental study of electric circuits and electromagnetic fields. (2 cr per qtr; prereq ¶61-62-63, ¶71-72-73; 1 conf and 3 lab hrs per wk)

81H-82H-83H. Honors Course: Electrical Engineering Laboratory. Experimental study of electric circuits and electromagnetic fields. (2 cr per qtr; prereq ¶61H-62H-63H, ¶71H-72H-73H, △; 1 conf and 3 lab hrs per wk)

101-102-103. Summer Engineering Employment. Summer work of not less than 360 hours per summer in an engineering field. Requires a technical report. (1-3 cr each; prereq completion of 2nd-, 3rd-, or 4th-yr work; declaration of intention before end of spring qtr; regis in fall qtr)

104-105-106. Electronics. 104: An introduction to physical electronics; electronic properties of metals, insulators, semiconductors, junctions; electron emission and gaseous discharge phenomena. 105-106: Quasi-linear and nonlinear behavior of vacuum, gas, and semiconductor devices; principles of rectification, amplification, frequency-conversion, oscillation; generic 2- and 4-terminal active circuits. (4 cr per qtr; prereq 73 or equiv for 104...63 and 104 or equiv for 105-106; 4 lect hrs per wk)

104H-105H-106H. Honors Course: Electronics. A more intensive treatment of the topics of 104-105-106. (4 cr per qtr; prereq 63, 73, ¶111H-112H-113H, ¶114H-115H-116H, △; 4 lect hrs per wk)

109. Electromagnetic Fields. A theoretical study of electricity and electromagnetism leading to the development and simple applications of Maxwell's equations. Vector notation is employed. (4 cr; prereq 55, 56; 3 lect and 2 rec hrs per wk; offered 1961-62 for last time)

111-112-113. Circuits and Fields. Lumped linear circuits in the transient and steady state; application of transform techniques in transient analysis; general multi-port network analysis. Fields, energy, and forces with application to electromagnetic and electromechanical devices. (3 cr per qtr; prereq 63 and 73 or equiv; 3 lect hrs per wk)

111H-112H-113H. Honors Course: Circuits and Fields. A more intensive treatment of the topics of 111-112-113. (3 cr per qtr; prereq 63, 73, ¶104H-105H-106H, ¶114H-115H-116H, △; 3 lect hrs per wk)

114-115-116. Electrical Engineering Laboratory. Experimental studies in electrical engineering for fourth-year students. (2 cr per qtr; prereq 83, ¶104-105-106, ¶111-112-113; 1 conf and 3 lab hrs per wk)

114H-115H-116H. Honors Course: Electrical Engineering Laboratory. Experimental studies in electrical engineering for fourth-year students. (2 cr per qtr; prereq 83, ¶104H-105H-106H, ¶111H-112H-113H, △; 1 conf and 3 lab hrs per wk)

121-123-125. Analysis of Electromagnetic Devices. Principles of storage, transfer, and control of electromagnetic energy; application to analysis of transformers, saturable reactors, magnetic amplifiers, memory devices. Fundamentals of electromechanical energy conversion; application to transducers and rotating machines. Steady state and transient behavior of rotating machines in control and power systems. (3 cr per qtr; prereq 55, 56, ¶122-124-126, ¶161; 3 lect hrs per wk; offered 1961-62 for last time)

121H-123H-125H. Honors Course: Principles of Electromechanics. Macroscopic treatment of electromagnetism based on Maxwell's equations. Interaction of fields and matter; Poynting's theorem; forces between media in relative motion. Transition to lumped circuit concepts in electromechanical converters. Application of Lagrangian techniques to incremental-motion transducers, rotating machines, and machine systems. Electromechanical energy conversion in the solid state and in fluid flow. (3 cr per qtr; prereq 55H, ¶150, ¶161H, △; 3 lect hrs per wk; offered 1961-62 for last time)

122-124-126. Experimental Study of Electromagnetic Devices. Laboratory designed to illustrate principles and techniques developed in EE 121-123-125. (1 cr per qtr; prereq ¶121-123-125; 2 lab hrs per wk; offered 1961-62 for last time)

122H-124H-126H. Honors Course: Experimental Study of Electromagnetic Devices. Laboratory designed to illustrate principles and techniques developed in EE 121H-123H-125H. (1 cr per qtr; prereq ¶121H-123H-125H; 2 lab hrs per wk; offered 1961-62 for last time)

131-133-135. Electronic Circuit Design. Analysis and design of vacuum-tube and transistor circuits, rectifiers, amplifiers, oscillators, etc. Laboratory construction and check of designs. (3 cr per qtr; prereq 163; 2 lect and 2 lab hrs per wk)

132-134-136. Study of Electric Machines. Broadly applicable principles with special emphasis on design. Prediction of performance, steady and transient behavior, direct-current generators and motors, alternating-current transformers, generators, and synchronous motors. (3 cr per qtr; prereq 125; 2 lect and 2 lab hrs per wk)

138-139-140. Electric Power Control. Analysis of power circuits and machines using symmetrical component methods. Control of motors, generators, and metadynes; application of magnetic amplifiers. Control of power systems, power system stability. (3 cr per qtr; prereq 125; 2 lect and 2 lab hrs per wk)

141. Electrical Engineering Materials. Dielectric, magnetic, and conductive properties of materials used in electrical engineering, including methods of measurement and examples of application. (4 cr; prereq 109; 3 lect and 2 rec hrs per wk; offered 1961-62 for last time)

143-144-145. Engineering Acoustics. Acoustic equations; dynamical analogies with equivalent circuits and application to microphones, loudspeakers, and ultrasonic transducers; room acoustics and noise control; technological application of vibration and sound; power transducers for industrial purposes. (3 cr per qtr; prereq 38 or 53 or 73 or ♯, ITM 26A, MM 29 or equiv; 3 lect hrs per wk)

150. Dynamical Methods in Electrical Engineering. Lagrangian and Hamiltonian formulations of dynamics, with applications to electromagnetic systems. Lagrange's equations; dissipative forces; normal co-ordinates and small oscillations; Hamilton's equations; variational principles for discrete and continuous systems. (3 cr; prereq MM 29 or equiv, ITM 152, ♯; 3 lect hrs per wk)

151. Thermodynamic Methods in Electrical Engineering. Basic thermodynamic concepts and laws, with special application to electromagnetic systems. Energy, entropy, and thermodynamic potentials; application to electrically and magnetically polarizable materials, rigid or elastic, piezoelectricity, magnetostriction, thermoelectricity, reciprocal relations in reversible and irreversible processes. (3 cr; prereq ITM 153, Phys 51 or ME 30, ♯; 3 lect hrs per wk)

152. Statistical-Mechanical Methods in Electrical Engineering. Classical and quantum statistical mechanics, with applications to materials and problems of electrical engineering. Statistical ensembles, phase space, Liouville's theorem, the canonical ensemble, the partition function. Classical and quantum statistics. Relation between statistical mechanics and thermodynamics. Classical and quantum calculations of susceptibilities. (3 cr; prereq 150, 151, ♯; 3 lect hrs per wk)

153-154-155. Introduction to the Properties of Solids. Classical statistical theory of matter, thermal properties of solids, crystal structure, ionic crystals, dielectrics, the electron theory of metals, band theory of solids, imperfections in crystals, magnetism. (3 cr per qtr; prereq 152, Phys 109 or Phys 110, ♯; 3 lect hrs per wk)

157-158-159. Electronic Control. Analysis and applications of difference amplifiers, regulators, phase-sensitive demodulators, inverters, and timing circuits. Linear servomechanisms and associated stability analysis using Nyquist and Bode techniques. Analog computers and system error analysis. (3 cr per qtr; prereq 125, 163; 2 lect and 2 lab hrs per wk)

161-162-163. Electrical Engineering Networks. Theoretical studies of lumped linear networks in the transient and steady state. Application of Laplace Transforms in transient analysis. General lumped-constant network analysis; two-terminal-pair networks, filter theory, linear amplifier networks, and analysis of feedback amplifiers. (3 cr per qtr; prereq 53, 54, 59, 60, ¶161A-162A-163A; 3 lect hrs per wk; offered 1961-62 for last time)

161A-162A-163A. Networks Laboratory. General laboratory study of lumped electrical networks under transient and steady-state operation. Studies of transmission characteristics of active and passive networks. (1 cr per qtr; prereq ¶161-162-163; 2 lab hrs per wk; offered 1961-62 for last time)

161H-162H-163H. Honors Course: Electrical Engineering Networks. Analysis of the transient and steady-state behavior of lumped, linear circuits. Introduction to topology and matrix methods for treating general networks. Laplace and Fourier transform methods; properties of network functions; elementary network synthesis. Applications to active and passive 2-port networks, filter theory, the 4-pole parameters, scattering matrices. Dynamical analogies; stability criteria; noise in linear systems. Laboratory. (4 cr per qtr; prereq 53H, 54H, 59H, 60H, △; 3 lect and 2 lab hrs per wk; offered 1961-62 for last time)

164-165-166. Communication Circuits. Theoretical and laboratory study of selected topics in electric communication. Spectral analysis; modulation theory, including amplitude, frequency, and pulse modulation; noise; elements of information theory; system analysis. (3 cr per qtr; prereq 163; 2 lect and 2 lab hrs per wk)

167-168-169. Electromagnetic Theory and Application. Electromagnetic theory, Maxwell's equations, boundary value problems. Propagation of waves in space, on lines, and in waveguides. Cavities, antennas, and radiation. Introduction to microwave tubes. (3 cr per qtr; prereq 109, ♯; 2 lect and 2 lab hrs per wk)

173-174-175. Physical Electronics. Electron devices used in electrical engineering; thermionic, photo, secondary emission, semiconducting, and photo-conducting devices. Devices based upon the electric and magnetic properties of matter. (3 cr per qtr; prereq 141 or equiv, ♯; 3 lect hrs per wk for 173...2 lect hrs and 2 lab hrs per wk for 174 and 175)

176. Principles of Analog Computation. Theory, operation, and applications of differential analyzers; nonlinear elements, transient and steady-state response, stability. (3 cr; prereq 161)

177. Analog Computing Laboratory. (1-3 cr; prereq 161)

178-179-180. Nonlinear Active Circuits. Wave-shaping circuits, multivibrators, switching circuits. time-base and pulse generators, digital computer circuits. (3 cr per qtr; prereq 163; 3 lect hrs per wk)

182A-B. Transistor Principles and Circuits. Properties of semiconductors, low-frequency characteristics of p-n junctions, low-frequency characteristics and equivalent circuits of transistors, voltage and current amplifiers, stabilization of operating point, class A, AB, and B, single-ended and push-pull amplifiers, feedback and d-c amplifiers, oscillators. (3 cr per qtr, §133-135; prereq 163 or equiv, Phys 50, ♯)

182C. High-Frequency Transistor Circuits. High-frequency characteristics of p-n junctions and transistors, high-frequency broad and narrow-band amplifiers, large and small-signal transient response, high-speed switching circuits. Understanding of transmission line theory assumed. (3 cr; prereq 182A and ♯)

183-184-185.† Special Investigations. Undergraduate studies of approved topics, theoretical or experimental in nature. (Cr ar; prereq approval of faculty sponsor)

187-188-189. Problems in Electrical Engineering. Nonlinear network analysis applied to electrical problems involving signal and power amplification, modulation and demodulation, and oscillations. Special emphasis on approximate methods of solution and their interpretation. Problems in wave motion with special application to transmission of electrical signals and power. (3 cr per qtr; prereq 109, 125, 163; 3 lect and 1 rec hrs per wk)

191-192-193. Active Network Theory. Response of amplifiers to arbitrary excitation, selected topics in feedback amplifiers, negative-impedance networks, active filters, high-precision and high-frequency amplifiers, frequency and amplitude stability of oscillators, high-frequency oscillators. (3 cr per qtr; prereq 163, ITM 153 or equiv, ♯; 3 lect hrs per wk)

194-195-196. Servomechanisms. Analysis of linear feedback control systems, Nyquist and Bode diagrams; root-locus, gain-phase, and pole-zero techniques. Compensation and minor loops. Load disturbances. Performance criteria. Multivariable controls. Experimental laboratory on typical control systems; analogue computer simulation. (3 cr per qtr; prereq 125, 163, ♯; 3 lect hrs per wk)

197-198-199. Electrical Design of Machines I. 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, study of harmonics in air-gap flux waves, effect upon performance. Transformers for control and electronic applications. (3 cr per qtr; prereq 125 and ♯)

For Graduate Students Only

211-212-213. Network Analysis and Synthesis

221-222-223. Electric Power Seminar

227-228-229. Stability of A.C. Power Systems

233-234-235. Fluctuation Phenomena

236-237-238. Solid State Theory

242-243-244. Plasma Physics

255-256-257. Analysis of A.C. Power-System Circuits

261-263-265. Problems in Electromagnetism

262-264-266. Communication Seminar

267-268-269. Statistical Theory of Communication

272-273-274. Fundamentals of Acoustics

275-276-277. Electrical Design of Machines II

281-282-283. Seminar on Energy Conversion

287-288-289. Electron Tube Analysis

291-292-293. Electronics Seminar

294-295-296. Advanced Control Theory

English (Engl)

A-B-C. Freshman Literature and Composition. A combined course in composition (6 cr) and literature (9 cr) similar to Engl 1A-2A-3A, except that it puts heavier emphasis upon literature. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (5 cr per qtr; prereq assignment to Category 1, 1A, or 2; students absent on 1st day will lose their place in this class)

1A-2A-3A. Freshman English. A combined course in composition (6 cr) and literature (6 cr) similar to Engl 1B-2B-3B, except that it puts greater emphasis upon literature. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (4 cr per qtr; prereq assignment to Category 1, 1A, or 2; students absent on 1st day will lose their place in this class)

1B-2B-3B. Freshman English. A combined course in composition (9 cr) and literature (3 cr). It concentrates upon developing the student's skill in writing exposition, with an introduction to literary types as the chief means of providing subject matter for the writing. The literature read consists of novels, short stories, plays, and poems, both English and American. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (4 cr per qtr; prereq assignment to Category 1, 1A, 2, or 3; students absent on 1st day will lose their place in this class)

37-38-39.‡ Modern Literature. Intended for students in all departments and colleges, not particularly for English majors. Readings in 20th-century British and American fiction, drama, and poetry. Selected, arranged, and discussed—*not* to give a full historical survey but to enhance the student's pleasure in, and understanding of, imaginative literature generally. Short critical papers are required and count in determining grades. 37: Short fiction. 38: Poetry and drama. 39: The novel since Thomas Hardy. (3 cr per qtr; prereq soph, completion of or exemption from freshman English requirement; 3 rec hrs per wk) Foster, Myers

85-86. Advanced Technical Communication. Theory and practice in professional uses of language. 85: Reports and talks. 86: Letters, articles, conferences. (3 cr per qtr; prereq C or 3A or 3B; 3 rec hrs per wk) Guthrie, Haga

General Engineering (GE)

21. Orientation. Series of lectures designed to orient the student who has just begun his university course. (1 cr; 1 lect hr per wk)

70. The Slide Rule. Computation practice and theory. Design of special scales. (1 cr; prereq ITM 11 or ¶11; 1 rec hr per wk)

101. Contracts and Specifications. Synopsis of the law of contracts, sales, agency, negotiable instruments, real property, personal property, partnerships, corporations, insurance contracts, workman's compensation, labor law, mechanics liens, government construction contracts, and torts with applications to the performance of engineering and construction contracts. (3 cr; prereq 5th yr or grad; 3 rec hrs per wk)

103. Professional Problems. Lectures covering some of the problems the engineer will meet upon entering his professional career. (1 cr; 1 lect hr per wk)

Geology and Mineralogy (Geol)

(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 cr per qtr, §5-6; no prereq for 1...1 or 8 or 51 for 2; 3 lect hrs per wk)

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 cr per qtr; prereq 1 or 8 or 51 or ¶1 or 8 or 51 for A...A, 2 or ¶2 for B; 4 lab hrs per wk)

5-6. Geology for Engineers. 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 cr per qtr, §1-2; prereq InCh 15; 3 lect hrs per wk)

8. Earth Features and Their Meaning. Introductory course. A general education elective. 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 cr; 5 lect hrs per wk)

23-24. Mineralogy. Introduction to crystallography and crystal chemistry. Chemical and physical properties of minerals. Classification and description of common minerals. Crystallographic problems, study of crystal symmetry and sight identification of minerals in the laboratory. (4 cr per qtr; prereq soph, high school trigonometry, a term of college chemistry) Zoltai

25. Rock Study. The occurrence and origin of rocks; their mineral and chemical composition and classification. (2 cr; prereq 24; 1 lect, 1 rec, and 2 lab hrs per wk) Phinney

100. Field Work in Northern Minnesota. Geologic field methods and study of selected areas on the iron ranges and other parts of northern Minnesota. A comprehensive report is required for Graduate School credit. (3 cr; prereq 25)

101. Sedimentation. Origin of sedimentary rocks and their primary structures; lithologic associations. (3 cr; prereq 24; 3 lect hrs per wk)

102.* Methods of Study of Sediments. Sedimentary rocks. Textural and mineralogical analyses of clastic and nonclastic materials. (3 cr; prereq 101, 106; 1 lect and 4 lab hrs per wk)

103.* Micropaleontology. Classification of Foraminifera, Ostracoda, and other small fossils, their use in stratigraphy. (3 cr; prereq 107) Swain

104. Micropaleontology. Advanced study of selected groups of microfossils. (2 cr; prereq 103; offered 1962-63 and alt yrs) Swain

106. Optical Mineralogy. Optical methods for identification of minerals in thin sections and immersion media. (3 cr; prereq 25) Phinney

107. Invertebrate Paleontology. Morphology and classification of important fossil groups. Principles of paleontology. (3 cr; prereq B or △; 2 lect and 3 lab hrs per wk) Sloan

108.* Stratigraphic Paleontology. Uses of fossils in stratigraphy; environmental analysis; detailed study of a selected fauna. (3 cr; prereq 107; 1 lect and 4 lab hrs per wk) Sloan

109. Advanced Invertebrate Paleontology. Procedures in taxonomy; preparation of a paleontologic report. (3 cr; prereq 108) Sloan

110-111.* Economic Geology. The nature, genesis, and distribution of mineral deposits; relation of mineral deposits to structure and surficial alteration. (3 cr per qtr; prereq 125; 3 lect hrs per wk)

112.* Petroleum Geology. Composition and origin of petroleum, methods of exploration and the geology of the important oil producing regions. (3 cr; prereq 125; 3 lect hrs per wk) Swain

114.* Geology of Minnesota and Adjoining Areas. Structure, stratigraphy, lithology and their associated mineral resources, with emphasis on the Pre-Cambrian. (3 cr; prereq 25; 3 lect hrs per wk)

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 cr; prereq 25) Sloan

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 cr; prereq B; 3 lect hrs per wk) Wright

119A.* Geomorphology of Eastern United States. General geology of the physiographic provinces east of the Great Plains; landforms and Cenozoic history. Map study. (3 cr; prereq 118 or 125; 2 lect hrs per wk, lab ar; offered 1961-62 and alt yrs) Wright

119B.* Geomorphology of Western United States. (Complements Geol 119A) General geology of the physiographic provinces from the Great Plains westward; landforms and Cenozoic history. Map study. (3 cr; prereq 118 or 125; offered 1960-61 and alt yrs) Wright

120.* Glacial Geology. Modern glaciers. Erosion and deposition. Chronology of Pleistocene climatic changes in glaciated and nonglaciated areas. (3 cr; prereq B; 3 lect hrs per wk) Wright

121. Crystallography. Geometrical fundamentals of crystallography. Symmetry relations in the 32 crystal classes and 230 space groups. (3 cr; prereq trigonometry and 1 yr college chemistry) Zoltai

125. Structural Geology. Primary and secondary structures of rocks, mechanics and modes of deformation, and structural techniques. Laboratory exercises in three-dimensional representation and solution of selected structural problems. (4 cr; prereq 25 or ♯) Craddock

126. Advanced Structural Geology. Fundamental problems and genesis of secondary structural features with emphasis on detailed analysis of typical examples. Comprehensive term paper required for graduate credit. (3 cr; prereq 125) Craddock

131-132. Petrology. Petrographic description, classification, and origin of rocks. 131: Igneous rocks. 132: Metamorphic rocks. (4 cr per qtr; prereq 106) Phinney

145.* Aerial Photographs. Elements of photogrammetry, construction of mosaics and of planimetric and topographic maps, stereovision, geologic and geomorphic interpretation, field use. (3 cr; prereq 118 or 125 or ♯; 6 lab hrs per wk) Wright

146-147. Soil Mineralogy. Crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. (3 cr per qtr; prereq high school trigonometry, a term of college chemistry) Zoltai

150. Field Geology. (June 15-July 15) Detailed systematic field work in stratigraphy, structural geology and economic geology; preparation of geologic maps and other illustrations. Normally to be followed by Geol 171. Field, Blacks Hills, S. D. (6 cr; prereq 125)

151. Stratigraphy I. Principles of stratigraphic classification and correlation; biostratigraphic zones, sedimentary facies and cycles. Typical pre-Mesozoic sequences. (3 cr; prereq 25, 107; 3 lect hrs per wk) Swain

152.* Stratigraphy II. Typical Mesozoic and Cenozoic sequences; methods of presentation of stratigraphic data. (3 cr; prereq 151; 3 lect hrs per wk) Swain

153.* Subsurface Stratigraphy. Application of sample logs, electrical logs, and other methods to the detailed stratigraphy of the subsurface in selected areas. (2 cr; prereq 151; 4 lab hrs per wk) Swain

154.* Geological Oceanography and Limnology. Sedimentary and biological processes in modern oceans and lakes and their application to geology and paleontology. (2 cr; prereq 101 and 118 or ♯; offered 1961-62 and alt yrs) Swain

155.* Vertebrate Paleontology. Stratigraphic and morphologic aspects of fossil vertebrates. (3 cr; prereq 107 or Zool 22 or ♯) Sloan

161.* Advanced Mineralogy. Crystal chemistry and structures of minerals. Crystal growth. Lab study of specimens and structure models. (3 cr; prereq 24; offered 1961-62 and alt yrs) Zoltai

166-167.* Mineralography. Opaque minerals; applications to problems in ore genesis and history. (3 cr per qtr; prereq 111, 131)

170.* Geologic Problems. Individual research in laboratory, or field problems. (1-3 cr; prereq consent of major adviser)

171.* Preparation of Geologic Report. Supervised preparation of a geologic report, with maps and other illustrations, on an acceptable area or subject. Preliminary manuscript due at midquarter. (1 cr; prereq 4th yr, 150 or △)

175.* Field Work in Glacial Geology and Geomorphology. Mapping of surficial deposits and landforms of a selected area in Minnesota. One day in field each week. (3 cr; prereq 118, 120) Wright

176. Pleistocene Geology. Glaciated and unglaciated areas, particularly in North America, Europe, and the Mediterranean. Relation of Pleistocene climatic changes to soils, biogeography, and archaeology. (3 cr; prereq 120; offered 1961-62 and alt yrs) Wright

177. Advanced Geomorphology. Selected topics in river morphology, slope analysis, arctic and desert landforms. Methods of study. (3 cr; prereq 118; offered 1962-63 and alt yrs) Wright

178. Advanced Principles of Economic Geology. Fundamental principles involved in the origin of ore deposits. (3 cr; prereq 111)

179. Mining Geology. Economic geology applied to problems in mining. (3 cr; prereq 111; offered 1961-62 and alt yrs)

181. Principles of Geochemistry. Chemical structure and composition of the earth. Distribution of the elements within the lithosphere, hydrosphere, atmosphere, and biosphere. (3 cr; prereq 25 and 1 yr college chemistry) Gast

182. Isotopic and Nuclear Processes in Geology. Measurement of geologic time using natural radioactivity. Variations in isotopic compositions due to radioactivity and to natural isotope fractionation processes. (3 cr; prereq 25 and physical chemistry or ♯) Gast

183. Advanced Geochemistry. Selected topics in geochemistry. (2 cr; prereq 182 or ♯; offered 1961-62 and alt yrs) Gast

Geophysics (GPhy)

90-91-92. Industrial Employment. (Ar cr; prereq △)

108. Introduction to Earth Geophysics. Physics of the earth; evidence and data on origin, age, size and shape, internal constitution, thermal history, gravity, and magnetic fields. (3 cr; prereq Phys 9 or 14, Geol 2) Thiel

109. Introduction to Earthquake Seismology. Physics and geology of earthquakes; causes, effects, distribution, seismic waves. (3 cr; prereq Geol 125 or ♯) Mooney

110. Introduction to Exploration Geophysics. Principles of exploration by gravity, magnetic, seismic, and electrical measurements. (3 cr; prereq Phys 9 or 14, Geol 2) Mooney

125. Principles of Gravity and Magnetic Exploration. Instrumentation, surveying techniques, reduction of data, interpretation, case histories. (3 cr; prereq Phys 9 or 14, Geol 1, ITM 25A) Thiel

126. Principles of Seismic Exploration. Reflection and refraction seismology; theory, interpretation, instruments. (3 cr; prereq Phys 9 or 14, ITM 25A, Geol 2) Mooney

127. Principles of Electrical Exploration. Resistivity, electromagnetic, and other methods; theory, interpretation, instruments. (2 cr; prereq Phys 9 or 14, ITM 25A, Geol 2) Mooney

135-136-137-138.* Research Problem in Geophysics. (Cr ar; prereq ♯) Mooney, Thiel

175. Gravity and Geodesy. Gravity potential theory and measurements, reference ellipsoids and gravity formulas, gravity anomalies, earth tides, isostasy, geoid and deflections of the vertical, world geodetic system, satellite geodesy. (3 cr; prereq Phys 14, ITM 25A) Thiel

176. Geomagnetism. Main field and secular variation, dynamo theory, magnetic storms, aurora, ionospheric physics, rock magnetism, polar wandering. (3 cr; prereq Phys 14, ITM 25A) Thiel

178.* Physical Oceanography. Physical properties of sea water, oceanographic surveys, water masses and ocean currents, wind currents and waves, tides. (3 cr; prereq Phys 14, ITM 25A; offered 1962-63 and alt yrs) Thiel

179.* Glaciology. Physical properties of snow and ice, growth and deformation of ice crystals, densification, mechanics of glacier flow, temperature distribution in glaciers and ice sheets, application of geophysical techniques, Greenland and Antarctic ice sheets. (3 cr; prereq Phys 14, ITM 25A; offered 1961-62 and alt yrs) Thiel

For Graduate Students Only

232-233.* Theoretical Seismology

250.* Geotechtonics Seminar

251-252-253.* Geophysics Seminar

German (Ger)

(College of Science, Literature, and the Arts)

1A-2A-3A. Beginning German: Conversational Section. Five class meetings a week. Provides basic experience in speaking and understanding the German language through the use of texts dealing with everyday situations; provides a reading knowledge that is adequate for this level; provides necessary insight into the structure of the language by analysis of texts already learned. (5 cr per qtr)

1B-2B-3B. Beginning German: Language and Culture. Five class meetings a week. Provides, without emphasis on formal grammar, foundation of a reading knowledge adequate for cultural or professional purposes; gives an introduction to German culture and its contributions to Western civilization; encourages an understanding of the nature of language by systematic comparison between German and English. Stresses direct experience with a variety of reading material in German and English. (5 cr per qtr)

1C-2C-3C. Beginning German. Five class meetings a week. Gives a knowledge of the elements of grammar and the facility to read and write easy German. (5 cr per qtr; students submitting 1 yr high school German for entrance take Ger 2; those offering 2 yrs high school German take Ger 3)

50-51-52. Reading German: A Beginning Course for Juniors and Seniors. Develops reading proficiency by concentrating from the outset on vocabulary building and reading techniques and reduces presentation of formal grammar to a minimum. Intensive study of a variety of texts in class; individual projects in extensive reading. (3 cr per qtr)

History (Hist)

(College of Science, Literature, and the Arts)

20-21-22.† American History. A survey of the political, economic, and social history of the United States, with emphasis on the forces that resulted in the emergence of modern America. 20: Colonial and early national period. 21: Sectionalism and national development. 22: Modern America. (3 cr per qtr; prereq soph) Berkhofer, Chambers, Murphy, Rutman

79-80-81.† The United States in the Twentieth Century. Political, economic, diplomatic, and social history of the United States from the Spanish-American War to the present. 79: 1898-1916. 80: 1916-1932. 81: 1932 to present. (3 cr per qtr) Chambers

89. Economic History of Modern War. Economic aspects of the French Revolution and Napoleonic Wars, and of World War I and World War II. (3 cr; offered when feasible)

112-113-114.† Economic History of Europe. 112: Economic life in ancient and medieval times. 113: Economic developments in the early modern world. 114: Economic developments since 1750. (3 cr per qtr) Bamford

134-135-136.† World War II. 134: Origins and background. 135: The war period, 1939-1942. 136: The period 1943-1945. (3 cr per qtr) Deutsch

146-147-148.† American Economic and Social History. 146: Colonial life. 147: From the Revolution to 1860. 148: Developments since 1860. (3 cr per qtr) Loehr

Humanities (Hum)

(College of Science, Literature, and the Arts)

21-22-23.† American Life. Each quarter is organized around a topic, such as individualism in American life and thought, religious and philosophic attitudes in relation to American ideas, the rise of American nationalism and its place in the world. (3 cr per qtr) Berkhofer, Kwiat, Turpie, Weber

51-52-53.‡ Humanities in the Modern World. Similar to Hum 1-2-3 except that it is confined to juniors and seniors. (5 cr per qtr, §corresponding qtrs of 1-2-3) Amberg, Blum, Kwiat

71-72-73.‡ Humanities in the United States. Introduction to American cultural history. Each quarter is organized around topics which disclose a major conflict of ideals—for example, liberty and property in the early Republic, individualism and majority rule in the pre–Civil War era, materialism and idealism in the present industrial age. Such figures as Jefferson, Hamilton, Thoreau, Mark Twain, Frank Lloyd Wright, and William Faulkner are studied. (3 cr per qtr) Levenson

A student may take any combination of 21, 22, 23, 71, 72, 73 up to a maximum of 9 credits.

Hydromechanics (Hydr)

(Civil Engineering Department)

101. Fluid Mechanics. (Aero and EE) Fluid statics and dynamics for liquids and gases. Viscous effects, dimensional analysis and similitude, potential flow. (3 cr; prereq MM 27; 3 rec hrs per wk; 103 may be substituted for 101) Straub and staff

103. Fluid Mechanics. Fluid properties, hydro- and aerostatics, fluid dynamics for viscous and nonviscous liquids and gases, dimensional analysis and similitude, pipe flow, open-channel flow, principles of lift and drag, and introduction to boundary layers. (5 cr; prereq MM 27; 5 rec hrs per wk; 103 may be substituted for 101) Straub and staff

104. Fluid Mechanics Laboratory. Introduction to laboratory techniques, calibration principles, and fluid measurements. Open channel, pipe line, and hydraulic machinery experiments. (1 cr; prereq 101 or 103 or ChEn 101 or ¶Hydr 101 or Hydr 103 or ¶ChEn 101) Straub and staff

183.* Open Channel Flow. Theory of uniform and varied flow, with practical applications to design of hydraulic structures, computations of drawdown curves, backwater curves, hydraulic jump, measuring flumes, submerged weirs, etc. (3 cr; prereq 101 or 103 and 104; 3 rec hrs per wk) Anderson or Straub

184-185-186. Advanced Hydraulic Problems. (2 cr per qtr; prereq 183 or ¶183 or #; 6 lab hrs per wk; offered when demand warrants) Straub and staff

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 cr; prereq 101 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 cr; prereq 101 or 103 or #; 3 rec hrs per wk) Anderson or Straub

191. Hydraulic Motors and Pumps. Introductory theory of hydraulic pumps, turbines, motors, transmissions. (3 cr; prereq 187 or #; 3 rec hrs per wk) 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 cr; prereq 183 or #; 3 rec hrs per wk) Anderson or Straub

193. Hydraulic Measurements. Laboratory and field methods and instruments for measurement of hydraulic pressure, velocity, and discharge. (3 cr; prereq 187 or #; 3 rec hrs per wk) Ripken

194-195-196.* Advanced Hydraulics Laboratory. Experimental studies of the characteristics of turbines, pumps, etc. Hydraulic models. (2 cr per qtr; prereq 101 or 103 and 104; 6 lab hrs per wk; offered when demand warrants) Straub and staff

For Graduate Students Only

287. Fluid Turbulence

290-291-292. Advanced Fluid Mechanics

293. Hydrodynamics

294. Hydrodynamics
295. Hydrodynamics
296-297-298. Hydrodynamics

Mathematics (ITM)

8. Solid Geometry (High School). Lines, planes, dihedral and polyhedral angles, polyhedrons, surfaces, prisms, cylinders, cones, prismatoids, and spheres. Three-dimensional visualization and sketching. Numerical exercises in areas, volumes, weights. (Prereq plane geometry; 3 lect hrs per wk)

9. Higher Algebra (High School). Fundamental rules, factoring, fractions, linear equations, simultaneous equations, graphs, theory of exponents, surds, complex quantities, quadratic equations, numerical exercises. (Prereq elementary algebra; 5 rec hrs per wk)

11. College Algebra and Trigonometry I. Trigonometric functions, right triangles, slide rule, oblique triangles, vectors, radian measure. Factoring, fractions, functions and graphs, linear equations, exponents and radicals, quadratic equations, systems of quadratic equations, proportion and variation, logarithms. (5 cr; prereq 9 or equiv; 5 rec hrs per wk)

12. College Algebra and Trigonometry II. Inequalities, progressions, logarithmic and exponential equations. Trigonometric formulas and identities, trigonometric curves, inverse trigonometric functions, trigonometric equations, complex numbers. Theory of equations, permutations, combinations, probability, determinants. (5 cr; prereq 11; 5 rec hrs per wk)

13A. Calculus I: Analytic Geometry and Calculus. Fundamentals of analytic geometry, straight line, graphs, and equations. Functions, limits, derivative, applications to velocity, acceleration, geometry. Antiderivative, rectilinear motion, area. Rules of differentiation, conic sections, maxima and minima, rates. Calculus of trigonometric functions. (5 cr; prereq 8, 11, 12 or equiv; 5 rec hrs per wk)

13H. Honors Course: Calculus I—Analytic Geometry and Calculus. A more theoretical and intensive treatment of the topics in ITM 13A. (5 cr; prereq 8, 11, 12 and △; 5 rec hrs per wk)

14. Laboratory. History of mathematics, foundations and mathematical logic, simple computing devices, library facilities, employment opportunities. (1 cr; prereq 2nd yr; 2 hrs per wk)

24A. Calculus II: Analytic Geometry and Calculus. Differentials, parametric equations. Definite integral, mean-value theorem, areas, volumes, work, energy, moments of inertia. Further topics in analytic geometry. Calculus of exponential, logarithmic and hyperbolic functions. Techniques of integration. (5 cr; prereq 13A; 5 rec hrs per wk)

24H. Honors Course: Calculus II—Analytic Geometry and Calculus. A more theoretical and intensive treatment of the topics in ITM 24A. (5 cr; prereq 13H or ♯ or △; 5 rec hrs per wk)

25A. Calculus III: Analytic Geometry and Calculus. Further applications of integration, polar co-ordinates, vectorial treatment of motion in a curve. Methods of approximation, solid analytic geometry with vectors, partial differentiation, multiple integration. (5 cr; prereq 24A; 5 rec hrs per wk)

25H. Honors Course: Calculus III—Analytic Geometry and Calculus. A more theoretical and intensive treatment of the topics in ITM 25A. (5 cr; prereq 24H or ♯ or △; 5 rec hrs per wk)

26A. Calculus IV: Differential Equations and Calculus. Further study of limits, L'Hospital's rule. Sequences, series, Taylor's formula. Convergence, absolute and conditional, improper integrals, power series. Differential equations; equations of first order; standard methods of solution; linear equations with constant coefficients, applications; simultaneous equations; integration by series, numerical methods. (5 cr, §80; prereq 25A; 5 rec hrs per wk)

26H. Honors Course: Calculus IV—Differential Equations and Calculus. A more theoretical and intensive treatment of the topics in ITM 26A. (5 cr; prereq 25H or ♯ or △; 5 rec hrs per wk)

90. Elementary Engineering Statistics. Probability, permutations, and combinations. Frequency distributions. Introduction to sampling significance tests, regression charts. (3 cr; prereq 25 or 25A, or ¶25A; 3 rec hrs per wk)

99. Mathematical Problem Seminar. Problems ranging from elementary algebra and geometry through undergraduate mathematics will be assigned and discussed weekly. (3 cr; prereq 25 or 25A; 3 rec hrs per wk)

104. Variational Problems in Engineering. Euler-Lagrange equations, isoperimetric problems, geodesics, Fermat's and Hamilton's principle, vibration and stresses in elastic bodies, methods of Rayleigh-Ritz, Galerkin, Kantorovich, etc., eigenvalues and eigenfunctions. (3 cr; prereq 153 or 148 or 150 or 150A or ♯; 3 rec hrs per wk)

105A-B. Summer Employment. (2 cr per qtr; prereq completion of 3rd yr work and △)

132. Introduction to Statistics and Probability. Probability models, univariate and multivariate distributions, independence, basic limit theorems. (3 cr; prereq 25 or 25A; 3 rec hrs per wk)

133-134.* Statistical Theory with Applications. Random sampling, estimation, testing hypotheses, sampling from normal populations, quality control and acceptance sampling, regression, analysis of variance, nonparametric and distribution-free methods. (3 cr per qtr; prereq 132; 3 rec hrs per wk)

133A-134A.* Mathematical Methods in Operational Analysis. Linear programming, simplex technique, network flows, finite games, birth-death processes; applications to allocation, scheduling, transportation, waiting lines, inventory, reliability. (3 cr per qtr; prereq 90 or 132 or ♯; 3 rec hrs per wk)

133B-134B.* Probability with Technological Applications. Spectral analysis of stationary processes, linear and nonlinear transformations, prediction and smoothing, recurrent events, random walk and diffusion, Markoff chains, Poisson processes. (3 cr per qtr; prereq 132, 153 or 132, 148, 149 or ♯; 3 rec hrs per wk)

142-143.* Vector and Matrix Theory with Applications. Systems of linear equations, determinants, finite dimensional vector spaces, matrices, characteristic values and their numerical estimation, reduction to canonical forms, quadratic and bilinear forms. Application to engineering problems. (3 cr per qtr, §149; prereq 25 or 25A; 3 rec hrs per wk)

147.* Vector Analysis. Scalar and vector products, derivatives, geometry of space curves, del operator, line and surface integrals, divergence and Stokes' theorem, transformation of co-ordinates, dyadics, applications. (3 cr, §152; prereq 25 or 25A; 3 rec hrs per wk)

148.* Differential Equations. Linear differential and difference equations with constant coefficients, isoclines, phase plane, reduction in order, numerical solutions, series solutions, Bessel functions, Legendre polynomials, introduction to boundary value problems. (3 cr, §150 or 150A; prereq 80 or 26 or 26A; 3 rec hrs per wk)

149.* Determinants and Matrices. Determinants, matrices, linear equations, vector spaces, quadratic and bilinear forms, characteristic roots, applications to systems of ordinary differential equations. (3 cr, §142; prereq 25 or 25A; 3 rec hrs per wk)

150.* Ordinary Differential Equations. Linear equations of second order, successive approximations. Existence theorems, systems of ordinary differential equations. Numerical integration and solution by series. (3 cr, §148; prereq 26 or 26A or 80; 3 rec hrs per wk)

151. Calculus V: Advanced Calculus. Functions of one and several variables: continuity, Riemann integral, partial derivatives, Taylor's theorem, implicit function theorem, transformations, and mappings. (3 cr; prereq 26 or 26A or 80; 3 rec hrs per wk)

151H. Honors Course: Calculus V—Advanced Calculus. A more theoretical and intensive treatment of the topics in ITM 151. (3 cr; prereq 26H or ♯ or △; 3 rec hrs per wk)

152.* Calculus VI: Advanced Calculus. Maxima and minima in several variables, vector algebra and calculus, Green's and Stokes' theorems, integrals depending upon a parameter. (3 cr, §147; prereq 151; 3 rec hrs per wk)

152H. Honors Course: Calculus VI—Advanced Calculus. A more theoretical and intensive treatment of the topics in ITM 152. (3 cr; prereq 151H or ♯ or △; 3 rec hrs per wk)

153.* Calculus VII: Advanced Calculus. Infinite series, computation with series, series with variable terms, uniform convergence, power series. Fourier series and orthogonal functions, special functions. (3 cr; prereq 151; 3 rec hrs per wk)

153H. Honors Course: Calculus VII—Advanced Calculus. A more theoretical and intensive treatment of the topics in ITM 153. (3 cr; prereq 152H or ♯ or △; 3 rec hrs per wk)

155-156.* Tensor Analysis with Applications. (3 cr per qtr; prereq 147, 149 or 142, 152 or ♯; 3 rec hrs per wk)

161-162-163.* Analytical Dynamics. Newton's laws, energy, momentum, and angular momentum principles for inertial reference frames, modifications for noninertial reference frames. Lagrange's equations. Motion of particles, rigid bodies, e.g., planets, tops, gyroscopes. Stability, small oscillations. Hamilton's principle, motion of elastic bodies. Hamilton's equations, transformation theory. (3 cr per qtr; prereq MM 127 or 28, 29 or ♯; 3 rec hrs per wk) Koehler

165A. Introduction to Programming Modern Digital Calculators. Organization of a modern digital calculator. Number systems. Elementary coding, flow charts, code checking techniques, scaling, subroutines, assembly techniques, interpretive programs. Informal laboratory. (3 cr; prereq 25 or 25A; 3 rec hrs per wk) Stein, Munro

165B-C.* Theory and Programming of Modern Digital Calculators. Analysis of arithmetic operations, logical organization of arithmetic unit. Storage, control, and input-output units. Libraries, advanced assembly programs, interpretive systems, compilers. Applications to mathematical and physical problems. Informal laboratory. (3 cr per qtr; prereq 165A, 26A; 3 rec hrs per wk) Stein

168B.* Applications of Complex Variables. Conformal mapping, Poisson integral, potential flow, applications to electrostatics, Schwarz-Christoffel transformations, reflection principle, roots of polynomials, Nyquist and Hurwitz criteria, other applications. (3 cr; prereq 174 or ♯; 3 rec hrs per wk)

169.* Mathematical Theory of Fluid Flow. The general equations of fluid mechanics. Concepts from thermodynamics. The classical constitutive equations. Specialization to various subfields of fluid mechanics, including hydrostatics, barotropic perfect fluids, gas dynamics, and viscous flow theory. Examples of exact solutions. (3 cr; prereq 152, 168A or 152, 174 or 147, 168A or 147, 174 or ♯; 3 rec hrs per wk) Serrin

173.* Elementary Partial Differential Equations. Partial differential equations of theoretical physics, Fourier series, proof of convergence, orthogonal systems, Sturm-Liouville systems, solutions of boundary value problems by separation of variables, applications. (3 cr; prereq 147, 148 or 152, 153 or ♯; 3 rec hrs per wk)

174.* Elementary Theory of Complex Variables. Complex numbers, derivatives and integrals of analytic functions, elementary functions and their geometry, Cauchy's integral theorem and formula, Laurent expansions, evaluation of contour integrals by residues. (3 cr; prereq 26 or 26A; 3 rec hrs per wk)

175.* Integral Transforms. Laplace transforms, inversion formula and method of residues, applications to systems of ordinary and partial differential equations, problems in heat conduction and mechanical vibrations, Fourier transforms, three-dimensional wave equation. (3 cr; prereq 174; 3 rec hrs per wk)

180.* Finite Groups. Permutation groups, groups related to geometrical configuration; invariant subgroups, the Jordan-Holder composition theorem, Sylow groups, Abelian groups, elementary divisors, representation theory, applications. (3 cr; prereq 143 or ♯; 3 rec hrs per wk)

181-182-183.* Selected Topics in the Theory of Numbers. (3 cr per qtr; prereq 152, 153 or ♯; 3 rec hrs per wk)

184. Elementary Numerical Analysis in Engineering. Finite differences, interpolation, summation of series, numerical integration, Euler-McLaurin formula and asymptotic expansions. Numerical solutions of systems of algebraic and transcendental equations, Newton's and Graeffe's method. (3 cr; prereq 26 or 26A or 80; 3 rec hrs per wk) Koehler or Munro

185-186.* 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. Calculation of eigenvalues of matrices and differential problems, Rayleigh-Ritz method. Integral equations. Programming of computers. (3 cr per qtr; prereq 147, 148, 149, 184...or 152, 153, 184 or ♯; 3 rec hrs per wk) Koehler or Munro

190A-B-C.* Combinatorial Topology. General topological and metric spaces. Function spaces. The fundamental group and covering spaces. Singular and simplicial homology

theory. Betti and torsion groups. Fix point theorems and applications to analysis. Classification of surfaces. (3 cr per qtr; prereq 142 or ¶142 or #; 3 rec hrs per wk) Green or Markus

192.* Theory of Approximation in Numerical Analysis. Orthogonal functions, Chebyshev approximations, rational approximations, approximations in several variables, use of approximations in computing. (3 cr; prereq 186, 174, or #; 3 rec hrs per wk)

193A.* Axiomatic Geometry. Axiomatic presentations of Euclidean and non-Euclidean geometries. Vector spaces and metric spaces. (3 cr; prereq 152, 153 or #; 3 rec hrs per wk)

193B.* Elementary Projective Geometry. Projective space as a global manifold. Homogeneous co-ordinates and classical projective spaces. Lattice description of projective space. Theorems of Desargue, Pappus, and Pascal. Quadric surfaces. (3 cr; prereq 152, 153, or #; 3 rec hrs per wk)

193C.* Elementary Differential Geometry. Curves and surfaces in Euclidean three-space. Frenet-Serret formulas for a curve. First and second fundamental forms for a surface, Gauss curvature. Meusnier, Euler, Dupin theorems. (3 cr; prereq 152, 153 or #; 3 rec hrs per wk)

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 cr per qtr; prereq 174 or #; 3 rec hrs per wk)

199A-B-C.‡ Problem Course. Intended to develop problem-solving techniques in many areas of mathematics. Topics considered range from elementary to advanced levels, adapted to students of varied backgrounds. (3 cr per qtr; prereq #; 3 rec hrs per wk)

For Graduate Students Only

217-218-219.* Riemannian Geometry

227-228-229.* Mathematics of Computers and Control Devices

232-233-234.* Mathematical Theory of Fluid Dynamics

235A-B-C.* Homotopy Theory

238.* Joint Seminar

240A-B-C.* Asymptotic Methods in Linear Analysis

248-249-250.* Reading and Research

254A. Variational Methods in Boundary Value Problems

254B. Variational Methods in Eigenvalue Problems

261-262-263.* Functions of a Complex Variable

264-265-266.* Conformal Mapping

267-268-269.* Selected Topics in the Theory of Analytic Functions

270A.* Advanced Numerical Analysis of Partial Differential Equations

270B.* Advanced Numerical Analysis of Linear Systems

274-275-276.* Partial Differential and Integral Equations of Applied Mathematics

277-278-279.* Calculus of Variations and Minimal Surfaces

280A.* Galois Theory

280B.* Rings and Ideals

280C.* Algebraic Numbers

281-282-283.* Potential Theory

284-285-286.* Nonlinear Ordinary Differential Equations

287-288-289.* Hilbert Space and Functional Analysis

294A-B-C.* Theory of Local Rings

295A-B-C.* Homological Algebra

301-302-303.* Topics in Advanced Differential Geometry

304-305-306.* Advanced Topics in Differential and Difference Equations

307-308-309.* Mathematical Problems of Theoretical Physics

Mechanical Engineering

Engineering Graphics (EG)

14. Engineering Graphics. Engineering representation and analysis including systems of projection, co-ordinate systems, and solution of space problems with mathematical correlation. Engineering geometry, shape, description, sketching, and pictorial illustration. (3 cr; prereq solid geometry; 2 lect, 1 rec, and open lab hrs per wk)

15. Engineering Graphics. Engineering representation and analysis. Continuation of graphic solution of space problems. Intersections, developments, size description, common devices and application of theory and standard practices to graphic communication. (3 cr; prereq 14; 2 lect, 1 rec, and open lab hrs per wk)

16. Engineering Graphics. Graphical computation of engineering problems involving graphic algebra, calculus, and statics. Functional scales, nomography, representation and analysis of empirical data. (3 cr; prereq 15; 2 lect, 1 rec, and open lab hrs per wk)

17. Technical Sketching. Applications of orthographic projection as developed through sketching. Principles of pictorial representation, shading. Basic principles of dimensioning, sectioning. Pipe and flow diagrams. (1 cr; prereq 14; 2 lab hrs per wk)

50. Diagrams and Charts. Elementary course dealing with the construction of simple diagrams and charts. (2 cr; prereq 14; 2 lect and rec hrs per wk)

51. Graphic Representation and Computation. Types of charts and applications to the solution of problems and equations. (3 cr; prereq 15, ITM 11; 3 lect and rec hrs per wk)

52. Alignment Charts. Functional scales. Application of geometry to the development of straight-line alignment charts for equations of three or more variables. (3 cr; prereq 15, ITM 12; 3 lect and rec hrs per wk)

55. Production Illustration. Detail and assembly drawing by use of isometric, oblique, axonometric freehand, and mechanical perspective. Shaded drawings suitable for reproduction. (2 cr; prereq 16; 6 lab hrs per wk)

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 cr per qtr; prereq 16, ITM 25A; 3 lect and rec hrs per wk)

118. Curve Fitting. Derivation of formulas to fit experimental data. Combination of graphic and algebraic methods. (3 cr; prereq 16, ITM 25A, or ♯; 3 lect and rec hrs per wk)

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 co-ordinates. Use of determinants for the construction of alignment charts. Special rules. (3 cr per qtr; prereq 52, ITM 25A or ♯; 3 lect and rec hrs per wk)

157-158-159. Graphical Mathematics. Correlation of descriptive and algebraic geometry. Geometrography. Graphical calculus. Analysis of experimental data. Interpolation. (2 cr per qtr; prereq 16, ITM 25A; 2 lect and rec hrs per wk)

Industrial Engineering (IE)

50. Elements of Industrial Engineering and Management. Industrial plant operation, production management, and industrial engineering functions. (3 cr; prereq 3rd yr; 3 rec hrs per wk)

153. Methods Engineering and Work Measurement. Development of methods and processes for economical production; motion study, time study. (3 cr; prereq 50 or ¶50; 2 rec and 3 lab hrs per wk)

154. Advanced Methods Engineering and Work Measurement. Multiple operation analysis, advanced work measurement techniques, incentives. (3 cr; prereq 153; 2 rec and 3 lab hrs per wk)

155. Industrial Wage Administration. Job evaluation, wage surveys, wage policies, establishment and administration of incentive wage plans. (3 cr; prereq 153; 3 lect hrs per wk)

163. Process Planning and Development. Study of the major engineering materials and principal manufacturing processes together with their influence on the product design and manufacturing cost. (3 cr; prereq 50, ME 15, 16; 2 rec and 3 lab hrs per wk)

165. Industrial Plants. Analysis of materials flow; layout of production and service departments; plant buildings, service facilities, and handling equipment. (3 cr; prereq 153; 2 rec and 3 lab hrs per wk)

167. Materials Handling. Development of materials handling systems and selection of equipment; industrial packaging techniques. (3 cr; prereq 153; 3 rec hrs per wk)

170. Production Planning and Control. Planning of production requirements; routing, scheduling, and co-ordination of production; inventory policies and control. (3 cr; prereq 50; 3 rec hrs per wk)

171. Quality Control. Quality standards, application of statistical methods and sampling theory; interpretation of results and corrective action. (3 cr; prereq ITM 90 or 132 or ‡; 3 rec hrs per wk)

173. Engineering Economic Analysis. Analysis of capital expenditures and annual operating costs as the basis for management decisions. (3 cr; prereq 50)

174. Introduction to Operations Research. Industrial applications of operations research techniques using linear programming, decision models and Monte Carlo methods. Also industrial problems in allocation, sequencing, competitive strategies, and waiting lines. (3 cr; prereq ITM 90 or ‡; 3 rec hrs per wk)

175. Elements of Reliability. Principles of experimentation, systems design, measurement, simulation, and field data utilization necessary for a total approach to producing a reliable product. (3 cr; prereq ITM 90 or ‡; 3 lect hrs per wk)

180. Management for Engineers. Management functions and relations with employees, other supervisors, and staff departments. (3 cr; prereq 50; 3 rec hrs per wk)

182. Industrial Safety. Safety requirements for production processes, equipment, and plants; organization and administration of safety programs. (3 cr; prereq 50; 3 rec hrs per wk)

190. Industrial Engineering Seminar. Current developments in industrial engineering and management; assigned articles and classroom discussion. (1 cr; prereq 12 cr in industrial engineering; 2 rec hrs per wk)

194-195-196.‡ Applied Industrial Engineering. Industrial engineering surveys and programs; case problems; studies in local plants. (3 cr per qtr; prereq 15 cr in industrial engineering; 3 lect hrs per wk for 194, hrs ar for 195 and 196)

197. Industrial Sampling Techniques. Selection and operation of attributes sampling plans; operating characteristic curves; sampling techniques for continuous production; variables sampling plans; administrative and economic comparisons. (3 cr; prereq 171 or ITM 132 or ‡; 3 lect hrs per wk)

198. Sequential Analysis. Sequential vs. "classical" methods; operating characteristic functions for attributes and variables sequential plans; the average sample number function; economic considerations; applications in research and production. (3 cr; prereq ITM 133 or ‡; 3 lect hrs per wk)

199. Design of Industrial Experiments. Designs involving crossed, nested, and mixed classifications; mathematical models for the analysis of variance; estimation and comparison of effects; factorial experiments; confounding; balanced incomplete block designs; applications in research and production. (3 cr; prereq ITM 133 or ‡; 3 lect hrs per wk)

For Graduate Students Only

251-252-253.‡ Advanced Industrial Engineering

261-262-263.‡ Production Engineering Problems

271-272-273.‡ Industrial Engineering Research

Mechanical Engineering (ME)

15. Casting, Working, and Welding of Engineering Materials. Identification and classification of metals. Fundamentals of patterns. Sand molding, core making and shell molding. Machine molding and melting. Mechanical working of metals and alloys. Welding techniques, e.g., gas, arc. Properties of molding sands. Precision casting. Inspection testing, e.g., magnaflux, X-ray. Plastic materials and fabrication. (3 cr; prereq IE 50, Met 56, and MM 142; 2 lect and 3 lab hrs per wk)

16. Cold Processing of Materials. Machine tool operation, theory and economics of metal cutting, product inspection including measurement of dimensions, surface roughness and hardness. (3 cr; prereq IE 50, Met 56, and MM 142; 2 lect and 3 lab hrs per wk)

21. Mechanisms: Kinematic Analysis. Techniques of motion transfer. The influence of constraints. Analysis of velocities and accelerations including the Coriolis effect. Kinematic equivalence. (3 cr; prereq EG 16, MM 28; 2 lect and 3 lab hrs per wk)

22. Mechanisms: Dynamic Analysis. Application of the d'Alembert force. Transfer and inertial drive requirements. Balancing and gyroscopic effects in mechanisms. (3 cr; prereq 21; 2 lect and 3 lab hrs per wk)

23. Mechanisms: Components and Synthesis. Component classes. Standard components and their synthesis to produce desired motion. Influence of automatic control and materials on mechanism synthesis. (3 cr; prereq 22, MM 29; 2 lect and 3 lab hrs per wk)

24. Elements of Machine Design. Applications of the fundamentals of stress analysis in the design of machines. Analysis of machine elements. (3 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

30-31-32. Thermodynamics. Properties and processes for working fluids in engineering devices. Application of the fundamental laws correlating energy with heat and work. (3 cr per qtr; prereq ITM 26A or ¶ITM 26A, Phys 14; 3 rec hrs per wk)

33. Mechanical Engineering Laboratory I. Principles of industrial measuring instruments. Humidity, pressure, vacuum, level, area, and temperature measuring systems. Telemetering and calibration procedures. (2 cr; prereq 30 or ¶30; 1 lect and 3 lab hrs per wk)

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 cr; prereq 33; 1 lect and 3 lab hrs per wk)

90-91-92-93.† Industrial Assignment. Co-operative 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. (4 cr per qtr; prereq regis in co-operative work-study program)

101-102. Summer Employment I, II. (2 cr per qtr; prereq completion of 3rd yr work and △; fall qtr only)

110. Control of Metal Working Processes. Inspection by X-ray, gamma-ray, magnetic particle, metallographic, and chemical methods. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

111. Advanced Casting Processes. Advanced techniques and new developments in molding and casting; foundry control procedures. (3 cr; prereq 110; 2 lect and 3 lab hrs per wk)

112. Properties and Fabrication of Plastics. Materials, equipment, and processes for fabrication of plastics. Plastic product and mold design. (3 cr; prereq 15, 16 or ♯; 2 lect and 3 lab hrs per wk)

113. Advanced Metal Cutting. Advanced machine tool operation. Selection, tooling, and set-up of machine tools for production. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

114. Advanced Welding. Theory and applications of welding processes; factors affecting weldability; considerations in the design of weldments. (3 cr; prereq 15, 16; 2 lect and 3 lab hrs per wk)

115. Control of Manufacturing Standards. Precision measuring instruments and gauges for dimensional control in interchangeable manufacture. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

119. Design for Casting, Forming, and Welding. Basic factors in the design of parts and structures for most efficient processing and fabrications and maximum performance. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

121. Machine Design. Advanced machine elements. Design practice and machine layout. Analysis of complete machines. (3 cr; prereq 24; 2 lect and 3 lab hrs per wk)

122. Mechanical Engineering Design. Advanced statics, dynamics, and stress analysis applied to machines. Special design problems. (3 cr; prereq 121; 1 lect and 6 lab hrs per wk)

123. Creative Engineering. Application of fundamentals of engineering design with emphasis on creative aspects. (3 cr; prereq 4th-yr engr; 1 lect and 6 lab hrs per wk)

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 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

125. Machine Design Laboratory. Use of vibration instruments, stroboscopes, sound meters and analyzers, photoelastic, polariscope, electronic measuring devices and testing machines. (2 cr; prereq 24; 1 lect and 3 lab hrs per wk)

127. Lubrication. Hydrodynamic theory of lubrication. Bearing design and construction, laboratory tests on 8-inch journal bearings. (3 cr; prereq 121; 3 lect hrs per wk)

128. Photoelastic Stress Analysis. Fundamentals of advanced stress analysis. Theory of photoelasticity and operation of polariscopes. Applications to solutions of special design problems. (3 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

129. Vibration Engineering. Advanced vibration theory with application to vibration absorption and isolation. (3 cr; prereq MM 193; 3 lect hrs per wk)

133. Heat Transmission. Introduction to conduction, convection, and radiation of heat and their utilization in engineering applications. Heat exchangers. (3 cr; prereq 32 and Hydr 101 or 103 or ¶Hydr 101 or 103...or Hydr 101 or 103 and ♯; 3 lect or rec hrs per wk)

134. Thermodynamics of Fluid Flow. Thermodynamic analysis of internal flow of viscous and compressible fluids. Applications to various flow processes and components in engineering systems. (3 cr; prereq 32, Hydr 103; 3 rec hrs per wk)

136. Reactor Heat Transfer. Heat conduction with internal heat generation, thermal stresses, liquid metal heat transfer, forced convection in noncircular ducts, boiling and two-phase flow. (3 cr; prereq 133 or equiv; 3 rec hrs per wk)

137. Thermodynamics of High Temperature Gases. Determination of composition and properties of high temperature gases. Experimental and analytical methods useful in calculating thermodynamic and heat transfer data of plasmas. (3 cr; prereq 148 or ♯; 3 rec hrs per wk)

141. Heat Power Engineering. Application and control of fuels and combustion and applications of thermodynamics and heat transmission to steam power and process engineering. (3 cr; prereq 32; 3 rec hrs per wk)

142. Advanced Heat Power Engineering. Exploration of potentially fruitful areas of power plant progress; performance limiting elements in a power system that control its competitive position in present and future power plants. (3 cr; prereq 141; 3 rec hrs per wk)

143. Turbomachinery. Theoretical analysis of energy transfer between fluid and rotor, principles of axial, mixed, and radial flow compressors and turbines. Applications to gas turbines, fluid transmissions and power plants. (3 cr; prereq 134 or ¶134; 3 rec hrs per wk)

146. An Introduction to Combustion. Flame propagation, quenching and ignition in a homogeneous gaseous mixture; combustion of solid and liquid particles, packed beds, and gaseous jets. (3 cr; prereq 133 or ¶133; 3 rec hrs per wk)

147. Heat Power Design. Design methods for internal combustion engines, steam power plants, and other power generation systems. Detail design and layout of specific devices. (3 cr; prereq 143, 146; 1 lect and 6 lab hrs per wk)

148-149. Chemistry of Combustion. The nature of combustion problems. Ignition, propagation, quenching, and burning limits. Thermochemistry and the use of the partition function in calculating thermodynamic properties, free energy, and equilibrium constants. Chemical kinetics and the steady state approximation applied to combustion phenomena. (3 cr; prereq 146, InCh 15; 3 lect hrs per wk)

150. Internal Combustion Engines. Principles of spark ignition engine, fuel–air cycle analysis, combustion flames, knock phenomena, air flow and volumetric efficiency, mixture requirements, ignition requirements and performance. (3 cr; prereq 32; 3 rec hrs per wk)

151. Advanced Internal Combustion Engines. Principles of supercharging, turbocharging and compounding, heat transfer in air and liquid cooled cylinders, chemistry of fuels, knock sensitivity, deposits and preignition, engine lubrication, wear and contaminant control. (3 cr; prereq 150; 3 rec hrs per wk)

152. Diesel and Free Piston Engines. Principles of the Diesel engine and free piston gasifier, combustion of stratified charge, theory of fuel spray formation and vaporization, hydraulic phenomena in fuel injection systems, air flow, scavenging processes, and performance. (3 cr; prereq 150; 3 rec hrs per wk)

154. Design of Internal Combustion Engines. Principal components, piston, rod, crankshaft, and valve mechanism, or compressor and turbine for compounded engine. (3 cr; prereq 121 and 150; 3 rec hrs per wk)

155. Rocket Propulsion. Mode of operation and performance limitations of: chemical rockets with liquid, solid and free radical propellants, nuclear and solar rockets with thermal and electromagnetic propellant acceleration. (3 cr; prereq 134 and 146... or 146 and Aero 102A; 3 rec hrs per wk)

157. Gas Turbine and Jet Propulsion Power Plants. Gas turbine and ramjet cycles and principles; characteristics of compressors and turbines; power and efficiency calculations. (3 cr; prereq 143; 3 rec hrs per wk)

158. Aircraft Power Plant Laboratory. Laboratory performance of piston engine and jet engine components, heat balance analysis, characteristics of compressor, turbine, and combustion chambers, fuels and lubricant properties. (2 cr; prereq 143, 146; 1 lect and 3 lab hrs per wk)

159. Heat Power Laboratory. Laboratory performance of gasoline and Diesel engines, steam turbines and engines, also characteristics of nozzles and ejectors. Analysis of indicator diagrams. Correlation of test data with theory and practice. (2 cr; prereq 143, 146; 1 lect and 3 lab hrs per wk)

160. Psychrometrics and Air Conditioning. Atmospheric environmental control and relation to human comfort. Psychrometers, air distribution, air cleaning. Heat transmission in building materials. (3 cr; prereq 133 or ¶133; 3 lect hrs per wk)

161. Heating and Air Conditioning Design. Application of the fundamentals to the design of year around heating and air conditioning systems; heating and cooling loads, fluid flow systems, warm air, hot water, steam heating, and heat transfer components. (3 cr; prereq 160 and 180; 1 lect and 6 lab hrs per wk)

163. Principles of Particle Technology. Definition, theory, and measurement of particle properties, particle dynamics, size distributions, and characteristics of powders encountered in particle transport, gas cleaning, and particle processing. (3 cr; prereq 32 or #; 3 lect hrs per wk)

166. Industrial Ventilation and Exhaust System. Contaminants, dispersion mechanisms, fans, injectors, natural drafts, and control velocities as applied to manufacturing and processing systems. (3 cr; prereq 160; 3 lect hrs per wk)

169. Air Conditioning and Refrigeration Laboratory. Experimental studies of heating, air conditioning, and refrigeration equipment. Correlation of test data with theory. (2 cr; prereq 34, 160 and 180; 1 lect and 3 lab hrs per wk)

170. Tool Design. Design of jigs, fixtures, and dies for machining, forming, welding, and assembly operations. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

180. Mechanical Refrigeration. Applied thermodynamic studies of single-stage and two-stage vapor cycles, air cycle, steam jet, and absorption systems. Refrigerants, refrigeration equipment. (3 cr; prereq 32; 3 lect hrs per wk)

181. Advanced Mechanical Refrigeration. Low temperature refrigeration methods including multi-stage and other vapor cycle systems; production of dry ice; liquefaction of gases. The heat pump and other special topics. (3 cr; prereq 180; 3 lect hrs per wk)

194. Advanced Engineering Problems. Work pertaining to special investigations in the various fields of mechanical engineering. (2-4 cr; open only to 5th-yr ME with a minimum of 2.5 G.P.A.; prereq consent of chief of division concerned)

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 cr; prereq EE 38 or ¶EE 38; 2 lect and 3 lab hrs per wk)

199. Servomechanisms. Study of basic servomechanisms. Mechanical and electrical error indicators. Analysis of various types of damping. (3 cr; prereq EE 37, ITM 26A; 2 lect and 3 lab hrs per wk)

For Graduate Students Only

224-225-226. Advanced Applied Dynamics
228. Photoelasticity
229. Advanced Vibration Engineering
230. Advanced Thermodynamics
231. Statistical and Nonequilibrium Thermodynamics
232. Advanced Thermodynamics of Fluid Flow
233. Conduction
234. Convection
235. Radiation
236. Advanced Theory of Heat Transfer
242. Advanced Power Plants
246. Flames of Homogeneous Mixtures
247. Diffusion Flames
248. Atomization Vaporization and Mixing
250. Dynamics of High Speed Engines
253. Advanced Gas Turbines and Jet Propulsion
255. Advanced Rocket Propulsion
265. Advanced Psychrometric Theory and Atmospheric Environmental Control
266. Advanced Psychrometric Processing
267. Advanced Air Conditioning
268. Control and Utilization of Solar Radiation
280. Theoretical Refrigeration
282. Reverse Applications of Refrigeraton—Heat Pump
290-291-292. Mechanical Engineering Research
293. Graduate Seminar
296-297. Advanced Servomechanisms
298. Advanced Instrumentation and Automatic Control

Metallurgical Engineering (MetE)

1. Metallurgical Engineering Laboratory. The fields of mineral and metallurgical engineering described in lectures, laboratories, and field trips. (1 cr; 1 hr per wk) Staff

11. Elements of Metallurgical Engineering. Generation of heat and reducing gas in smelting processes. Effect of physical properties of raw materials upon recoveries, quality of product, heat transfer, and thermal efficiency. (3 cr; prereq 8 cr inorganic chemistry) Joseph

12. Metallurgical Processes. Introduction to the principles of process metallurgy. Survey of iron and steel processes and important nonferrous processes. (3 cr; prereq 8 cr inorganic chemistry) Joseph

75. Metallurgical Engineering Inspection Trip. Metallurgical practice in the Chicago-Milwaukee area. (2 cr; offered between winter and spring qtrs alt yrs) Bitsianes

90-91-92.‡ Industrial Employment. Summer work in mineral dressing, process metallurgy or allied fields for a period of 2 or more months. Character of work to be approved by the division. Satisfactory record of employment and an acceptable report are required. (2 cr per course; prereq ♯) Staff

106. Principles of Process Metallurgy. Material and heat balances in metallurgical processes, combustion of fuels, heat utilization. (3 cr; prereq 8 cr inorganic chemistry) Bitsianes

107. Principles of Process Metallurgy. Phases in pyrometallurgical systems. Roasting, agglomeration, matte and reduction smelting. (3-4 cr depending on lab; prereq 106) Bitsianes

108. Principles of Process Metallurgy. Converting, metal refining, retorting, hydrometallurgical processes, electrolytic methods. (3-4 cr depending on lab; prereq 107) Bitsianes

110. Mineral Dressing. Theory and practice of comminution. Volumetric and gravimetric sizing. Principles of the movement of solids in fluids. Laboratory investigation of crushing, grinding, size analysis, and size of liberation of ores. (4 cr) Cooke

111. Mineral Dressing. Principles of ore beneficiation by gravity, magnetic, and electrostatic processes. Material balances. Laboratory examination and concentration of ores. (4 cr; prereq 110) Cooke

112. Mineral Dressing. Principles of flotation in ore concentration. Theory of frothing, collecting, depression, activation, conditioning. Integration of processes into flowsheets. (4 cr; prereq 111) Cooke

118-119-120.‡ Metallurgical Engineering Practice. Report writing on current problems in mineral dressing and in ferrous and nonferrous metallurgical practice. (Cr ar; prereq ♯) Staff

121. Iron Ore Beneficiation. Principles and methods. Metallurgical and economic factors in the concentration of iron ores. (3 cr; prereq 111; 2 lect and 3 lab hrs per wk) Wade

122. Hydrometallurgy. Application of physicochemical principles to the leaching of ores and concentrates, to phase separation and purification, and to the recovery of metals or their compounds from leached phases. (3 cr; prereq 112) Cooke

123. Hydrometallurgy. Integration of operations and processes on a plant basis. Applications in nonferrous metallurgy. (3 cr; prereq 122) Cooke

124-125-126.*‡ Special Problems in Mineral Dressing. (Cr and hrs ar; prereq 112) Cooke

134.* Metallurgical Unit Processes. Physicochemical principles as applied to the unit processes. Slag-metal equilibriums, kinetics of metallurgical reactions, slag constitution. (3 cr; prereq 108) Bitsianes

135.* Metallurgical Unit Processes. Gas-solid processes. Blast furnace smelting, control of slag-metal and gas-solid reactions. Oxygen-enriched blast and high top pressure. (3 cr; prereq 11) Joseph

136.* Metallurgical Unit Processes. Integration of operations and processes on a plant basis. Applications in ferrous metallurgy. (3 cr; prereq 108) Joseph

138. Advanced Process Metallurgy. Application of physical chemistry to some advanced problems in metallurgical engineering. Heterogeneous chemical reactions. (2 cr; prereq 134) Bitsianes

141-142-143.‡ Special Problems in Process Metallurgy. Laboratory investigation of problems involved in metallurgical unit processes. (Cr and hrs ar; prereq 108) Joseph, Bitsianes

144. Metallurgical Unit Operations. Preparation, handling, and control of particulate solids and of their fluid suspensions. (2 cr; prereq 111 or ♯) Schulz

For Graduate Students Only

201-202-203.*‡ Research in Process Metallurgy

204-205-206.‡ Research in Mineral Dressing

210-211-212.*‡ Seminar in Metallurgical Engineering

220. Flotation Theory

Metallurgy (Met)

(Department of Metallurgy, School of Chemistry)

1. Metallurgy Laboratory. The field of metallurgy, what a metallurgist does, experiments demonstrating the behavior of metals and alloys. (1 cr; 1 hr per wk) Staff

56. Physical Metallurgy. (MechE, MinE, PetE, IndAdm) Introduction to principles. Theory of metals and alloys, constitution diagrams, heat treatment, relation of structure to properties. (3 cr; prereq 3rd yr [IndAdm see adviser]) Nicholson, Jerabek, Swalin, Sivertsen

57. Physical Metallurgy of Industrial Alloys. Alloy steels, stainless steels, high temperature alloys, alloys of aluminum, copper, and nickel. (3 cr; prereq 153 or 56 or 60) Jerabek

60. Physical Metallurgy. (ChemE) Theory of metals and alloys, constitution diagrams, heat treatment. Relation of structure to properties. (3 cr; prereq 3rd yr) Nicholson, Jerabek

90-91-92.‡ Industrial Employment. Summer work in metallurgy or an allied field for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report are required. (2 cr per course; prereq ♯) Staff

153. Principles of Physical Metallurgy I. Atomic structure, crystal structure of metals, Hume-Rothery rules, elements of phase diagrams. (3 cr; prereq 3rd yr) Nicholson

153A. Laboratory in Physical Metallurgy. (2 cr; prereq ¶153) Nicholson

154. Principles of Physical Metallurgy II. Plastic deformation, dislocation theory, structure of cold worked metal, recovery, recrystallization, preferred orientation, X-ray metallography. (3 cr; prereq 153 or ♯) Sivertsen

154A. Laboratory in Physical Metallurgy. (2 cr; prereq ¶154) Sivertsen

155. Principles of Physical Metallurgy III. Transformations in solids, precipitation hardening, order-disorder, the iron-carbon diagram, heat treatment. (3 cr; prereq 154 or ♯) Jerabek

155A. Laboratory in Physical Metallurgy. (2 cr; prereq 154 or ¶155) Jerabek

159. Dental Physical Metallurgy. Basic course for dental students, involving theory of metals and alloys, constitution diagrams, heat treatment, properties and applications of metals and alloys used in dentistry. (2 cr; 20 hrs) Jerabek

161. Corrosion of Metals. Electrochemical theory and mechanism of corrosion, generalized film theory. Influence of structure, composition, and mechanical factors on metallic corrosion. Inhibitors, oxidation, corrosion protection. (2 cr; prereq 56, PCh 101 or 101H) Nicholson

162. Nuclear Metallurgy. Nature of radiation damage and effects of neutron irradiation on the properties of crystalline materials. (2 cr; prereq 56 or equiv or ♯; 1 lect hr per wk) Swalin

162A. Irradiation Effects Laboratory. Measurement of resistivity and magnetic susceptibility and a study of their relation to crystal imperfections. Hall effect and thermoelectric effect. (2 cr; prereq 162) Sivertsen

167. Control of Mechanical Properties in Metals and Alloys. Mechanical properties of metals and alloys are discussed in terms of dislocation behavior. Particular attention is given to the *control* of mechanical properties through manipulation of microstructure by metal processing. (3 cr; prereq 155) Nicholson

168. Principles of Metal Fabrication. General principles of fabrication from metallurgical standpoint. Techniques for reactive metals. Vacuum melting, casting, and cladding of reactive metals such as uranium. Rolling and swaging. Vacuum heat treatment. Testing and examination of materials. (3 cr; prereq 155) Nicholson

169. Analysis of Metallurgical Problems. Specialized metallurgical subjects such as embrittlement of steels, residual stresses, wear, and fatigue in metals. Seminar procedure. (3 cr; prereq 155, 182 or ♯) Jerabek

170-171-172.‡ Special Problems in Physical Metallurgy. Laboratory investigation. (1, 2, or 3 cr per qtr) Nicholson, Jerabek, Swalin, Sivertsen

173. Crystalline Properties of Metals. An introduction to the geometry and properties of metal crystals. Topics to be discussed are X-ray diffraction, electrical and thermal conductivity, Hall effect, optical properties, and elastic and plastic behavior of metals. (3 cr; prereq 155) Sivertsen

174. Modern Theory of Metals and Alloys. Free electron theory of metals and application. Imperfection in crystals. (3 cr; prereq Phys 51 or #) Sivertsen

175. Imperfections in Metals. Theory of imperfections and their effects on properties of metals. (3 cr; prereq 174 or #) Sivertsen

180-181-182. Thermodynamics and Kinetics of the Solid State. Theory of liquids, heterogeneous equilibria, free energy-composition diagrams and reaction kinetics. (3 cr per qtr; prereq PCh 103 or 103H or #) Swalin

For Graduate Students Only

207-208-209. Research in Physical Metallurgy

213-214-215.‡ Seminar in Physical Metallurgy

250. Thermodynamics of Alloys

251-252. Kinetics of Solid State Reactions

255. Transformations and Microstructure

260. Dislocation Theory of Crystals

263. Advanced X-ray Diffraction of Metals

Microbiology (Micb)

(Medical School)

53. General Bacteriology. Lectures, demonstrations, and laboratory instruction in the morphology, physiology, taxonomy, and ecology of bacteria. Practical applications of fundamental principles are emphasized. (5 cr; prereq soph with C avg in prereq courses, 10 cr in chemistry and 4 cr in biological sciences or #) Staff

121. Physiology of Bacteria. Chemical and physical structure; staining; growth; influence of environment on growth; nutrition; enzymes; metabolism. (3 cr; prereq 53 [min grade C] and 8 cr in organic chemistry or biochemistry, #) Staff

122. Physiology of Bacteria Laboratory. Techniques employed in the study of bacterial physiology and metabolism. (3 cr; prereq 121, #) Staff

123. Bacterial Metabolism. Advanced treatment of metabolism; enzymes; biological energy; fermentation; respiration; nitrogen metabolism. (3 cr; prereq 121, 122 or equiv and introductory biochemistry, #; offered 1961-62 and alt yrs) Staff

Military Science (Mil)

(Department of Military Science)

The program in military science, leading to a commission in the United States Army Reserve, is available for IT students as well as for those in other colleges of the University. Instruction encompasses military fundamentals common to all branches of the Army. The aim is to provide a basic military education and, in conjunction with other college curriculums, to develop individual characteristics and attributes of leadership essential to an officer. For information concerning the requirements and the opportunities of this program, consult the *Bulletin of the Army-Navy-Air Force ROTC* of the University of Minnesota, or call at the Military Science office, 106 Armory.

The Institute of Technology will accept credits from the basic and the advanced courses in military science to fulfill a minor toward the Bachelor's degree.

Mining Engineering (MinE)

1. Mineral Engineering Laboratory. The fields of geophysics and of mining, geological, petroleum, and metallurgical engineering described in lectures, laboratories, and field trips. (1 cr; 1 hr per wk) Staff

13. Mine Surveying. Mining claims, bore holes, shaft plumbing, underground traversing, and leveling. (3 cr per qtr; prereq CE 18 or ♯; 3 lect and 1 quiz hr per wk) Yardley

15A. Mine Surveying Field Work. Surveying of an underground mine located on Iron Range, including shaft plumbing. Survey of an open-pit mine, including an estimate of surface stripping. Solar and stellar observations. Study of mining operations and plants for 1 week. (6 cr; prereq 13; 4 wks beginning about June 15) Yardley, Lacabanne

15B. Mine Surveying Field Work. Same as MinE 15A, but without 1 week study of mining operations. (5 cr; prereq 13; 3 wks beginning about June 15) Yardley, Lacabanne

16. Mine Maps. Various methods of mine mapping; preparation of map from mine survey notes taken in MinE 15A or 15B. Ore estimates. (1-2 cr; prereq 15A or 15B; 3 lab hrs per wk)

90-91-92. Industrial Employment. Summer work in the mineral industries for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report required. (2 cr per course; prereq ♯)

111-112. Exploration, Development, and Exploitation of Mineral Deposits. Principles and techniques of exploration, factors and concepts involved. Sampling design, combining theory. Drilling, explosives, development openings, haulage systems. Shafts, drainage, underground mining systems. (3 cr per qtr; prereq 3rd yr or ♯; 4 lect hrs per wk) Yardley

121. Mine and Petroleum Plant Engineering. Basic engineering principles in 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 cr; prereq Hydr 103, ME 30 or ♯, EE 37; 3 lect and 3 lab hrs per wk) Dorenfeld

122. Mine Plant Engineering. Basic engineering principles in design and selection of mine plant equipment. Calculations involving power transmission and drilling, transporting, and hoisting of materials. (3 cr; prereq 121, MM 28, or ♯; 2 lect and 4 lab hrs per wk) Dorenfeld

123. Mine Air Conditioning. Mine gases, dust control, and physical properties of air; measurement of air properties. Design of ventilation, heating and refrigeration systems. (3 cr; prereq 112, Hydr 103; 3 lect and 3 lab hrs per wk) Dorenfeld

124. Mill-Plant Engineering. Basic methods used in selection of mill-plant equipment; problems of scale-up from pilot-plant and laboratory data; integration of equipment into a working plant and its economics, construction, and operation. (3 cr; prereq 121, MetE 112; 3 lect and 3 lab hrs per wk) Dorenfeld

131-132. Rock Mechanics I-II. Elementary analysis of stress and strain. Rock stresses in mining. Design and layout of tunnels and mine workings. Rockbursts, subsidence. Techniques of underground stress measurement. Elementary blasting theory. Laboratory investigation of physical behavior of rocks. (3 cr; prereq MM 142 or ♯) Fairhurst

133. Rock Mechanics III. Theories of blasting. Hydrodynamic theory of detonation. Calculation of explosion pressure. Design of blasting patterns. (3 cr; prereq 132) Fairhurst

139. Inspection Trip. Study of mining operations, mine plant, and metallurgical plants in several mining camps. Engineering report. (3 cr; prereq ♯; 2 wks beginning about September 15)

141.* Mineral Economics. Forecasted demands, resources, and conservation of minerals. Mine and oil field examinations and valuation. Costs, taxation, depletion. Organization and administration. (3 cr; prereq 112 or PetE 112 or ♯; 4 lect hrs per wk) Pfleider

142.* Surface Mining Engineering. Development, engineering, planning, and operation of open-cut properties. Drilling, blasting, excavation, and transportation. Quarries methods, equipment, field for product. Placers dredging, hydraulicking. (3 cr; prereq 112 or ♯; 4 lect hrs per wk) Pfleider

143. Coal Mining Engineering. Coal measure rocks. Method of working and mechanized coal mining. Methane and coal dust explosions. Flame-proofing and intrinsic safety of equipment. Methane drainage. Subsidence and strata control. (3 cr; prereq 112; 4 lect hrs per wk) Fairhurst

144-145.* Advanced Mining Engineering. Preparation of a report on a mining property or some phase of the mineral industry. (2 cr for 144, 4 cr for 145; prereq 141; 6 lab hrs per wk for 144, 10 lab hrs per wk for 145) Pfleider and staff

151-152-153.*‡ Special Mining Engineering Problems. Literature survey or research work on mining problems. (Cr and hrs ar; prereq 112)

160.* Mining and Processing Industrial Minerals. Survey of minerals and rocks industrially important but primarily not mined for recovery of metals. Origin, geographic distribution, mining methods, processing, uses, etc. (Cr ar; prereq 112 or #; 2 lect hrs per wk) Yardley

180.* Geochemical Exploration. Application of geochemical techniques and principles to the search for orebodies. Laboratory work on geochemical methods for the determination of total and specific heavy metal content of rocks, soil, water, and plants. (3 cr; prereq #; 2 lect and 2 lab hrs per wk) Yardley

185.* Selected Topics in Mineral Exploration. Exploration programming in relation to theories of ore genesis. Analysis of effects of contract requirements on exploration decisions. Theory of ore sampling and combining. Statistical analysis of grade estimates. Search theory in exploration. (3 cr; prereq 5th yr, grad, or #; 3 lect hrs per wk; offered 1962-63 and alt yrs) Yardley

For Graduate Students Only

201-202-203.*‡ Mineral Engineering Seminar

210.* Engineering Report

212-213-214.*‡ Mining Research Problems

220. Advanced Mine Air Conditioning

230.* Advanced Geochemical Exploration

240.* Advanced Concepts in Drilling of Rocks

Naval Science (Nav)

(Department of Naval Science)

LOWER DIVISION COURSES

1st Year

11. Naval Orientation. Naval customs. The organization for national security. Naval leadership. Forms of modern naval warfare. (3 cr)

12-13. Sea Power. Survey of sea power's influence on history from ancient times to present. (3 cr per qtr)

2nd Year

21. Naval ROTC students enroll in appropriate psychology course (Psy 1 recommended) in lieu of the naval science lecture course. Students attend 1 hour per week laboratory period with NROTC instructor.

22. Naval Weapons. The objectives of this course are to give the student an understanding of the underlying reasons and circumstances under which the family of naval weapons has been developed; to bring into focus the impact of these developments on naval warfare; to consider the influence of weapons on national policy and conversely those considerations of national policy that govern and influence the development of weapons; to point out the integration of the family of naval weapons into modern effective naval weapons systems; and to examine some possible courses of future development of naval weapons systems. (3 cr)

23. **Naval Weapons.** The objectives of this course are to examine the components of naval weapons, including the applications of scientific principles involved, and to consider some of the basic features of space technology. (3 cr)

UPPER DIVISION COURSES

I. Line Sequence

3rd Year

51. **Naval Engineering.** Ship stability and shipboard propulsion. Principles and theory of operation of the ship's engineering plant and associated equipment. Effect of propulsion and ship design on naval affairs. (3 cr)
52. **Naval Engineering: Introduction to Navigation.** Types and theory of internal combustion engines and shipborne nuclear propulsion plants. Dead reckoning, piloting, and electronic navigation. (3 cr)
53. **Celestial Navigation.** Theory and practical application of navigating using the stars, sun, moon, and planets. (3 cr)

4th Year

61. **Naval Operations.** Elements of shipboard operations: relative motion, tactical communications, rules of the nautical road and naval maneuvering. (3 cr)
62. **Naval Operations: Leadership.** Fleet communications and meteorology. Principles of naval leadership and management. (3 cr)
63. **Leadership.** Principles of naval leadership and functions of the Uniform Code of Military Justice. Naval administration. (3 cr)

II. Supply Corps Sequence

3rd Year

57. **Supply Management I.** An introduction to Navy supply management. Case studies and problems in organization, budgets, and inventory management. (3 cr)
58. **Supply Management II.** Series of problems in financial management and accounting, allowance lists and the procurement of naval material. (3 cr)
59. **Supply Management III.** Series of problems in management of material in a shipboard supply department, security, inventories, and supply support. (3 cr)

4th Year

67. **Clothing and Small Stores.** Ship's stores afloat introduction. Organization and operation of clothing stores and ship's stores afloat. Problems in clothing and small stores. (3 cr)
68. **Ship's Stores Afloat: Leadership.** Operation and management of service activities inventories, balance sheets, and operating statements. Problems in ship's stores afloat. Principles of naval leadership and group management. (3 cr)
63. **Leadership.** (See 4th year of Line Sequence)

III. Marine Corps Sequence

3rd Year

54. **Evolution of the Art of War I.** Evolution of warfare from earliest recorded times up to and including the Mexican War. (3 cr)
55. **Evolution of the Art of War II.** Continuation of the evolution of the art of war, to include Civil War campaigns, World Wars I and II, plus a consideration of U.S. military and foreign policy. (3 cr)
56. **Modern Basic Strategy and Tactics.** The theoretical principles behind modern strategy and tactics. (3 cr)

4th Year

64. Amphibious Warfare I. Evolution of current amphibious warfare techniques and doctrine commencing with Gallipoli and up to the Korean conflict. (3 cr)

65. Amphibious Warfare II. Introduction to doctrinal techniques and present concepts to include planning, embarkation, rehearsal, support, and logistics. (3 cr)

66. Leadership. Functioning of the Uniform Code of Military Justice. Service leadership as pertinent to the Marine Corps. (3 cr)

Petroleum Engineering (PetE)

90-91-92. Industrial Employment. Summer work in the petroleum industry or an allied field for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report are required. (2 cr per course; prereq ♯)

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 cr; prereq Geol 25 or ♯; 4 lect hrs per wk) Lacabanne

112. Oil Field Production. Principles and methods. Petrophysics of oil reservoirs, oil and gas phase relations under reservoir conditions; condensate fields; sand drainage; oil reservoir performance; lifting oil; secondary methods of recovery; gas wells. (3 cr; prereq 111 or ♯; 4 lect hrs per wk) Lacabanne

131. Reservoir Mechanics. Reservoir rocks, fluids, forces, and classification of energies. Rock-fluid systems and equations of flow for principal reservoir drives. (3 cr; prereq 134, Hydr 103 or ♯)

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, measurement of gas flow. Gas well capacities by back pressure. Gas hydrates. (2 cr; prereq 112 or ♯; 2 lect hrs per wk) Lacabanne

135. Engineering Study Through Field Trip of Several Oil Fields. Oil well drilling, production methods, refining practices, reservoir features, etc. (3 cr; prereq ♯; 2-wk field trip ar) 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 cr for 144, 4 cr for 145; prereq MinE 141; 6 lab hrs per wk for 144, 10 lab hrs per wk 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 cr per qtr; prereq 112 or ♯; 1 lect and 6 lab hrs per wk) Lacabanne

155-156-157.°‡ Special Problems in Petroleum Engineering. Seminar in petroleum problems. (Cr and hrs ar; prereq ¶144 or ¶145 or ♯) Lacabanne

For Graduate Students Only

201-202-203. Petroleum and Natural Gas Engineering Seminar

206.° Engineering Study of an Oil Field

207-208-209.°‡ Research Problems in Petroleum Engineering

Philosophy (Phil)

(College of Science, Literature, and the Arts)

1. Problems of Philosophy. Introduction; main fields of investigation; permanent problems; principal methods and schools of philosophy; historical and contemporary views. (5 cr; prereq 3rd qtr fr)

2. Logic. Difference between logical and fallacious reasoning; the functions and uses of language; rules of good definition and sound argument. (5 cr) Staff

3. Ethics. 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 cr; prereq 3rd qtr fr)

10. Science and Religion. Inquiry into nature of science and religion as currently interpreted, with an attempt to find grounds of conflict and/or reconciliation. (2 cr; prereq soph)

40. Logic of Scientific Reasoning. Introduction to the principles of scientific method; definition and classification; observation, measurement, experiment; elementary statistical concepts; hypotheses, theories, evidence, and confirmation; nature and limits of the scientific enterprise. (3 cr; prereq 2; offered when feasible)

Physics (Phys)

1-2-3. Introduction to Physical Science. Demonstration lectures on the principles of physics and the physical phenomena underlying these principles. (3 cr per qtr; prereq high school algebra and plane geometry for 1, 1 for 2 and 3; 3 lect hrs per wk)

1A-2A-3A. Introduction to Physical Science Laboratory. Laboratory course given in conjunction with 1-2-3. (1 cr per qtr; prereq 1-2-3 or ¶1-2-3; combination of 1-2-3 with 1A-2A-3A may be used to fulfill the laboratory science group requirement; 2 lab hrs per wk)

4-5-6. General Physics. (Primarily for premedical students) 4: Mechanics. 5: Heat and electricity. 6: Sound and light. Laboratory work is an integral part of course. (5 cr per qtr; prereq Math 40 or ¶Math 40; 4 lect, 1 quiz, 2 lab hrs per wk)

7-8-9. General Physics. Mechanics, heat, electricity, sound and light. Laboratory work is an integral part of course. (5 cr per qtr; prereq ¶ITM 13A or ¶Math 40 for 7, ¶ITM 24A or ¶Math 53 for 8, ¶ITM 25A or ¶Math 54 for 9; 4 lect, 1 quiz, 2 lab hrs per wk)

11-12-13. General Physics. Mechanics, heat, electricity, sound, and light. Laboratory work is an integral part of course. (5 cr per qtr; prereq ¶ITM 11 or ¶Math T for 11, ¶ITM 12 or ¶Math 10 for 12, ¶ITM 13A or ¶Math 40 for 13; 4 lect, 1 quiz, 1 rec, 2 lab hrs per wk for 11...4 lect, 1 quiz, 2 lab hrs per wk for 12 and 13)

14. Intermediate General Physics. Mechanics, electromagnetism, thermodynamics. (4 cr; prereq 13 and ¶ITM 24A or ¶Math 53; 4 lect and 1 quiz hr per wk)

14A. Physics Laboratory. Parallel to Phys 14. (1 cr; prereq 14 or ¶14; 2 lab hrs per wk)

14H. Honors Course: Intermediate General Physics. Mechanics, electromagnetism, thermodynamics. (4 cr; prereq 13 and ¶ITM 24A or ¶Math 53, △; 4 lect and 1 quiz hr per wk)

15H. Honors Course: Physics Laboratory. Parallel to Phys 14H. (1 cr; prereq 14H or ¶14H, △; 3 lab hrs per wk)

50. Intermediate General Physics. Elementary kinetic theory, charged particle dynamics, special relativity, electromagnetic radiation, elementary atomic physics. (4 cr; prereq 6 or 9 or 14, ¶ITM 25A or ¶Math 54; 4 lect and 1 quiz hr per wk)

50A. Physics Laboratory. Parallel to 50. (1 cr; prereq 50 or ¶50; 2 lab hrs per wk)

50H. Honors Course: Intermediate General Physics. Elementary kinetic theory, charged particle dynamics, special relativity, electromagnetic radiation, elementary atomic physics. (4 cr; prereq 6 or 9 or 14, ¶ITM 25A or ¶Math 54, △; 4 lect and 1 quiz hr per wk)

51. Intermediate General Physics. Elementary nuclear physics, wave motion, wave phenomena. (4 cr; prereq 50 and ¶ITM 26A or ¶Math 55; 4 lect and 1 quiz hr per wk)

51A. Physics Laboratory. Parallel to 51. (1 cr; prereq 51 or ¶51; 2 lab hrs per wk)

51H. Honors Course: Intermediate General Physics. Elementary nuclear physics, wave motion, wave phenomena. (4 cr; prereq 50 and ¶ITM 26A or ¶Math 55, △; 4 lect and 1 quiz hr per wk)

52H. Honors Course: Physics Laboratory. Parallel to 50H. (1 cr; prereq 50H or ¶50H, △; 3 lab hrs per wk)

53H. Honors Course: Physics Laboratory. Parallel to 51H. (1 cr; prereq 51H or ¶51H, △; 3 lab hrs per wk)

70. Industrial Summer Employment. Employment with an industrial firm in a professional or semiprofessional capacity doing work in the field of physics. Applications must be approved by the department prior to employment. Ten weeks of summer employment with a written report on this work approved by both employer and the department. (1 cr; prereq 3 yrs academic work plus △ during previous spring qtr)

80. Introduction to Atmospheric Science. An introductory course. Measurement and distributions of atmospheric variables; physical processes in the atmosphere, rain, fog, and air pollution; thunderstorms and tornadoes; wind and pressure; air masses, fronts, and cyclones; principles of weather forecasting; climate and climatic changes; recent exploration of the upper atmosphere. (3 cr)

100-102-104. Mechanics, Electricity, and Magnetism. Theoretical course in mechanics, electricity, and magnetism designed to prepare students for advanced work. (4 cr per qtr, §MM 29 and Phys 100; prereq 3rd yr, 9 or 14, ITM 26A or Math 55, 59 or Math 55, 106 for 100...100 or MM 29 for 102...102 for 104; 4 lect hrs per wk)

100A-101A-102A. Introduction to Analytic Mechanics. An analytic course in Newtonian mechanics with emphasis on conservation principles. Topics include: particle dynamics in 1, 2 and 3 dimensions with special attention to the central force problem; dynamics of a system of particles, including general motion of a rigid body and normal-mode analysis of coupled systems; moving co-ordinate systems; mechanics of continuous media including wave motion and elementary hydrodynamics; general coordinates and the Lagrange formulation of mechanics. Mathematics beyond the prerequisites is developed as required. (3 cr per qtr [no cr for 100A if §100 or §MM29]; prereq 3rd yr, 9 or 14, ITM 26A or Math 55, 59 or Math 55, 106 for 100A...100A or MM 29 for 101A...101A for 102A; 3 lect hrs per wk)

103A-104A-105A. Introduction to Electric and Magnetic Fields. The classical theory of electric and magnetic fields making free use of vector algebra and vector calculus. Maxwell's equations are developed from the basic experimental laws in form applicable both to free space and to material media. Wave solutions for these equations are discussed, with application to simple situations. (3 cr per qtr; prereq 3rd yr, 9 or 14, ITM 26A or Math 55, 59 or Math 55, 106 for 103A...103A for 104A...104A for 105A; 3 lect hrs per wk)

107-109-111. Atomic and Nuclear Physics. Emphasis on an interpretation of experimental phenomena. Topics include special relativity, the nuclear atom, atomic and molecular structure and spectra, quanta and atoms, wave mechanics, nuclear physics, modern developments in classical physics, astrophysics, particle physics. (3 cr per qtr; prereq 9 or 14, ITM 26A or Math 55, 59 or Math 55, 106, # if taken out of sequence; 3 lect hrs per wk)

108-110-112. Principles of Modern Physics. An analytical course developing elementary quantum mechanics from its historical background with applications to atomic and nuclear physics. Topics include special relativity, origin of quantum theory, electrons and quanta, atomic structure, particles and waves, the theory of quantum mechanics, one-electron atoms, exclusion principle, multi-electron atoms, X rays, scattering and nuclear physics. (3 cr per qtr; prereq 50, ITM 153 or Math 108; 3 lect hrs per wk)

114-116-118.‡ Elementary Physical Investigation. Problems, either experimental or theoretical, in which student has special interest. Written report required. (3 cr per qtr; prereq 3rd yr or above and △)

120. Atomic Physics. Laboratory course in 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 cr; prereq 50 or ¶107 or ¶108, #; 8 hrs per wk)

121. Experimental Nuclear Physics I. Laboratory course 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 cr; prereq 50 or 107 or 108, #; 8 hrs per wk)

122. Experimental Nuclear Physics II. Laboratory. Techniques requiring knowledge of electronic circuits. Geiger, proportional, scintillation, and coincidence counters, cosmic rays, nuclear resonance phenomena, health monitoring instruments. (3 cr; prereq 50 or 107 or 108, ♯; 8 hrs per wk)

123-124-125. Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter. Analytical course in principles of thermodynamics and introductory statistical mechanics. Laws of thermodynamics, thermodynamic potential functions, equations of state, phase transitions; transport phenomena, ensembles of identical systems, classical and quantum statistics; thermal, electric, and magnetic properties of matter. (3 cr per qtr; prereq 50 and ITM 152 or equiv for 123, 123 for 124, 124 for 125 or ♯; 3 lect hrs per wk)

126-127-128. Elementary Solid State Physics. Introduction to physics of bulk matter. Structure and types of solids; ionic, molecular, and metallic solids; thermal, electrical, and magnetic behavior of matter; theory of conduction in metals and semiconductors; crystal imperfections and their effects. (3 cr per qtr; prereq 50 and ¶ITM 26A or ¶Math 59)

131. Geometrical Optics. Fundamentals of ray optics and a study of its applications to optical instruments and their components. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 3 lect hrs per wk)

133. Physical Optics. Wave theory of interference, diffraction, polarization and double refraction, with a study of their applications. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 3 lect hrs per wk)

133A. Physical Optics Laboratory. Parallel to 133. (1 cr; prereq ¶133; 3 lab hrs per wk)

134. Experimental Optics. Laboratory. Spectrometry, optics of compound lenses, photometry, absorption, interferometry, and polarized light. (3 cr; prereq 3rd yr; 15 cr in physics, ITM 25A or Math 54; 1 lect and 5 lab hrs per wk)

136. Spectrum Analysis. Laboratory. Measurement of wave lengths, intensities, and absorption coefficients in the infrared, visible, and ultraviolet regions of the spectrum. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 1 lect and 5 lab hrs per wk)

144. Electrical Measurements. Experimental course. Ballistic and current galvanometers, magnetic flux measurements, potentiometer methods, D.C. bridges, and audiofrequency A.C. bridges. (4 cr; prereq 9 or 14 and ITM 25A or Math 54; 3 lect and one 3-hr lab per wk)

146. Physics of Vacuum Tubes and Associated Circuits. Thermionics and vacuum tube circuits, with emphasis on applications to physics research. (4 cr; prereq 144 or ♯; 3 lect and one 3-hr lab per wk)

148. Application of Electronic Circuits. Lecture and laboratory. Amplifiers, computing circuits, servomechanisms, regulating circuits, and other devices employed in physics research. (4 cr; prereq 146 or ♯; 3 lect and one 3-hr lab per wk)

165. Introduction to Physics of the Atmosphere. Review of the laws of radiative transfer. The thermal structure of the atmosphere as determined by radiation. Hydrostatics and thermodynamics of the atmosphere, stability and convection. Basic relations between pressure, temperature, and wind and the mean state of the atmosphere. A selection from topics of current interest: atmospheric electricity, mechanism of cloud formation and precipitation, ozone and the energy budget and circulation of the upper stratosphere. (3 cr; prereq 50 and ITM 26A or Math 55, 59 or Math 55, 106)

166. Meteorology I. Basic meteorological hydrodynamics. The quantitative description of the flow processes of large scale weather systems. (3 cr; prereq 165 or ♯)

167. Meteorology II. Introduction to theoretical meteorology. Critical examination of the equations of motion. The mathematical models and methods used to describe the large-scale motions of the atmosphere. The transformation of energy in large-scale weather systems. (3 cr; prereq 166, vector analysis or ♯)

171-172-173. Theoretical Physics. Classical theories of physics including as major topics analytical dynamics, electromagnetism and the relativistic formulation of these theories. Intended to serve both as a termination course in classical physics and as a preparation course for more advanced courses in mathematical physics and quantum mechanics. (3 cr per qtr; prereq 104, ITM 153, or Math 108 or equiv; 3 lect hrs per wk)

181-183-185. Atomistics and Elementary Quantum Mechanics. A unified course on the structure of matter and electromagnetic radiation in the light of modern experimental and theoretical work. The topics considered are fundamental particles; atomic, molecular, and nuclear structure; solid state; elementary quantum mechanics. (3 cr per qtr; prereq 111 or 112 or #; 3 lect hrs per wk)

For Graduate Students Only

201-202-203. Dynamics of Fluid Motion
204-205-206. Statistical Thermodynamics
207-208-209. Electrodynamics, Theoretical Optics, and the Theory of Relativity
210-211-212. Quantum Mechanics
213-214-215.‡ Seminar in Contemporary Experimental Physics
216-217-218.‡ Seminar in Contemporary Theoretical Physics
222-223-224. Principles of Mathematical Physics
225-226-227. Advanced Quantum Theory
228-229-230. Nuclear Physics
231-232-233. Theory of Atomic and Molecular Structure
237-238-239.‡ Seminar in Radiofrequency Spectroscopy
240-241-242.‡ Seminar in Solid State and Low Temperature Physics
246-247-248. Cosmic Rays
249-250-251. Solid State Physics
252-253-254.‡ Seminar in Nuclear Physics
255-256-257.‡ Seminar in Mass Spectroscopy
258-259-260.‡ Seminar in Cosmic Rays
261-262-263. Mathematical Foundations of Quantum Mechanics
264-265-266. Elementary Particle Physics
267-268-269. Atmospheric Physics
270-271-272. Special Topics in Nuclear Theory
273-274-275. Plasma Physics
301-302-303. Research in Physics

Physiology (Phsl)

(College of Medical Sciences)

52-53. Principles of Physiology. Emphasizes physical and chemical foundations and utilizes a quantitative approach. Lectures, demonstrations, and readings. (3 cr per qtr; prereq Phys 9 or 14, InCh 15, ¶ITM 26A)

Political Science (Pol)

(College of Science, Literature, and the Arts)

1-2.† American Government and Politics. Analysis of principles, organization, procedures, and functions of government in the United States—national, state, and local. Attention will be given throughout to current issues. (3 cr per qtr) Backstrom

A-B.† The State in the Modern World. 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 cr per qtr) Lippincott, Holt

5. American Government and Politics. Covers most of Pol 1-2. (5 cr, §1-2)

25. World Politics. Introduction to contemporary international relations; the policies of the great powers; nationalism; imperialism; internationalism. (3 cr) Mills

Psychology (Psy)

(College of Science, Literature, and the Arts)

1-2.† General Psychology. General introduction to the study of human behavior. Prerequisite to all advanced courses in psychology. (3 cr per qtr; prereq 2nd yr or 3rd qtr fr with B avg) Heron, Jenkins, LaBerge, Wright

155. Engineering and Industrial Psychology. Human factors as they relate to industrial production, biomechanics (adaptation of the machine to the capacities and limitations of the operator), work and effort, and the role of communication, motivation, and supervision in an industrial organization. (3 cr; prereq 2, 5 or 3 cr in statistics) Dunnette

Public Health (PubH)

(College of Medical Sciences)

2. Personal and Public Health. Individual and community activities for promotion of health and safety. (2 cr, §3, §50)

3. Personal Health. Normal body function; causes and prevention of disease. (2 cr, §2, §50)

50. Personal and Community Health. Fundamental principles of health conservation and disease prevention. (3 cr, §2, §3, §4, §5, §51, §52, §53, §100A)

75. Introduction to Environmental Sanitation. Principles of urban and rural sanitation relating to water, food, wastes, housing, air, insects, rodents. (3 cr; prereq 3 cr in public health)

100A. Elements of Public Health I. Occurrence and prevention of communicable, degenerative, and industrial diseases. Protection of food, water, and milk; maternal and child health. (3 cr; prereq 3 or 50, and a course in bacteriology)

102. Environmental Sanitation. Methods for promoting man's health and comfort by controlling environment. (3 cr; prereq 50 or ¶50, or 51 or ¶51, or 100A or ¶100A)

154. Control of Radiation Hazards. Methods used in study and control of radiation hazards in laboratories, hospitals, and industrial plants. (Cr ar; prereq ‡)

Rhetoric (Rhet)

(College of Agriculture, Forestry, and Home Economics)

22. Public Speaking. A practical course in the fundamentals of speechmaking. Emphasis upon organizing the speech and projecting it to the audience. (3 cr; prereq rhetoric communication requirement or equiv)

Social Science (SSci)

(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 and are influenced by man's conduct. The course is organized around three basic themes: (a) development of personality, (b) work as a central aspect of modern life, and (c) the quest for community. (3 cr per qtr) Blum, Cooperman, Sibley, and staff

Sociology (Soc)

(College of Science, Literature, and the Arts)

1. Man in Modern Society. Characteristics of human group life. Analysis of the factors associated with development of human group life and man's social environment; structure of the social environment and its influence upon individual's behavior. (3 cr) Sirjamaki

2. The American Community. Sociological analysis of modern American society. Topics emphasized include the distribution of population, urban-rural differences, social factors in the business systems, occupational groups, the determination of social status, and minority group adjustment. Attempts to familiarize student with current research methods. (3 cr; prereq 1 or 1A or 3) Martindale

14. Rural Sociology. Presentation of factual data necessary to an understanding of the problems of rural social life. (3 cr) Taylor

Soils (Soil)

(College of Agriculture, Forestry, and Home Economics)

19. Intermediate Soils. Basic physical, chemical, and microbiological properties of soils. Soil genesis, classification, and principles of soil fertility. Lectures, laboratory. (4 cr; prereq InCh 5)

126. Soil Physics. Soil structure, compaction, tilth, tillage; water infiltration, retention, availability, movement and evaporation; heat capacity, flow, air porosity, diffusion, deficiency effects on plants, drainage requirements. Lectures and laboratory. (4 cr; prereq 3 or 19, Math 10 or MeAg 23 or equiv)

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