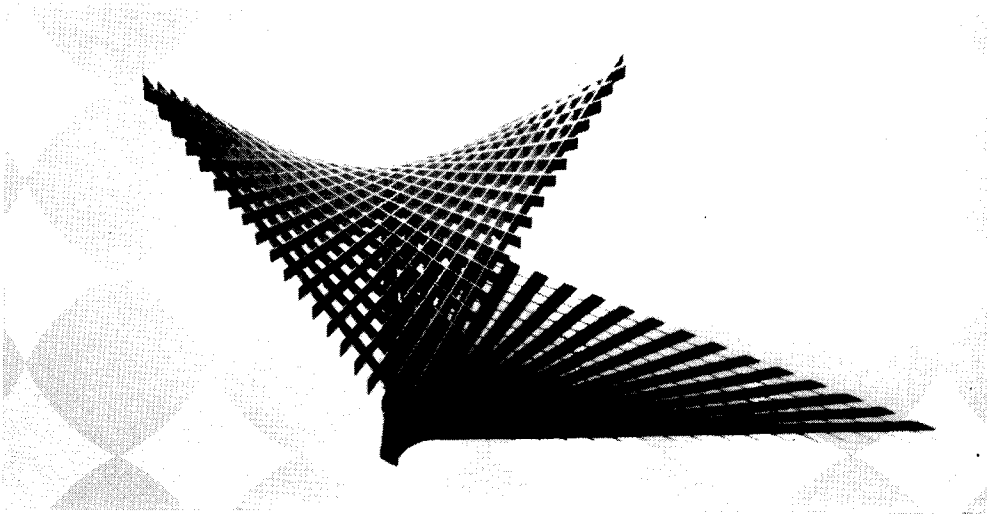
# INSTITUTE OF TECHNOLOGY



1963-1965

# UNIVERSITY OF MINNESOTA BULLETIN

# 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 Morrill Hall. 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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School of Chemistry, 139 Chemistry

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College of Engineering, 133 Main Engineering

School of Mathematics, 114 Main Engineering

School of Mineral and Metallurgical Engineering, 112 Mines and Metallurgy

School of Physics and Astronomy, 148 Physics

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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 seven related curricular units:

College of Engineering
School of Mineral and Metallurgical Engineering
School of Architecture
School of Chemistry
School of Earth Sciences (Department of Geology and Geophysics)
Department of Mathematics
School of Physics and Astronomy

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 with 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 colleges and schools. The curriculums they offer are tabulated below. Both 4-year and 5-year curriculums are available.

College of Engineering—Aeronautics and engineering mechanics; agricultural, civil, electrical, and mechanical engineering
School of Architecture—Architecture
School of Chemistry—Chemical engineering, chemistry
School of Earth Sciences—Geology; mineralogy and petrology; geophysics
Department of Mathematics—Mathematics
School of Mineral and Metallurgical Engineering—Geological engineering, metallurgy, metallurgical engineering, mineral engineering
School of Physics and Astronomy—Physics, astronomy

Most of the curriculums in the College of Engineering, in the School of Mineral and Metallurgical Engineering, and in the Department of Chemical Engineering 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 agrees to spend the year following the award of the degree in full-time residence at an accredited graduate school. (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 Liberal Arts. The Department of Chemistry, the Department of Mathematics, the School of Physics and Astronomy, and the School of Earth Sciences (Department of Geology and Geophysics) 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 mineral engineering providing practical work experience in conjunction with regular classes and laboratory work are available, beginning with the fourth year, 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 alternate quarters in industry. While on the work assignments students are paid at regular rates by the company.

A 4-year combination of courses in the Lower Division of the Institute of Technology 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 2 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. The Scholastic Standards Committees may extend the residence limit in the Lower Division from 8 to 9 quarters where extenuating circumstances exist. These regulations apply to all Institute of Technology units except the School of Architecture.

**High School Requirements**—It is strongly recommended that students wishing to enter the Institute of Technology complete 4 years of high school mathematics. 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 cor-

respondence courses (see *Bulletin of Correspondence Study*) and extension classes (see *Bulletin of Evening and Special Classes*). To be admitted, a high school graduate must satisfy the two major requirements 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. Four years of high school mathematics, divided approximately into 2 years of algebra and 2 years of geometry of 2 and 3 dimensions, including trigonometry. The beginning course given for credit in the fall of 1963 will be ITM 12, College Algebra and Trigonometry.

If a student lacks either a half unit in algebra or a half unit in geometry, or a half unit in both of these subjects, he can be admitted on the condition that he make up his deficiency by the end of his first quarter in residence (without Institute of Technology credit). A deficiency in algebra or trigonometry can be removed by registration in ITM 11 (Algebra and Trigonometry) and a deficiency in geometry can be removed by registration in ITM 8 (Solid Geometry). If deficiencies are not removed by the end of the first quarter, the student will not be permitted to continue in the Institute of Technology. However, it should be emphasized that the first quarter is a difficult one and every effort should be made to avoid the added burden caused by mathematics deficiencies. Such deficiencies should be made up, if possible, during the summer or any other period preceding registration in IT—through correspondence, extension, or summer school courses.

*2. Academic Standing*

A student is admitted on the basis of an aptitude rating which combines his high school rank and his achievement in a mathematics entrance examination which he takes during his senior year. The percentile rank in this examination is calculated on the basis of a norm established by students who in the past have taken the examination and who also enrolled in IT. The average percentile rank on the examination for the typical student therefore is usually lower than his high school rank. A student who has a high school rank of 50-percentile or above and who also has a math test rank of 25-percentile or above usually qualifies for admission without further review. For a student who does not satisfy either or both of these standards, an aptitude rating is calculated by adding his high school rank to his mathematics test percentile rank multiplied by four. If this sum lies below 125, the student usually is not admitted. If the aptitude rating is 125 or slightly above, the application is reviewed on the basis of other test information which appears on the student's application. It should be noted that a student who is admitted without special review must have an aptitude rating of 150 or above, with the additional condition that each of the 2 individual percentile scores must be above a minimum level.

The entrance examination is made available to Minnesota high schools so that those high schools that wish to do so may administer the test. Seniors interested in applying for admission to IT should contact their principal or counselor by February 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 for information and procedures to follow.

Students not eligible for admission directly may apply for transfer after 1 or more years of satisfactory work in some other college, such as a local junior college, a liberal arts college, or the University General College. Students who enter another college hoping to transfer later to IT must consult with the counselors in that college at the very beginning of the school year in order to plan for this transfer and to receive help in planning their programs in relation to this goal.

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.

**Opportunities for the Superior Student**—*Advanced Placement*—High school students entering the Institute of Technology can, on the basis of exceptional background, qualify for advanced placement in one or more departments.

Entering freshmen in IT can receive advanced standing from the Department of English, and receive 6 credits toward the language-literature requirement for graduation.

Advanced placement for entering freshmen is also available in chemistry, mathematics, and physics. Students desirous of such consideration should consult the chairmen of the three departments.

The University of Minnesota participates in the Advanced Placement Program of the College Entrance Examination Board. Advanced placement is available at the University in all areas in which those examinations are offered.

*Honors Programs and Independent Study*—A wide variety of special opportunities is available to students of superior ability. Honors courses are available in a number of departments, at both the Lower Division and Upper Division levels. Students should consult the bulletin section on Course Descriptions for details. Students may by petition to the departmental Scholastic Standards Committee request permission to take comprehensive examinations in courses which have been mastered through independent study; in this way, the student may enrich his educational program and accelerate his progress. Full credit for such work done outside of regular classes may be allowed by the Scholastic Standards Committees.

*Comprehensive examinations are a means of enrichment for the superior student; they cannot, in general, be used for the removal of failures.* (See section on Special Examinations.)

**Research Participation**—Opportunities for research are available in most of the departments of the Institute of Technology. Students should consult the department chairmen for details. Usually, the student participates in one of the on-going research programs of the department. In individual instances, a student may be assigned an independent project, and writes a thesis on his project. In such cases, a student may, upon approval of the department, receive credit toward graduation.

**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.

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 (GPA) 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.

Students must complete the work of the Lower Division in a total of 8 quarters, not including summer sessions. Subject to his adviser's approval, a student may register for *any* course for which he has met the prerequisites. It is the student's responsibility to meet all admission requirements for the Upper Division by the end of his eighth quarter in the Lower Division.

Students who have been admitted by their Scholastic Standards Committee to the Upper Division with any course deficiencies are required, of course, to make up such deficiencies before graduation. The Lower Division deficiencies are indicated on the student's Upper Division application form. The program for these deficiencies in the Upper Division is specified by the Scholastic Standards Committee at the time of admission. It is the responsibility of the student to plan his program so as to remove these Lower Division course deficiencies.

**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. Applications should be filed well in advance of the quarter of entrance. The application must receive the approval of the department in which the student wishes to take the majority of his courses. To be accepted, the student must have a Bachelor's degree or show satisfactory evidence of maturity. An adult special student must receive departmental approval of his adult special status each year that he wishes to register.

**Change of Major Department**—A student desiring to change his major department within IT must submit a petition, using the regular form. Forms are available in Main Engineering 133. The petition must be approved by the chairman of the department to which the student wishes to transfer, or by his representative.

A student in IT who wants to transfer to another college, school, or campus within the University must meet the requirements of the second. Application for transfer should be made at the Office of Admissions and Records as far in advance as possible of the actual date of transfer.

## 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). All students begin their registration in the Main Engineering building (E 135). Registration instructions are furnished by the Institute of Technology Registration Committee and are placed on bulletin boards in the buildings in which the IT departments are located.

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 must be filled out in duplicate and approved. One copy is filed in Main Engineering 133; the second copy is for the student.

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 in Main Engineering 133.

**Cancellation of Courses**—*During the first 6 weeks of classes*, a student may not cancel a course without failure unless he receives the consent of his adviser and has

departmental approval. A formal request must be filed to cancel a course at any time. All cancellations should be processed with Form A195 obtainable in 133 Main Engineering.

*After* the first 6 weeks of classes, 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 and of the Office of the Associate Dean and only if the student is not failing at the time of official cancellation. A student who cancels officially after the sixth week of classes and is failing at the time shall receive an F. A student who leaves a class at any time without officially canceling shall receive an F.

Cancellation of back work will not be granted except in case of unusual circumstances, and only by petition in the usual manner.

During the last 2 weeks before the beginning of final examinations, cancellation is not permitted except under the most unusual circumstances.

**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.

**Special Examinations**—Two types of special examinations are available: (a) Examination for proficiency, and (b) Examination for credit.

Examinations for proficiency require no fee and yield no credit or grade points. If the student's work is of passing quality, a notation will be made on his record "Course X satisfied by proficiency examination."

An examination for credit (or comprehensive examination) requires a $5 fee unless taken within 6 weeks after the student enters the University. These examinations cannot, in general, be used for the removal of failures. In no event will approval be granted in less than 90 days after the failure has been recorded.

Final decision as to whether or not an examination will be given will be made by the department concerned.

An examination for credit will usually be assigned a grade, though the Scholastic Standards Committee may determine whether or not a grade will be assigned. If the committee directs that a grade be assigned, it will count in the grade point average.

**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 31 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. Transfer credit is allowed only for grades of C or better, but all grades will be counted in determining grade point averages. A student in an exclusion status may, by petition to his Scholastic Standards Committee, enroll for credit in evening or correspondence courses approved as courses that contribute directly to his academic progress and can be used by the committee in its consideration of the student's readmission.

**Field Trips**—In some curriculums, field trips are required. Students should consult the departmental programs for details.

**Reserve Officers' Training Corps**—Information concerning requirements, opportunities, and courses in air science, military science, and naval science may be procured 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 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 office, Main Engineering 133. When the petition form has been completed, it should be left in the college office for the appropriate action. When the departmental committees and the associate dean have 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 freshman student is 14-17 credits per quarter; after the first year it is 17 credits. 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 associate dean. Usually the approval will be noted on the Admissions and Records and college 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.

*Effective fall quarter, 1963, all graduating seniors in the Institute of Technology are required to take final examinations.*

**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 grades 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 officially without grade in the first 6 weeks of the quarter or was canceled by petition 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. If, due to extenuating circumstances, a student is allowed by petition to repeat a course, both grades will be used in the computation of the grade point average.

**Requirements for Graduation**—The Bachelor's degree with professional 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. A student eligible to graduate on the basis of his grade point average but lacking not

more than 6 credits may complete these credits in the Extension Division or by Correspondence Study.

Students having a grade point average of 3.50 or better for their undergraduate work within the University (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 within the University (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:

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

The award of the B.S. degree by the Institute of Technology is a privilege accorded to students of unusual promise in order that they might secure an early admission to graduate study. The intent of the faculty is that the recipients of this degree shall participate fully in normal graduate study.

In recognition of these conditions, the applicant for the B.S. degree from the Institute of Technology agrees to spend the year following the award of the degree in full-time residence at an accredited 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. ITM 24A, 25A
   c. GeCh 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 in 8 quarters or less. A quarter of registration shall be any fall, winter, or spring quarter during which the student is enrolled, irrespective of the number of credits for which he is enrolled. The summer sessions will not be included in the computation, irrespective of the number of credits in which the student is enrolled during the summer sessions.

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.

## General Regulations

Satisfactory work is represented by a C average or better. That is, the number of grade points must be at least twice the number of course credits.

A student whose cumulative grade point average (GPA) is less than 2.00 is placed on probation. If his grade point deficiency is greater than that of a tolerated maximum, he may be excluded from college. However, usually a student is allowed a grace quarter when he appears on the exclusion list *for the first time.* Such a student may register for this quarter without special permission of his Scholastic Standards Committee. He must, however, consult the committee chairman prior to the end of the sixth week of the quarter. At the end of the quarter the student is subject to exclusion action on the regular basis.

**Lower Division**—A minimum GPA of 2.00 is required for admission to the Upper Division. A student whose cumulative GPA is less than 2.00 is placed on probation. A student whose grade point deficiency is more than that specified on the schedule below may be excluded from IT. (See procedures below.) *Failure to appeal will mean automatic exclusion.* (See exception noted under General Regulations.)

| Quarter | Completed Credits Earned and Failed | Tolerated Grade Point Deficiency |
|---|---|---|
| 1 | 1-14 | 10 |
| 2 | 15-29 | 16 |
| 3 | 30-44 | 20 |
| 4 | 45-59 | 20 |
| 5 | 60-74 | 20 |
| 6 | 75-89 | 16 |
| 7 | 90-104 | 10 |
| 8 | 105-120 | 6 |

**Upper Division**—A grade point average of 2.00 is required for graduation. Students who have a grade point deficiency will be placed on the exclusion list at the end of the quarter. *Failure to appeal will mean automatic exclusion.* (See exception noted under General Regulations.)

**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. 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 Standards Committee and complete the Exclusion Action Appeal (form E-100).

A student on the exclusion list should see his department representative at a time specified by the department. The three copies of the exclusion appeal form E-100 will be prepared by the student in advance of the meeting. Following action of the departmental committee, the student will present two forms at the IT office, Main Engineering 133. The department action will be considered final, following a review by the associate dean. The departmental copy of the exclusion appeal will remain in the department with its action.

A student who appears on the exclusion list *for the first time* may register for the grace quarter without appeal. Such a student must consult with his departmental Scholastic Standards Committee representative prior to the end of the sixth week of the quarter. At the end of the quarter the student will appeal on the regular basis.

No student in his grace quarter (or one who has been readmitted on appeal) may register during the regular early registration period. He will be allowed to register only following departmental action at the end of the quarter.

A student appearing before the departmental committee should present his grade slip for the quarter to the committee at the time of the appeal.

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. (See change of major.)

**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 his 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 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, astronomy, chemical engineering, chemistry, civil engineering, electrical engineering, fluid mechanics, geology and geophysics, industrial engineering, mathematics, mechanical engineering, mechanics and materials, metallurgical engineering, metallurgy, mineral engineering, and physics. For a complete description of graduate work in the Institute of Technology 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. Fellowships carry stipends from $1,400 to $2,700 and assistantships have stipends of $2,178 for half-time 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 a department, he is assigned an adviser from the Institute of Technology mathematics staff. Such a student should specify a major department prior to registration for the spring quarter of the freshman year. If a student 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 approved by the adviser.

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**—This service, located in 135 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 finding a position 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, Institute of the Aerospace Sciences, and the Institute of Electrical and Electronic Engineers. In addition there are the Architectural Society, the School of Mineral and Metallurgical Engineering 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 editor in chief and business manager and assists them in their work. The *Minnesota Technolog* is a member of the Engineering 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 Official Daily Bulletin or from the Bureau of Student Loans and Scholarships, 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. Students are advised to read the Official Daily Bulletin the first week of winter quarter each year for details on procedures to follow to make application.

## ALL DIVISIONS

*Alcoa Foundation Scholarships:* For undergraduates who have completed at least 2 quarters in college and are working toward a degree in agricultural, chemical, civil, mechanical engineering; or metallurgy; or equally qualified candidates in other engineering majors. Amount is $625. One award in each field annually.

*Babcock and Wilcox Company Scholarships:* For undergraduate students in the Institute of Technology. Amount is $100-$300. Entering freshmen given special consideration.

*Boeing Airplane Company Scholarships:* For aeronautical, electrical, mechanical, and civil engineering students for use in the fourth year (may be renewed for fifth-year undergraduates). Amount is tuition plus incidental fee at the resident rate. Four awards annually.

*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.

*Elmer W. Johnson Scholarship:* In memory of the late Assistant Dean Elmer W. Johnson of the Institute of Technology. Will be awarded to students in the Institute of Technology on the basis of scholarship and need.

*Minneapolis Gas Company Engineering Scholarship:* To aid and encourage students in engineering, especially chemical and mechanical. 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 students in engineering and science. Amount is $250-$300.

*Minnesota Mining and Manufacturing Company Scholarship:* For one or more scholarships in the Institute of Technology. Amount is tuition plus incidental fee.

*North Star Concrete Company University of Minnesota Scholarship:* For one student entering his fourth year who is enrolled in one of the following majors: civil engineering, architecture. Amount is $500.

*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. Six or more awards annually.

*Rosemount Engineering Company Awards:* For undergraduates in the Institute of Technology for papers on topics broadly concerned with measurement techniques. Amount is $100-$250.

*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 sophomores 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.

*William Sturm Memorial Scholarship Fund:* For outstanding recipient of the Ellerbe and Company Engineering Scholarship. Amount is $100.

*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 and 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 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 usually is tuition and incidental fee resident rate.

*Douglas Aircraft Scholarship:* For senior or fifth-year student in aeronautical, electrical, or mechanical engineering (in this order of preference).

*Irvin M. Nestigen Memorial Loan Fund:* Loans may be made to aeronautics students without interest until graduation, and at 3% thereafter.

## 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.

## ARCHITECTURE

*Blumcraft of Pittsburgh Scholarship Fund:* For aid to needy students in architecture. Amount is $250.

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

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

*Mankato Stone Company Education Fund:* For undergraduates with advanced standing in architecture. Amount varies.

*Minnesota Lathing and Plastering Bureau Scholarship:* For students in the School of Architecture. Amount is $500.

*National Association of Home Builders Scholarship:* For advanced students in architecture. Amount is $1,000.

*North Star Concrete Company University of Minnesota Scholarship:* See description under All Divisions.

*A. C. Ochs Brick and Tile Company Scholarship:* For advanced students in architecture. Amount is $250.

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

*Rollin B. Child, Incorporated, Education Fund:* For students in the School of Architecture. Amount varies.

*Thomas F. Ellerbe Prize in Architecture* (sponsored by the Co-operative Foundation): For excellence in study of buildings for co-operatives. Amount is $300. One to three awards 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:* For undergraduates in the School of Architecture. Amount is $500. Two to four 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

*American Institute of Chemical Engineers Scholarship:* For use of fifth-year undergraduate who is an active member of the local chapter.

*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.

*I. M. Kolthoff Scholarship in Analytical Chemistry Fund*

*Monsanto Chemical Company Scholarship:* For students who have completed at least 1 year toward a major in chemical engineering. Amount is $500.

*Twin Cities Chemical and Allied Trades Association, Incorporated, 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, Incorporated, 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 of Minnesota Scholarships:* For undergraduate Civil Engineering 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.

*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.

*North Star Concrete Company University of Minnesota Scholarship:* See description under All Divisions.

## ELECTRICAL ENGINEERING

*Collins Radio Company Scholarship:* For graduates or undergraduates in electrical engineering. Amount is tuition and incidental fee at resident rate.

*Crossley Associates, Incorporated, Scholarship:* For junior students studying electronics or physics. Amount is $300 offered alternate years.

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

*Radio Corporation of America Scholarships:* For undergraduates with advanced standing in physics or electrical engineering who are specializing in radio or electronics. Amount is $400. Two awards annually.

## GEOLOGY AND GEOPHYSICS (School of Earth Sciences)

*California Company Scholarship:* For senior or junior students in geological sciences. May be renewed annually at discretion of donor. Amount is $500.

*California Exploration Company Scholarship in Geophysics:* For senior or junior students interested in careers in geophysics. Amount is $750.

*Continental Oil Company Scholarship:* For senior student in geological sciences. May be renewed annually at discretion of donor. Amount is $500.

*E. J. Longyear Memorial Scholarship:* For undergraduate student in the fields of metallurgical engineering, mineral engineering, geology, and other earth sciences. Amount is $300-$400. Up to three 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.

*Central Warehouse Company Scholarship:* To assist industrial engineering students whose training in engineering would qualify them as industrial management trainees.

*Continental Oil Company Scholarship in Mechanical Engineering:* Amount is $500. Must have completed 2 quarters and continue to major in mechanical engineering.

*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 scholarships.

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

*Pfeifer and Shultz Scholarship in Mechanical Engineering:* For resident high school graduates and junior college transfers 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.

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

## MINERAL, METALLURGICAL ENGINEERING; METALLURGY

*American Institute of Mining, Metallurgical, and Petroleum Engineers, Minnesota Section, Scholarship:* For undergraduates in the School of Mineral and Metallurgical Engineering. 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.

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

*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 Mineral and Metallurgical Engineering), but students in mechanical, electrical, chemical, or civil engineering are also eligible. Amount is $500. Entering students apply through their high school by January 1 each year; University students follow regular procedure. 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 Mineral and Metallurgical Engineering. Amount is $200-$300.

*International Nickel Company Scholarship:* For entering freshmen in engineering, with preference to mineral 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 Mineral and Metallurgical Engineering. Amount is $100-$300.

*Ladish Company Scholarships in Metallurgy and Mechanical Engineering* (Ladish Company, Cudahy, Wisconsin): For entering freshmen or advanced standing students in metallurgy or mechanical engineering who are willing to accept summer employment near 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, Minneapolis): For undergraduates in the fields of metallurgical engineering, mineral engineering, geology, and other earth sciences. Amount is $300-$400. Up to three awards annually.

*Mesabi Tire Scholarships:* For students in the School of Mineral and Metallurgical Engineering or in 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 mineral and metallurgical engineering. Amount is $350. Three awards annually.

*School of Mineral and Metallurgical Engineering General Scholarship Fund:* For students in the School of Mineral and Metallurgical Engineering.

*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 Mineral and Metallurgical Engineering 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:* For junior students studying electronics or physics. Amount is $300 offered alternate years.

*Radio Corporation of America Scholarships:* For undergraduates with advanced standing in physics or electrical engineering who are specializing in radio or electronics. Amount is $400. Two awards annually.

*Alfred P. Sloan Foundation Scholarships:* For male sophomores 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, mathematics, or physics. Amount is $200-$250. Two awards annually.

## 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 engineering graphics 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 Mineral and Metallurgical Engineering, School of Earth Sciences (Department of Geology and Geophysics), School of Physics and Astronomy, and the Department of Mathematics. 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. 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.

The intent of the program of Nontechnical Electives which form a part of the several curriculums in the Institute of Technology is to provide the student an opportunity to enhance his familiarity and understanding of our cultural heritage, of the framework of our society, and of our physical and biological environment. Students are expected to complete 3 sequences of a minimum of 6 quarter credits each in the groups specified by the department of his major. Beyond this minimum core of 18 credits and the 12 credits of Freshman English the student is given considerable freedom of choice in the selection of the additional subjects which he offers in satisfaction of the specified total requirement. The student should be aware of certain restrictions which have been imposed by the faculty of the Institute of Technology. He may not offer in satisfaction of the Nontechnical Requirements any courses which are specified as prerequisite to the technical course requirements of the curriculum of his

choice. Similarly, courses closely related to the technical objectives of one curriculum could not properly be labeled as nontechnical courses for a student in that curriculum. For example, courses in geology could not be accepted as nontechnical courses for a student majoring in geology or geophysics but might be quite appropriate for a student in, for instance, electrical engineering.

In general, the initial electives in a given subject should be chosen to provide perspective of the fields; more advanced courses are available for the student whose interest is aroused. Students in the Institute of Technology are encouraged to elect courses in the environmental sciences (subject to the restrictions above noted) which take advantage of their background in mathematics, physics, and chemistry. Students in the Upper Division are also encouraged wherever possible to choose Upper Division courses as Nontechnical Electives. Students are urged to consult advisers in their major departments to determine the suitability of nontechnical offerings.

## Course Requirements for Graduation

Each curriculum in the Institute of Technology specifies the course requirements for that curriculum.

### *Nontechnical Requirements*

The following minimal requirements in nontechnical courses apply to all curriculums:

1. Twelve credits in language-literature area. This is usually satisfied by a course sequence in Freshman English.
2. Thirty-four additional credits in nontechnical courses for a 5-year curriculum (25 credits for a 4-year curriculum). These are satisfied by the Nontechnical Group Requirements and the Nontechnical Electives. Engl 85 or 85A-B-C, Technical Writing for Engineers, cannot be used to satisfy this requirement.

**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.

**Nontechnical Group Requirements**—These include courses in three groups: Group H—Humanities; Group N—Environmental Sciences; Group S—Social Sciences. To satisfy a group requirement, a minimum of 6 credits must be taken in a single course sequence. Three such course sequences are required for graduation, including at least 1 in Group S and 1 in Group H. Some departments require a Group N sequence; other departments allow an additional sequence in either Group S or H. Students should consult the departmental curriculums for details. (In the School of Architecture, a 6-credit sequence in art satisfies one of the group requirements. The

remaining two groups must be from the departments listed, but may include, with the adviser's approval and by petition, courses other than those listed.)

In each group, credits beyond the minimum of 6 credits required may be used as Nontechnical Elective credits.

Group H—Humanities

1. Hum 1A-2A-3A, 21, 22, 23, or 51, 52, 53, or 71, 72, 73
2. Hist 1-2-3, 17-18-19, 20, 21, 22 or 53, 54, 55 or 79, 80, 81, or 93, 94, 95, or 134, 135, 136, or 149, 150, 151
3. Philosophy
4. Engl 37, 38, 39
5. Foreign language

Group N—Environmental Sciences

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

Group S—Social Sciences

1. Econ 1T-2T (Other Econ courses may be used as additional electives.)
2. Pol 1-2, or 5 or A-B which may be followed by 25, 26, 27
3. Psy 1-2, 155
4. Soc 1-2, 14 or 1-2, 104
5. SSci 1-2-3

The foreign language courses may not include those designed to meet technical needs of a particular scientific area; specifically, 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 H may be used as electives. In the School of Physics, a year course in German or Russian is required in addition to the requirement in Group H.

**Nontechnical Electives**—To complete the basic requirement of 46 nontechnical credits, a student may select courses from the areas or departments listed below. Students in the Upper Division should, in general, select courses numbered 50 and above. No course may be used as a Nontechnical Elective or as a group requirement if it is also a prerequisite to a required technical course in the student's program.

ADDITIONAL ELECTIVES LIST

| | | | |
|---|---|---|---|
| Anthropology | Economics | Languages | Psychology |
| Art | Geography | Literature | Social Science |
| Astronomy | Geology | Music (theory) | Sociology |
| Botany | History | Philosophy | Speech |
| Classics | Humanities | Political Science | Zoology |

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

A maximum of 6 credits will be allowed by petition toward graduation from the combined areas of physical education and applied arts (art, drama, and music). The grades in these courses are not to be included in the determination of grade point averages. For exceptions, see required art courses in the School of Architecture.

A maximum of 4½ transfer credits in religion will be accepted as Nontechnical Electives but may not satisfy any part of the Nontechnical Group Requirements.

Transfer of credits from General College for students admitted into the Institute of Technology is subject to the following conditions:

1. Only courses in which a student makes a grade of C or better will be approved for credit. (However, see 3 below.)

2. Credits will be approved only toward graduation. They will not be included in the computation of the grade point average.

3. The requirement of 9 credits of the Engl 31 sequence combined with 3 credits of the Engl 29 sequence may be used to meet the 12-credit language-literature requirement. However, to receive such credit, the student must earn an average grade of "top C" (grade C7).

4. The Nontechnical Group Requirements in IT can be satisfied only with courses specified by IT. If, however, a student has completed a sequence which is included both in the Arts College "overlap list" (courses for which credit may not be received if equivalent courses have been taken) and in the IT Nontechnical Group Requirements list, one group requirement may, by petition, be satisfied by such a sequence. The remaining two group requirements must be met by courses specified in the IT bulletin.

5. Additional courses may, by petition, be used to satisfy the elective requirements; however, the total credits approved shall not exceed 17 credits in addition to credits toward the language-literature requirement.

SUMMARY OF MINIMAL CREDIT REQUIREMENTS

| Institute of Technology Unit | | English[1] | Group Requirement | Nontechnical[2] Electives | Electives and Technical Electives |
|---|---|---|---|---|---|
| College of Engineering | (4 yr) | 12 | 18 | 7° | ↑ |
| | (5 yr) | 12 | 18 | 16° | |
| School of Mineral and Metallurgical Engineering | (4 yr) | 12 | 18 | 7° | |
| | (5 yr) | 12 | 18 | 16° | |
| Department of Chemical Engineering | (4 yr) | 12 | 18 | 7° | |
| | (5 yr) | 12 | 18 | 16° | See the curriculum of each individual department |
| Department of Mathematics | | 12 | 18 | 7° | |
| School of Architecture | | 12 | 18 | See departmental curriculum | |
| Department of Geology and Geophysics | | 12 | 18 | See departmental curriculum | |
| Department of Chemistry | | 12 | 18 | See departmental curriculum | |
| School of Physics | | 12 | 18 | 0-18°° | ↓ |

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

[2] Electives from *Groups* or from the *Nontechnical Electives* list.

° Does not include Engl 85 or Engl 85A-B-C.

°° Plus a year course in German or Russian.

## *Technical Electives*

Most curriculums include elective 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 N. Students should consult the departmental curriculums for details.

### *Optional or "Free" Electives*

Most departmental curriculums provide a minimum of 9 free elective credits, for which the student has the option of selecting *either* technical or nontechnical courses. If the student selects nontechnical courses, these credits are over and above the minimum Nontechnical Requirements of 46 credits (5-year program).

### *Requirements for IT Students Enrolled in ROTC*

1. Academic courses which are allowed in the ROTC program as substitute courses and which satisfy requirements for graduation from IT will receive full credit.
2. All ROTC courses which have been accepted for credit by the related academic departments will be approved for credit toward graduation in IT as if the course had originated in that academic department.
3. Any student who *completes* an ROTC program will be allowed up to 9 credits toward graduation, either as electives or as technical electives, in addition to those allowed in 1 or 2 above but not as Nontechnical Electives. These additional credits may *not* be used toward meeting the minimum nontechnical requirement of 46 credits.
4. No proportionate credit will be allowed for *partial* completion of any ROTC program.
5. Credits for ROTC courses based on a comprehensive examination for military service are not accepted in IT.
6. Transfer credit for ROTC courses needed to complete an ROTC program at the time of graduation may be petitioned.

## 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.

**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:

   GeCh 4-5, 6; OrCh 61-62, 63; CE 18, 19, 20, 31, 32, 33, 130, 131, 132, 160; EE 61-62-63, 71-72-73, 81-82-83, 104-105-106, 111-112-113, 114-115-116; EG 25, 26, 27; Engl 1B-2B-3B, 85; Geo 1, 2; Hydr 103; ITM 8, 9, 11 (no cr 8, 9, 11—admission requirement), 12, 13A, 25B, 26A, 26B, 27, 90, 160; ME 21, 22, 23, 30-31-32; MM 27, 28, 29, 40, 41, 142; Phys 11, 12, 13, 14, 14A, 50, 50A; electives—Group H, N, S.

2. Correspondence Study Courses:

   CE 146; EG 25, 26, 27; Engl 1B-2B-3B; Geo 2C; ITM 8, 9, 11 (no cr for 8, 9, 11—admission requirement), 12, 13A, 24A, 25A, 25B, 26A, 26B, 27; MM 27; electives—Group H, N, S.

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 engineering science and engineering technician 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 Mineral and Metallurgical Engineering

B. School of Architecture

C. School of Chemistry

D. School of Earth Sciences (Department of Geology and Geophysics)

E. Department of Mathematics

F. School of Physics and Astronomy

## *COLLEGE OF ENGINEERING and SCHOOL OF MINERAL AND METALLURGICAL ENGINEERING*

**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 ideal 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 in the

School of Mineral and Metallurgical Engineering. The courses included in the first 2 years are listed as follows:

**First Year**

(For students entering IT fall quarter, 1963)

| | Credits—f, w, s | | |
|---|---|---|---|
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | ..... | 1 | 1 |
| EG 25—Engineering Graphics | ..... | ..... | 4-0 |
| Electives—Group H, N, S (see Index for Nontechnical Group Requirements) | 0-3 | 0-3 | 0-3 |
| Total credits | 14-18 | 14-18 | 18-19 |

EG 25 may be postponed until the second year. Students should consult the curriculum of the department in which they plan to major.

Students are encouraged to take 6 credits of nontechnical courses in their freshman year if their high school performance and academic capability warrant it. Electives are to be chosen from the Nontechnical Elective Groups H, N, or S, or other approved Nontechnical Electives (see list).

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| OrCh 16—Carbon Compounds (or) Phys 51—Intermediate General Physics (or) GeCh 6—Principles of Solution Chemistry | ..... | ..... | 4 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| MM 27—Rigid-Body Mechanics I | ..... | ..... | 3 |
| Phys 14, 50—General Physics: Intermediate General Physics | 4 | 4 | ..... |
| Phys 14A—Physics Laboratory Laboratory | 1 | 1 | 1 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Engineering Graphics (see below) | 3-4 | 3-4 | 3-4 |
| Total credits | 17-18 | 17-18 | 16-17 |

Some departments in the Institute of Technology recommend that students take courses in engineering graphics in the second year in lieu of courses from the Groups H, N, or S. Students should consult the curriculum of the department in which they plan to major.

**General Suggestions for Selecting Electives**—A review of the various third-year, fourth-year, 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 *professional fields* and by *engineering function.* Since students must select a professional field for concentration, they are familiar with such fields of en-

gineering 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**—Detailed Upper Division curriculums for each degree program in the College of Engineering and in the School of Mineral and Metallurgical Engineering are presented in following sections (in the order shown in the list below):

Aeronautics and Engineering Mechanics
Agricultural Engineering
Civil Engineering
Electrical Engineering (and Industrial Engineering Option)
Engineering and Business Program (1st yr and 2nd yr)
Geological Engineering
Mechanical Engineering (and Industrial Engineering Option)
Metallurgy and Metallurgical Engineering
Mineral Engineering

## 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 and aerospace systems. In order to cope with the rapidly changing objectives which characterize an engineering field so close to the frontiers of science, the curriculum emphasizes a broad engineering science base rather than selected specialties. 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 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 multidisciplinary fields.

A major part of the course work offered by the Department lies in the area of fluid mechanics and solid mechanics pertinent to *aerospace engineering*.

A review of the aeronautics 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**—Further study of engineering subjects important in aerospace engineering. For example, electives are offered in such areas as astrodynamics, stability and control of aerospace vehicles, and performance of ballistic and space vehicles.

In addition to the required courses, sufficient electives are offered to permit students to develop such functional interests as research, development, design, production, operation, application, or management.

The 5-year curriculum leads to the degree bachelor of aeronautical engineering, B.Aero.E. in which a broad "aero-space" viewpoint is emphasized. 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 provides not only good job opportunities but also excellent engineering work experience. In addition, many fourth-year 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. For nontechnical group requirements, see *Note* below.

### 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 | | |
|---|---|---|---|
| Phys 14A—Laboratory | ..... | 1 | ..... |
| Aero 5-6—Aeromechanics Survey | 1 | ..... | 1 |
| Phys 51—Intermediate General Physics<br>(or) OrCh 16—Carbon Compounds | ..... | ..... | 4 |

*Note*—A 6-credit sequence is required from each of Groups S and H. At least one more 6-credit sequence must be taken from 1 of the 3 Groups H, N, or S. Those students who may be interested in the biological or medical aspects of aerospace problems are urged to select a Group N sequence.

**UPPER DIVISION**

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Aero 100, 101, 102—Aerodynamics I, II, III | 3 | 3 | 3 |
| ME 30-31—Thermodynamics | 3 | 3 | ..... |
| ME 133—Heat Transmission | ..... | ..... | 3 |
| MM 28, 29—Rigid-Body Mechanics II, III | 3 | 3 | ..... |
| MM 193—Introduction to the Theory of Mechanical Vibrations | ..... | ..... | 3 |
| MM 40, 41—Deformable-Body Mechanics I, II | 3 | 3 | ..... |
| Met 56—Physical Metallurgy | ..... | ..... | 3 |
| MM 142—Experimental Mechanics I | ..... | ..... | 2 |
| Electives (see statement following fifth-year curriculum) | 3 | 3 | 3 |
| Total credits | 15 | 15 | 17 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Aero 103—Aerodynamics IV | 3 | ..... | ..... |
| MM 150—Rheology and Strength of Solids | ..... | 3 | ..... |
| EE 41-43-45—Principles of Electrical Networks (see statement below) | 3 | 3 | 3 |
| EE 41A-43A-45A—Electrical Engineering Laboratory (see statement below) | 1 | 1 | 1 |
| Aero 145-146-147—Aeromechanics Laboratory | 2 | 2 | 2 |
| Engl 85A-B-C—Technical Writing for Engineers | 1 | 1 | 1 |
| Electives (see statement following fifth year curriculum) | 7 | 7 | 10 |
| Total credits | 17 | 17 | 17 |

With permission of adviser: (a) EE 44 may be substituted for EE 45 and suitable technical electives substituted for EE 100A-B-C, or (b) Phys 144, 146, 148 plus 9 credits of technical electives (Phys 103A-104A-105A suggested) may be substituted for EE 41, 43, 45, 100A-B-C.

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Aero 106—Aerodynamics of Lifting Surfaces<br>Aero 109—Ballistic and Space Vehicles<br>Aero 150—Aeroelasticity I<br>Aero 159—Aerodynamic Deceleration<br>Aero 180—Introduction to Astrodynamics<br>ME 146—Introduction to Combustion | 3 | 3 | 3 |
| see *Note* below | | | |
| Aero 115, 116—Aerospace Structures I, II<br>(or) MM 180, 181—Applied Elasticity I, II<br>(or) MM 180, 182—Applied Elasticity I, III | 3 | 3 | ..... |
| EE 100A-B-C—Fundamentals of Electronics (see statement following fourth-year curriculum) | 3 | 3 | 3 |
| Aero 130—Design Methods for Aerospace Systems | 3 | ..... | ..... |
| Aero 131—Aerospace Systems Design | ..... | 4 | ..... |
| Electives (see statement below) | 6 | 3 | 10 |
| Total credits | 18 | 16 | 16 |

*Note*—Some of these courses are not offered every year (see course descriptions). They may be taken in the fourth year as electives provided the prerequisite requirements are satisfied.

**Electives**—The number of elective credits shown per quarter is intended to serve as a guide which, if followed on the average, would lead to the required number of credits for graduation. In addition to the Nontechnical Elective Requirements in the College of Engineering, the minimum elective requirements for Aero students are as follows:

| | Four year (B.S) | Five year (B.Aero.E.) |
|---|---|---|
| Technical | 17 | 24 |
| Free | 6 | 9 |

Technical electives are to be selected from 4 or less of the following 10 fields (unless work in other fields is approved by adviser): (a) mathematics, (b) physics, (c) chemistry, (d) fluid mechanics, (e) solid and structural mechanics, (f) materials and metallurgy, (g) electrical engineering electronics, and controls, (h) combustion and propulsion, (i) management and industrial engineering, and (j) biomechanics. See adviser for suggested courses.

Spch 50 (3 cr) is recommended as a Nontechnical Elective in the fourth year.

Students having industrial engineering and management interests are advised to schedule Econ 1T-2T, and 65T or IR 52 in their Lower Division program.

## 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.

### 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 | ..... | ..... |
| EG 25—Engineering Graphics | 4 | ..... | ..... |
| Biol 1A-2A—General Biology | ..... | 3 | 4 |
| OrCh 16—Carbon Compounds | ..... | ..... | 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 | ..... | ..... |

| | Credits—f, w, s | | |
|---|---|---|---|
| Hydr 103, 104—Fluid Mechanics; Fluid Mechanics Laboratory | ..... | 6 | ..... |
| ME 24—Mechanical Design and Analysis | ..... | ..... | 3 |
| ME 30-31-32—Thermodynamics | 3 | 3 | 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 I | ..... | ..... | 2 |
| Soil 19—Intermediate Soils | 4 | ..... | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements; Econ 1T-2T recommended for agricultural engineering students) | ..... | ..... | 3 |
| Elective | ..... | ..... | 3 |
| 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 | ..... |
| CE 18, 20—Surveying | 3 | ..... | 3 |
| CE 37—Elements of Structural Engineering | 3 | ..... | ..... |
| ME 21—Mechanisms: Kinematic Analysis | 3 | ..... | ..... |
| ME 99—Introduction to Engineering Analysis | ..... | 3 | ..... |
| ME 133—Heat Transmission | ..... | 3 | ..... |
| Met 56—Physical Metallurgy | 3 | ..... | ..... |
| Electives—Groups H, N, or S (see Index for Nontechnical Group Requirements; Econ 1T-2T recommended for agricultural engineering students) | 3 | 3 | 6 |
| Elective | ..... | 3 | ..... |
| Technical elective (a minimum of 6 cr selected from AgEn 167, 170, 171, 172, 176, 180, 181 required for graduation) | ..... | ..... | 3 |
| Total credits | 18 | 18 | 15 |

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| AgEn 145—Soils Engineering | ..... | 3 | ..... |
| AgEn 149—Radioisotope Measurements | 3 | ..... | ..... |
| AgEn 159—Agricultural Engineering Instrumentation | ..... | ..... | 3 |
| AgEn 179—Agricultural Process Engineering | ..... | ..... | 3 |
| EE 41-43—Principles of Electrical Networks and Fields | 3 | 3 | ..... |
| EE 41A-43A—Electrical Engineering Laboratory | 1 | 1 | ..... |
| Engl 85—Technical Writing for Engineers | ..... | ..... | 3 |
| ME 160—Psychrometrics, Air Conditioning | 3 | ..... | ..... |
| Soil 126—Soil Physics | 4 | ..... | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | ..... | 3 | ..... |
| Elective | ..... | ..... | 3 |
| Technical elective | 3 | 6 | 3 |
| Total credits | 17 | 16 | 15 |

## 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.

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.

It is recommended that students in civil engineering take EG 25, Engineering Graphics, in the spring quarter of the first year.

### 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 | | |
|---|---|---|---|
| Phys 14A—Physics Laboratory | 1 | ..... | ..... |
| CE 1-2—Civil Engineering Laboratory | 1 | 1 | ..... |
| OrCh 16—Carbon Compounds | ..... | ..... | 4 |
| EG 26, 27—Graphical Computation; Graphical Communication and Analysis (see *Note* below) | 2 | 2 | ..... |
| Geo 1—Physical Geology (see *Note* below) | ..... | ..... | 4 |

*Note*—It is recommended that students in civil engineering take EG 26, 27 instead of Nontechnical Group Requirements during fall and winter quarters of the second year, and take Geo 1 as a Nontechnical Group Requirement spring quarter of the second year.

## 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 |
| EG 26, 27—Graphical Computation; Graphical Communication and Analysis (see statement below) | 2 | ..... | 2 |
| Engl 85—Technical Writing for Engineers | 3 | ..... | ..... |
| Hydr 103—Fluid Mechanics | ..... | 5 | ..... |
| Hydr 104—Fluid Mechanics Laboratory | ..... | 1 | ..... |
| MM 28, 29—Rigid-Body Mechanics II, III | 3 | ..... | 3 |
| MM 40, 41—Deformable-Body Mechanics I, II | 3 | 3 | ..... |
| MM 142—Experimental Mechanics I | ..... | ..... | 2 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) (or) CE 160—Applied Hydraulics } see *Note* below | ..... | ..... | 3 |
| Technical elective—(taken in the Institute of Technology, or other colleges by departmental approval; see statement below) | ..... | 3 | ..... |
| Total credits | 17 | 18 | 16 |

If EG 26 and 27 were taken in the second year, take Nontechnical Electives, 3 credits per quarter.

The department recommends MinE 70, Geological Engineering I, as the technical elective.

*Note*—Students who take CE 160 should take Plan A of the fourth-year program. Those taking Group H or S should take Plan B of the fourth-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<br>(or) ITM 90—Elementary Engineering Statistics<br>(or) Hydr 187—Intermediate Fluid Mechanics | ..... | ..... | 3 |
| Technical elective (taken in the Institute of Technology, or other colleges 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 H or S (see Index for Nontechnical Group Requirements; Spch 50, Public Speaking, is required for 3 of the Nontechnical Elective credits) | 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 H or S (see Index for Nontechnical Group Requirements; Spch 50, Public Speaking, is required for 3 of the Nontechnical Elective credits) | 3 | 3 | 3 |
| Total credits | 15 | 17 | 17 |

**Fifth Year**

| | Credits—f, w. s | | |
|---|---|---|---|
| CE 141, 142—Reinforced and Prestressed Concrete; Design of Reinforced and Prestressed Concrete I | 3 | 3 | ..... |
| CE 147—Foundations | ..... | ..... | 3 |
| EE 41, 42—Principles of Electrical Networks and Fields; Electrical Engineering Survey: Machines | 3 | 4 | ..... |
| EE 41A—Laboratory | 1 | ..... | ..... |
| CE 101—Contracts and Specifications | 3 | ..... | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements; see statement below) | 3 | 3 | 0-6 |
| Technical elective (taken in the Institute of Technology, or other colleges by departmental approval) | 3 | 6 | 3 |
| Total credits | 16 | 16 | 6-12 |

There are 34 nontechnical elective credits required, in addition to 12 credits of freshman English. If none were taken in freshman year, 12 credits are required in fifth year.

**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 153, 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 selec-

tion 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 and Prestressed 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 153—General Microbiology | ..... | 3 | ..... |
| CE 101—Contracts and Specifications | ..... | ..... | 3 |
| PubH 100A—Elements of Public Health | 3 | ..... | ..... |
| PubH 102—Environmental Sanitation | ..... | ..... | 3 |
| EE 41, 41A, 42—Principles of Electrical Networks and Fields; Laboratory; Electrical Engineering Survey: Machines | 4 | 4 | ..... |
| Total credits | 17 | 11 | 10 |

CE 172, MicB 153, 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, 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. Pol A-B should be taken for the Nontechnical Elective. EG 25 should be taken in spring quarter.

**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; EG 26, 27; MM 28, 29, 40, 41, 142; Hydr 103, 104; Econ 1T-2T.

**Fourth Year**

CE 130, 141, 146, 147, 161, 170, 171; EE 41, 41A, 42; Engl 85; Hist 103C, 104C, 105C; Phil 2, 3; Geo 1.

## Electrical Engineering

The electrical engineering curriculum is designed to acquaint the student with the scientific background, the engineering principles, and the cultural heritage with which he will be concerned throughout his professional and civic career. Building on the foundation of the first 2 years, the technical program of the third and fourth years develops and interrelates the 2 major aspects of electrical engineering. One aspect is concerned with the electronic properties of materials and the electromagnetic phenomena which are essential to an understanding of electronic, magnetic, and other de-

vices. The other involves the techniques for the analysis and synthesis of systems of devices assembled to perform complex tasks such as automatic control or communications. The fifth year is reserved for electives through which the student may enhance his competence in the areas of his particular interest. The list of courses following the program for the fifth year shows the breadth of these elective offerings. In addition to the technical and nontechnical requirements the curriculum also includes free electives in the fourth and fifth years as an opportunity to pursue special interests in any available area.

The 5-year curriculum leads to the degree of bachelor of electrical engineering, B.E.E. A total of 250 credits is required for graduation.

The degree of bachelor of science, B.S., may be granted after 4 years to permit outstanding students who satisfy the requirements outlined in the general section on Requirements for Graduation to enter graduate school in the fifth year. Students interested in graduate study 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.

An honors program is offered in electrical engineering for strongly motivated and exceptionally able students. The program replaces the electrical engineering courses of the third and fourth years with a similar but more intensive 2-year sequence; class size is limited to encourage the free exchange of ideas between students and instructor. Other modifications are made in the curriculum to provide a broader background in mathematics and physics. The honors program may be entered at the beginning of the junior year by students who have completed the requirements of the Lower Division, but enrollment is subject to the approval of the faculty adviser for the program.

A combined program with the Law School is available for interested and able students.

*Students in the electrical engineering curriculum must offer sequences in each of the three Groups H, N, and S in satisfaction of the Group Requirements.*

## 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—Elements of Electrical Engineering Laboratory | ..... | 1 | 1 |
| Phys 51—Intermediate General Physics | ..... | ..... | 4 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Nontechnical Electives | 3-4 | 3-4 | 3-4 |

## 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 |
| Engl 85A-B-C—Technical Writing for Engineers | 1 | 1 | 1 |
| ITM 60—Operational Methods for Linear Systems | ..... | ..... | 3 |
| MM 28, 29—Rigid Body Mechanics II, III | 3 | 3 | ..... |
| ME 30—Thermodynamics | ..... | ..... | 3 |

| | Credits—f, w, s | | |
|---|---|---|---|
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Nontechnical Electives | 3 | 3 | ..... |
| Total credits | 17 | 17 | 17 |

**Fourth Year**

| | 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 |
| Spch 50—Public Speaking | 3 | ..... | ..... |
| Technical electives (see below) | 3 | 3 | 3 |
| Electives | ..... | 3 | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Nontechnical Electives | 3 | 3 | ..... |
| Total credits | 18 | 18 | 15 |

**Technical Electives**—To be selected, in consultation with the adviser, from Upper Division courses offered in mathematics, the physical sciences, or engineering. The following sequences are typical of faculty recommendations:

| | |
|---|---|
| ITM 147, 148, 149 | Vector Analysis;<br>Differential Equations;<br>Determinants and Matrices |
| ITM 164-165-166 | Theory and Programming of Modern Digital Computers |
| Hydr 101, ME 133, MM 40 | Fluid Mechanics;<br>Heat Transmission;<br>Deformable-Body Mechanics I |
| Met 101-102-103 | Introduction to Science of Materials |
| PCh 101-102-103 | Physical Chemistry |

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Electrical engineering electives (see below) | 9 | 9 | 9 |
| Electives | 6 | 6 | 3 |
| Electives—Groups H, N, or S (see Index for Nontechnical Group Requirements) or Nontechnical Electives | 3-0 | 3-0 | 4 |
| Total credits | 18-15 | 18-15 | 16 |

**Electrical Engineering Electives**—A minimum of three of the following sequences must be completed, except that, with the consent of the adviser and upon approval of a petition, courses not included in this list may be substituted.

| | |
|---|---|
| EE 131-133-135 | Applied Electronics |
| EE 138-139-140 | Electric Power Systems and Power Control |
| EE 150, 151, 152 | Dynamical Methods in Electrical Engineering;<br>Thermodynamic Methods in Electrical Engineering;<br>Statistical-Mechanical Methods in Electrical Engineering |
| EE 157-158-159 | Control Systems |
| EE 160A-B-C | Electrical Energy Conversion |
| EE 164-165-166 | Communications |
| EE 167-168-169 | Electromagnetic Theory and Application |
| EE 170-171-172 | Linear Network Theory |
| EE 173-174-175 | Physical Electronics |
| EE 178-179-180 | Nonlinear Circuit Analysis |
| EE 186A-B-C | Communications Theory |
| EE 194-195-196 | Control Theory |

**Industrial Engineering List**—The following group of courses has been selected as a core program in industrial engineering for students majoring in electrical engineering who wish to pursue this supplementary field of interest.

Econ 1T-2T is recommended in Group S (see Index for Nontechnical Group Requirements).

As preparatory courses, ME 99 (or ITM 90), IE 100, IE 153, IE 170, and IE 172, are to be taken in the fourth year. Of these, 9 credits will be accepted in satisfaction of the technical elective requirement.

A student who completes the program below for the fifth year may petition to substitute 9 of the 18 credits for one sequence of electrical engineering electives.

| | Credits—f, w, s | | |
|---|---|---|---|
| IE 171—Quality Control | 3 | ..... | ..... |
| IE 173—Engineering Economic Analysis | ..... | 3 | ..... |
| IE 194—Applied Industrial Engineering | ..... | ..... | 3 |
| Minimum of 9 credits from IE 154, 155, 165, 167, 174, 175, 177, 180, 182, 193 | 3 | 3 | 3 |

## Engineering-Business Program (Four-Year)

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, the 4-year program in engineering and business administration (industrial administration) has been developed.

Students who wish to combine training for business management with a basic engineering curriculum may enroll in the Institute of Technology for 2 years and then transfer to the School of Business Administration to complete the requirements for a bachelor of science in business degree. Such students will take the freshman and sophomore years as prescribed for students in the Institute of Technology with the exception that elective credits in the freshman and sophomore years should be taken in the following:

Econ 1T-2T—Principles of Economics (6 credits)
Acct 55A-B—Elementary Accounting (8 credits [no credit toward graduation in IT])
QA 5—Elements of Statistics (4 credits) (ITM 90 may be substituted for QA 5)

A minimum of 90 credits with a grade point average of 2.00 is required for admission to the School of Business Administration for this program. Upon such admission, the student must complete the requirements set forth for the Upper Division work in business administration.

See also the *Bulletin of the School of Business Administration* for further details.

### First Year

| | Credits—f, w, s | | |
|---|---|---|---|
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | ..... | 1 | 1 |
| EG 25—Engineering Graphics | ..... | ..... | 4 |
| Econ 1T-2T—Principles of Economics | 3 | 3 | ..... |
| Total credits | 18-17 | 18-17 | 19-18 |

### Second Year

| | Credits—f, w, s | | |
|---|---|---|---|
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| OrCh 16—Carbon Compounds (or) Phys 51—Intermediate General Physics (or) GeCh 6—Principles of Solution Chemistry | ..... | ..... | 4 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| MM 27—Rigid-Body Mechanics I | ..... | ..... | 3 |
| Phys 14, 50—General Physics; Intermediate General Physics | 4 | 4 | ..... |

| | Credits—f, w, s | | |
|---|---|---|---|
| Phys 14A—Physics Laboratory<br>Laboratory | 1 | 1 | 1 |
| Acct 55A, 55B—Accounting (do not carry credit toward any IT degree) | 4 | 4 | ..... |
| QA 5—Statistics<br>(or) ITM 90—Engineering Statistics | ..... | ..... | 3-4 |
| Total credits | 18 | 18 | 16-17 |

## Geological Engineering

A 5-year curriculum is offered that leads to the degree of bachelor of geological engineering, B.Geol.E. A total of 248 credits, exclusive of summer field work, is required for graduation. Sufficient flexibility is provided so that a student may emphasize one or more of the mining, petroleum, construction, or mineral economics fields.

Geological engineering is an integrated engineering field, strongly dependent on a sound understanding of chemistry, mathematics, and physics, together with engineering and earth sciences and mineral economics.

The curriculum is designed to prepare students for responsible positions in the geological and engineering departments of exploration, mining, petroleum, or construction companies, or in governmental branches related to these industries. The geological engineer conducts investigations in the fields of metallic minerals, industrial minerals and rocks, petroleum, and construction materials. He makes engineering analyses on such works as foundations, dams, canals, highways, harbor facilities, and water supply; in these evaluations he utilizes geology, geophysics, and rock or soil mechanics. In addition the geological engineer must be familiar with exploration principles, with the various systems of mining, and know something of the possibilities of ore dressing to recover valuable minerals. Further, he may make estimates of mineral reserves and appraise their economic value. To exercise professional judgment in these matters understanding is needed of the many nontechnical factors which affect valuation analysis as, for example, taxation and government policy.

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 reservoir engineering is necessary.

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.

The geological engineer may travel extensively, in this country and abroad, and the more remote the location the more diversified the work. One liking the outdoors will find satisfaction in geological engineering.

**Four-Year Degree**—A student may be granted the degree, bachelor of science (B.S.) at the end of 4 years, then start graduate study in the fifth year if he satisfies the requirements spelled out in the general section on Requirements for Graduation. A student contemplating a 4-year degree should consult his faculty adviser early in the third year to plan a schedule of study that will meet course requirements. A foreign language should be elected, selected from the humanities group of the nontechnical electives.

**Faculty Adviser**—An undergraduate student upon entering the School of Mineral and Metallurgical Engineering is assigned a member of the faculty as his adviser. The adviser will aid the student in the selection of courses, particularly electives, and will serve as consultant during his scholastic career. The adviser's approval of the study plan must be obtained each quarter before registration is permitted.

**Electives**—A student should consider the areas of his principal interests and discuss with his adviser a selection of the technical electives best suited to serve his needs

and promote his interests. Those who intend to take graduate work in preparation for a career in research or teaching are encouraged to elect courses in mathematics, chemistry, mechanics, and fluid dynamics. Students interested in engineering management should elect courses in industrial engineering, economics, and business. A program of related courses is preferable where electives are permitted.

**Undergraduate Job Opportunities**—The research programs in the department provide job opportunities for good engineering and research experience, developing scientific interest and motivation.

## 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 take the following courses:

| | Credits—f, w, s |
|---|---|
| OrCh 16—Carbon Compounds<br>(or) GeCh 6—Principles of Solution Chemistry | ..... ..... 4 |
| Phys 14A, 50A—Physics Laboratory | 1 1 ..... |
| MinE 1—Mineral Engineering Laboratory | ..... ..... 1 |

*Note*—The department recommends that students in geological engineering take EG 26, Graphical Computation, in the second year if possible rather than in the third year, where it is now scheduled.

*Students in the geological engineering curriculum are required to complete a minimum of 6 credits in a single course sequence of environmental science electives (Group N, see Index for Nontechnical Group Requirements).*

## UPPER DIVISION

### Third Year

| | Credits—f, w, s |
|---|---|
| MinE 111-112-113—Principles of Mineral Engineering I-II-III | 3 3 3 |
| MinE 13—Mine Surveying | ..... ..... 4 |
| Geo 11, 22, 62—Introductory Physical Geology; Historical Geology; Mineralogy and Lithology | 5 5 5 |
| EG 26—Graphical Computations | ..... 2 ..... |
| CE 18, 20—Surveying | 3 ..... 3 |
| MM 40, 28, 142—Deformable-Body Mechanics I; Rigid-Body Mechanics II; Experimental Mechanics I | 3 3 2 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Electives List (see Index for Additional Electives) | 3 3 ..... |
| Total credits | 17 16 17 |

### Summer Field Trip

Summer Field Work (see adviser) (2 weeks) ..... 3 credits

### Fourth Year

| | Credits—f, w, s |
|---|---|
| MinE 131-132—Rock Mechanics I-II | 3 3 ..... |
| MinE 141, 142—Mineral Economics I, II | 3 3 ..... |
| Geo 140, 141—Mineral Systems I, II | 4 4 ..... |
| Geo 120—Structural Geology | 4 ..... ..... |
| PCh 107-108—Physical Chemistry | 4 4 ..... |
| CE 53—Elements of Soils Mechanics | ..... ..... 3 |
| ME 99—Introduction to Engineering Analysis | ..... ..... 3 |
| Engl 85—Technical Writing for Engineers | ..... 3 ..... |

| | Credits—f, w, s | | |
|---|---|---|---|
| Technical electives | ..... | ..... | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | ..... | ..... | 9 |
| Total credits | 18 | 17 | 18 |

**Summer Field Trip**

Summer Field Work (see adviser) (6 weeks) ..... 9 credits

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| MinE 171, 171A—Fluid Flow Through Porous Media I; Laboratory | ..... | 3 | ..... |
| MinE 180—Geochemical Exploration | 3 | ..... | ..... |
| MetE 110, 111—Mineral Dressing (see statement below and Group 3 note) | 4 | 4 | ..... |
| Geo 155-156—Mineral Deposits (see statement below and Group 3 note) | ..... | 3 | 3 |
| Electives | 3 | 3 | 3 |
| Technical electives | 3 | ..... | 7 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | 3 | 3 | 4 |
| Total credits | 16 | 16 | 17 |

Students interested in petroleum courses, see Group 3 note in the following technical electives list.

*Technical Credits Note*—Of the total 13 credits of technical electives, 6 to 9 credits must be taken in Group 1, and 6 to 9 credits must be taken in Group 2 in the technical electives list that follows.

If the 9 elective credits in the fifth year are not used for ROTC, all or part of them may be applied to Groups 1 and 2 of the technical electives list.

**Technical Electives**—Technical electives must be selected from the following groups:

Group 1

MinE 70—Geological Engineering I
MinE 121, 122—Mine Plant Engineering I, II
MinE 133—Rock Mechanics III
MinE 155—Materials Handling and Bulk Flow
MinE 160—Mining and Processing Industrial Minerals
MinE 172—Fluid Flow Through Porous Media II
MinE 173—Natural Gas Engineering
MinE 185—Selected Topics in Mineral Exploration
MetE 112—Mineral Dressing

Group 2

Geo 170—Introduction to Earth Geophysics
Geo 172—Introduction to Exploration Geophysics
Geo 110—Stratigraphy I
Geo 115—Geomorphology
Hydr 101, 104—Fluid Mechanics; Laboratory
CE 159—Soil Mechanics
CE 161—Hydrology

Group 3

(suggested substitutions for petroleum oriented students):

Geo 115—Geomorphology
Geo 110—Stratigraphy I
ME 30-31—Thermodynamics
MinE 172—Fluid Flow Through Porous Media II
MinE 173—Natural Gas Engineering

(for)

Geo 155-156—Mineral Deposits
MetE 110, 111—Mineral Dressing

## 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 |
|---|---|
| ME 99—Introduction to Engineering Analysis | 3 |
| IE 100—Introduction to Industrial Engineering Analysis | 3 |
| IE 153—Methods Engineering and Work Measurement | 3 |
| IE 170—Production Planning and Control | 3 |
| IE 171—Quality Control | 3 |
| IE 172—Manufacturing Cost Analysis | 3 |
| IE 173—Engineering Economic Analysis | 3 |

| | Credits |
|---|---|
| IE 194—Topics in Management Science | 3 |
| Industrial engineering electives | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements; Econ 1T-2T is recommended for Group S) | 9 |

**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.

## 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 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 environmental science electives, Group N (see Index for Nontechnical Group Requirements).*

## UPPER DIVISION

### Third Year

| | Credits—f, w, s | | |
|---|---|---|---|
| ME 30-31-32—Thermodynamics | 3 | 3 | 3 |
| ME 99—Introduction to Engineering Analysis | 3 | ..... | ..... |
| IE 100—Industrial Engineering Analysis | ..... | 3 | ..... |
| EE 41-43—Principles of Electrical Networks and Fields | 3 | 3 | ..... |
| EE 41A-43A—Electrical Engineering Laboratory | 1 | 1 | ..... |
| EE 44—Electrical Engineering Survey—Electronics (or) EE 45, 45A—Principles of Electrical Networks and Fields; Electrical Engineering Laboratory | ..... | ..... | 4 |
| MM 28—Rigid-Body Mechanics II | 3 | ..... | ..... |
| MM 29—Rigid-Body Mechanics III | ..... | 3 | ..... |
| MM 40—Deformable-Body Mechanics I | ..... | ..... | 3 |
| Hydr 103—Fluid Mechanics | ..... | 5 | ..... |
| Hydr 104—Fluid Mechanics Laboratory | ..... | ..... | 1 |
| ME 133—Heat Transmission | ..... | ..... | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | ..... | 3 |
| Total credits | 16 | 18 | 17 |

### Fourth Year

| | Credits—f, w, s | | |
|---|---|---|---|
| ME 21—Analysis of Mechanical Engineering Systems | 3 | ..... | ..... |
| ME 22—Kinetics of Mechanism Systems | ..... | 3 | ..... |
| ME 23—Synthesis of Mechanism Systems | ..... | ..... | 3 |
| ME 24—Optimum Design of Mechanical Elements<br>Met 56—Physical Metallurgy | 3 | 3 | ..... |
| ME 33—Measurements Laboratory I<br>ME 34—Measurements Laboratory II<br>MM 142—Experimental Mechanics I | 2 | 2 | 2 |
| EE 100A-B-C—Fundamentals of Electronics<br>(or) MM 41—Deformable-Body Mechanics II<br>ME 171—Process Engineering I<br>ME 172—Process Engineering II<br>Elect 1 sequence | 3 | 3 | 3 |
| ME 134—Thermodynamics of Fluid Flow<br>ME 146—An Introduction to Combustion<br>ME 160—Psychrometrics and Air Conditioning | 3 | 3 | 3 |
| Electives (see statement below) | ..... | ..... | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| Total credits | 17 | 17 | 17 |

### Fifth Year

| | Credits—f, w, s | | |
|---|---|---|---|
| ME 125—Machine Design Laboratory<br>ME 159—Power and Propulsion Laboratory<br>ME 169—Psychrometrics and Air Conditioning Laboratory | 2 | 2 | 2 |
| ME 143—Turbomachinery<br>ME 162—Thermal Environmental Engineering<br>ME 198—Industrial Instrumentation and Automatic Control | 3 | 3 | 3 |
| ME 191-192-193—Mechanical Engineering Design | 2 | 2 | 2 |
| Engl 85A-B-C—Technical Writing for Engineers | 1 | 1 | 1 |
| Electives (see statement below) | 6 | 5 | 3 |
| Nontechnical electives | 3 | 3 | 4 |
| Total credits | 17 | 16 | 15 |

To register in Engl 85A-B-C, Technical Writing for Engineers, a student must be concurrently registered in ME 191-192-193, Mechanical Engineering Design, or have completed a work-study assignment the previous quarter.

All students are required to have their elective courses approved by their adviser. The electives must be sufficient to complete a total of at least 250 credits for graduation.

MM 193, Introduction to the Theory of Mechanical Vibration, may be substituted for MM 41, Deformable-Body Mechanics II.

Spch 50, Public Speaking, is a recommended Nontechnical Elective.

**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.

### UPPER DIVISION

#### Third Year

| | | Credits—f, w, s | | |
|---|---|---|---|---|
| ME 30-31-32—Thermodynamics | 3 | 3 | 3 | |
| ME 99—Introduction to Engineering Analysis | 3 | ..... | ..... | |
| IE 100—Industrial Engineering Analysis | ..... | 3 | ..... | |
| EE 41-43—Principles of Electrical Networks and Fields | 3 | 3 | ..... | |
| EE 41A-43A—Electrical Engineering Laboratory | 1 | 1 | ..... | |
| EE 44—Electrical Engineering Survey—Electronics (or) EE 45, 45A—Principles of Electrical Networks and Fields; Electrical Engineering Laboratory | ..... | ..... | 4 | |
| MM 28—Rigid-Body Mechanics II | 3 | ..... | ..... | |
| MM 29—Rigid-Body Mechanics III | ..... | 3 | ..... | |
| MM 40—Deformable-Body Mechanics I | ..... | ..... | 3 | |
| Hydr 101—Fluid Mechanics | 3 | ..... | ..... | |
| Hydr 104—Fluid Mechanics Laboratory | ..... | 1 | ..... | |
| ME 133—Heat Transmission | ..... | ..... | 3 | |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | ..... | 3 | 3 | |
| Total credits | 16 | 17 | 16 | |

#### Fourth Year

| | | Credits—f, w, s | | |
|---|---|---|---|---|
| ME 24—Optimum Design of Mechanical Elements | ..... | ..... | 3 | |
| ME 33—Mechanical Engineering Laboratory I<br>ME 34—Mechanical Engineering Laboratory II<br>MM 142—Experimental Mechanics I | 2 | 2 | 2 | |
| Met 56—Physical Metallurgy | 3 | ..... | ..... | |
| ME 171—Process Engineering I | ..... | 3 | ..... | |
| ME 172—Process Engineering II | ..... | ..... | 3 | |
| EE 100A-B-C—Fundamentals of Electronics (or) ME 21—Analysis of Mechanical Engineering Systems<br>ME 22—Kinetics of Mechanism Systems<br>MM 41—Deformable-Body Mechanics II | Elect 1 sequence 3 | 3 | 3 | |
| IE 153—Method Engineering and Work Measurement | ..... | 3 | ..... | |
| IE 170—Production Planning and Control | ..... | ..... | 3 | |
| IE 171—Quality Control | ..... | 3 | ..... | |
| IE 172—Manufacturing Cost Analysis | 3 | ..... | ..... | |
| IE 173—Engineering Economic Analysis | 3 | ..... | ..... | |

| | Credits—f, w, s | | |
|---|---|---|---|
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| Total credits | 17 | 17 | 17 |

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| ME 191-192-193—Mechanical Engineering Design | 2 | 2 | 2 |
| ME 198—Industrial Instrumentation and Automatic Control | 3 | ..... | ..... |
| ME 199—Introduction to Feedback Control Systems | ..... | 3 | ..... |
| ME 134—Thermodynamics of Fluid Flow<br>ME 143—Turbomachinery<br>ME 146—An Introduction to Combustion<br>ME 160—Psychrometrics and Air Conditioning<br>ME 162—Thermal Environmental Engineering<br>(2 courses required) | 3 | ..... | 3 |
| IE 194—Topics in Management Science | ..... | 3 | ..... |
| Industrial Engineering electives | ..... | ..... | 3 |
| Engl 85A-B-C—Technical Writing for Engineers | 1 | 1 | 1 |
| Electives (see statement below) | 6 | 4 | 3 |
| Nontechnical Electives | 3 | 3 | 4 |
| Total credits | 18 | 16 | 16 |

To register in Engl 85A-B-C, Technical Writing for Engineers, a student must be concurrently registered in ME 191-192-193, Mechanical Engineering Design, or have completed a work-study assignment the previous quarter.

All students are required to have their elective courses approved by their adviser. The electives must be sufficient to complete a total of at least 250 credits for graduation.

Econ 1T-2T is recommended for Group S (see Index for Nontechnical Group Requirements). MM 193 may be substituted for MM 41.

Spch 50, Public Speaking, is a recommended Nontechnical Elective.

**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 will be followed. This leads to the degree of bachelor of laws.

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

# Metallurgy and Metallurgical Engineering

Currently, two 5-year curriculums are offered which lead to the degrees of bachelor of metallurgy, B.Met., and bachelor of metallurgical engineering, B.Met.E., respectively.

A total of 250 credits is required for graduation in both curriculums.

The fields of metallurgy and metallurgical engineering are represented by the co-ordinated application of scientific and engineering principles to the beneficiation of ores, extraction of metals from the ores and beneficiated products, purification of materials and the effective utilization of metals, alloys, and nonmetallic materials.

Metallurgy and metallurgical engineering are founded on the basic sciences of physics and chemistry. Emphasis is placed upon an understanding of the fundamentals of chemical reactions between solids, liquids, and gases and upon the structure of crystalline solids and the relation of structure to the properties of matter.

The need for metallurgically trained people is acute since technological and scientific advancements are becoming increasingly limited by the availability of suitable materials. For example, in the case of ore beneficiation the past exploitation of rich ores has left only low-grade material from which it is difficult to extract the contained minerals efficiently. The high demand for materials dictates that all sources of materials be developed and utilized efficiently. In the case of physical metallurgy the recent advances in such fields as electronics, nuclear power generation, jet propulsion, and rocketry have created demands for materials with properties heretofore not available.

Because of the importance of metallurgy and metallurgical engineering to modern technology, metallurgists are in demand not only in metal-producing industries but also in the industries which use materials. They are employed in research, development, and plant operation.

A student may be granted a B.S. degree after 4 years in order to initiate graduate work 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 department recommends that students in metallurgy and metallurgical engineering take the following courses:

| | Credits—f, w, s | | |
|---|---|---|---|
| OrCh 16—Carbon Compounds<br>(or) GeCh 6—Principles of Solution Chemistry | ..... | ..... | 4 |
| Phys 14A, 50A—Physics Laboratory | 1 | 1 | ..... |
| MetE 1—Metallurgical Engineering Laboratory | ..... | ..... | 1 |

## *Metallurgical Engineering*

### UPPER DIVISION

#### Third Year

| | Credits—f, w, s | | |
|---|---|---|---|
| PCh 101-102-103—Physical Chemistry | 4 | 4 | 4 |
| MetE 106, 107, 108—Principles of Process Metallurgy | 3 | 3 | 3 |
| MetE 107A—Process Metallurgy Laboratory | ..... | 1 | ..... |
| Met 101-102-103—Introduction to the Science of Materials | 3 | 3 | 3 |

| | Credits—f, w, s | | |
|---|---|---|---|
| Met 101A-102A—Science of Materials Laboratory | 1 | 1 | ..... |
| MM 40, 28—Deformable-Body Mechanics I; Rigid-Body Mechanics II | 3 | 3 | ..... |
| Geo 62—Mineralogy and Lithology | ..... | ..... | 5 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | 3 | 3 | 3 |
| Total credits | 17 | 18 | 18 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| PCh 109—Physical Chemistry | 4 | ..... | ..... |
| ChEn 101, 102—Principles of Chemical Engineering | 5 | 5 | ..... |
| MetE 110, 111, 112—Mineral Dressing | 4 | 4 | 4 |
| ITM 90—Elementary Engineering Statistics | ..... | 3 | ..... |
| Engl 85—Technical Writing for Engineers | ..... | 3 | ..... |
| MinE 141—Mineral Economics | 3 | ..... | ..... |
| Technical Electives | ..... | ..... | 7 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | ..... | 3 | 7 |
| Total credits | 16 | 18 | 18 |

**Field Trip**

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

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| MetE 122, 123—Hydrometallurgy | ..... | 3 | 3 |
| MetE 134, 135, 136—Metallurgical Unit Processes | 3 | 3 | 3 |
| MetE 150-151—Mineral Processing Research I, II | 3 | 3 | ..... |
| MetE 155—Electric and Magnetic Separation of Minerals | ..... | ..... | 2 |
| Electives | 3 | 3 | 3 |
| Technical electives (see statement below) | 4 | 4 | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | 3 | ..... | 3 |
| Total credits | 16 | 16 | 14 |

Credits beyond the curriculum requirements may be taken by special permission (see your adviser).

**Technical Electives**—The total 15 technical elective credits must be taken from the following list:

MetE 124-125-126—Special Problems in Mineral Dressing
MetE 138, 144—Advanced Process Metallurgy; Metallurgical Unit Operations
MetE 141-142-143—Special Problems in Process Metallurgy
MinE 121, 124-125—Mine Plant Engineering I; Mill Plant Engineering I, II
MinE 142—Mineral Economics II
PCh 104-105-106—Physical Chemistry Laboratory
PCh 128—Colloid and Surface Chemistry
Geo 140, 141—Mineral Systems I, II
ChEn 119-120—Chemical Engineering Thermodynamics
EE 41, 41A, 42—Principles of Electrical Networks and Fields; Laboratory; Survey: Machines
Met 103A—Science of Materials Laboratory
Met 180-181-182—Thermodynamics and Kinetics of the Solid State

If the 9 elective credits in the fifth year are not used for ROTC, all or part may be applied to the above list of technical electives.

**Co-operative Work-Study Curriculums**—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 years 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 Mineral and Metallurgical Engineering (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 Mineral and Metallurgical Engineering.

## *Metallurgy*

### 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 | | |
|---|---|---|---|
| Met 101-102-103—Introduction to Science of Materials | 3 | 3 | 3 |
| Met 101A-102A-103A—Science of Materials Laboratory | 1 | 1 | 1 |
| PCh 101-102-103—Physical Chemistry | 4 | 4 | 4 |
| MM 40, 28, 142—Deformable-Body Mechanics I; Rigid-Body Mechanics II; Experimental Mechanics I | 3 | 3 | 2 |
| Technical electives | 3 | 3 | 4 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| Total credits | 17 | 17 | 17 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Met 153-154-155—Physical Metallurgy | 3 | 3 | 3 |
| Met 153A-154A-155A—Laboratory in Physical Metallurgy | 1 | 1 | 1 |
| Met 173, 174, 175—Crystalline Properties in Metals; Modern Theory of Metals and Alloys; Imperfections in Metals | 3 | 3 | 3 |
| Met 180-181-182—Thermodynamics and Kinetics of the Solid State | 3 | 3 | 3 |
| EE 41-43, 44—Principles of Electrical Networks and Fields; Electrical Engineering Survey—Electronics (see below) | 3 | 3 | 3 |
| PCh 109—Physical Chemistry | 3 | ..... | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | ..... | 3 | 3 |
| Total credits | 16 | 16 | 16 |

Students may register for Phys 144 and 146 instead of EE 41-43, 44 with permission.

**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 167, 168, 169—Control of Properties; Principles of Fabrication; Analysis of Metallurgical Problems | 3 | 3 | 3 |
| Met 57—Physical Metallurgy of Industrial Alloys | ..... | 3 | ..... |
| Met 161—Corrosion of Metals | ..... | ..... | 3 |
| MM 142—Experimental Mechanics I | 2 | ..... | ..... |
| Engl 85—Technical Writing for Engineers | 3 | ..... | ..... |
| Technical electives | 6 | 3 | 3 |
| Nontechnical Electives (see below) | ..... | 3 | 3 |
| Electives | 3 | 3 | 3 |
| Total credits | 17 | 15 | 15 |

It is recommended that students register for Spch 50 during one of the quarters.

**Recommended Technical Electives**—ChEn 101, 102, 161-162-163; ITM 147, 148, 149; MetE 106, 107, 108, 134, 135, 136; Phys 51, 108-110-112; OrCh 61-62; PCh 110, 111, 112.

## Mineral Engineering

A 5-year curriculum is offered that leads to the degree of bachelor of mineral engineering, B.Min.E. A total of 248 credits, exclusive of summer field work, is required for graduation. If a student has the aptitudes and is interested in research, he may obtain a bachelor of science degree (without designation) in 4 years and proceed on to graduate work.

Mineral engineering is concerned with the development, production, and management of mines and oil fields. The mineral (mining or petroleum) engineer generally begins his professional life working on the design of production systems and plants and their economic analysis. Later, if so inclined, he advances to supervision and management. In these capacities he must work closely with geologists and with civil, mechanical, metallurgical, and chemical engineers. The mineral engineer should be familiar with exploration methods used in the search for new minerals or petroleum deposits. He requires knowledge of rock mechanics which is concerned with the physical characteristics and behavior of rocks. Mineral economics is essential as it deals with supply and demand, examination and valuation of mineral properties, and problems of financing, depletion, and conservation.

Students interested in the mining branch of mineral engineering must know the principles of ore deposits and of mineral beneficiation. Those interested in the petroleum branch must be familiar with the geology and nature of the fluids in an oil reservoir, and understand the characteristics of the flow of fluids through porous and permeable rocks. The mineral engineer must also understand water supply, the flow of water through aquifers, and the behavior of water wells.

The education of a mineral engineer, to prepare him for the varied and complex demands of his profession, must be broad and include courses not only in the basic

and allied engineering sciences but also in geology and economics as well. An important side product of this basic and broad education is a versatility of talents. With his sound engineering science background a student is not confined to a narrow specialty but has the flexibility to cross over successfully into other fields of technology, as many of the school's graduates have done.

The mineral engineer may travel extensively, in this country and abroad, and the more remote the location the more diversified the work. One liking the outdoors will find satisfaction in mining and petroleum work.

**Four-Year Degree**—A student may be granted the degree bachelor of science (B.S.) at the end of 4 years, then start graduate study in the fifth year if he satisfies the requirements spelled out in the general section on Requirements for Graduation. A student contemplating a 4-year degree should consult his faculty adviser early in the third year to plan a schedule of study that will meet course requirements. A foreign language should be elected, selected from the humanities group of the nontechnical electives.

**Faculty Adviser**—An undergraduate student upon entering the School of Mineral and Metallurgical Engineering is assigned a member of the faculty as his adviser. The adviser will aid the student in the selection of courses, particularly electives, and will serve as consultant during his scholastic career. The adviser's approval of the study plan must be obtained each quarter before registration is permitted.

**Electives**—A student should consider the areas of his principal interests and discuss with his adviser a selection of the technical electives best suited to serve his needs and promote his interests. Those who intend to take graduate work in preparation for a career in research or teaching are encouraged to elect courses in mathematics, chemistry, mechanics, and fluid dynamics. Students interested in engineering management should elect courses in industrial engineering, economics, and business. A program of related courses is preferable where electives are permitted.

**Work-Study Program**—Co-operative work-study programs in mineral engineering are available to qualified students. See detailed section on page 59.

**Undergraduate Job Opportunities**—The research programs in the department provide job opportunities for good engineering and research experience, developing scientific interest and motivation.

## 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 mineral engineering take the following courses:

| | Credits—f, w, s | | |
|---|---|---|---|
| OrCh 16—Carbon Compounds<br>(or) GeCh 6—Principles of Solution Chemistry | ..... | ..... | 4 |
| Phys 14A, 50A—Physics Laboratory | 1 | 1 | ..... |
| MinE 1—Mineral Engineering Laboratory | ..... | ..... | 1 |

*Note*—The department recommends that students in mineral engineering take EG 26, Graphical Computation, in the second year if posible, rather than in the third year where it is now scheduled.

**UPPER DIVISION**

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| MinE 111-112-113—Principles of Mineral Engineering I-II-III | 3 | 3 | 3 |
| MinE 13—Mine Surveying | ..... | ..... | 4 |
| Geo 11, 22, 62—Introductory Physical Geology; Historical Geology; Mineralogy and Lithology | 5 | 5 | 5 |
| EG 26—Graphical Computation | ..... | 2 | ..... |
| CE 18-20—Surveying | 3 | ..... | 3 |
| MM 40, 28, 142—Deformable-Body Mechanics I; Rigid-Body Mechanics II; Experimental Mechanics I) | 3 | 3 | 2 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | 3 | 3 | ..... |
| Total credits | 17 | 16 | 17 |

**Summer Field Trip**

Summer Field Work (see adviser) (2 weeks) ..... 3 credits

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| MinE 121—Mine Plant Engineering I | ..... | ..... | 3 |
| MinE 131-132—Rock Mechanics I-II | 3 | 3 | ..... |
| MinE 141, 142—Mineral Economics I-II | 3 | 3 | ..... |
| MetE 110, 111, 112—Mineral Dressing (see statement below) | 4 | 4 | 4 |
| Geo 120—Structural Geology | 4 | ..... | ..... |
| ME 99—Introduction to Engineering Analysis | ..... | 3 | ..... |
| IE 100—Introduction to Industrial Engineering Analysis | ..... | ..... | 3 |
| Engl 85—Technical Writing for Engineers | 3 | ..... | ..... |
| Technical electives | ..... | ..... | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | ..... | 4 | 4 |
| Total credits | 17 | 17 | 17 |

Students interested in petroleum courses, see Group 3 note in the following technical electives list.

**Summer Field Trip**

Engineering Field Study (see adviser) (2 weeks) ..... 3 credits

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| MinE 122—Mine Plant Engineering II (see statement below) | 3 | ..... | ..... |
| MinE 144-145—Mine Systems Analysis | ..... | 2 | 4 |
| Geo 155-156—Mineral Deposits (see statement below) | ..... | 3 | 3 |
| Electives | 3 | 3 | 3 |
| Technical electives | 6 | 6 | 4 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) or Additional Elective List (see Index for Additional Electives) | 6 | 3 | 3 |
| Total credits | 18 | 17 | 17 |

Students interested in petroleum courses, see Group 3 note in the following technical electives list.

*Technical Credits Note*—Of the total 19 technical electives credits, 9-12 credits must be taken in Group 1 and 9-12 credits must be taken in Group 2 in the technical electives list that follows.

If the 9 elective credits in the fifth year are not used for ROTC, all or part may be applied to Groups 1 and 2 of the technical electives list.

Students desiring to pursue industrial engineering as a supplementary field of interest should consider IE 153, 170 and 173 as part of the core program to supplement ME 99 and IE 100. Econ 1T-2T is recommended in Group S.

**Technical Electives**—Technical electives must be selected from the following groups.

Group 1

MinE 70—Geological Engineering I
MinE 123—Mine Air Conditioning
MinE 124-125—Mill-Plant Engineering I-II
MinE 126—Operations Analysis in Mineral Engineering
MinE 133—Rock Mechanics III
MinE 155—Materials Handling and Bulk Flow
MinE 160—Mining and Processing Industrial Minerals
MinE 171, 171A—Fluid Flow Through Porous Media I; Laboratory
MinE 172—Fluid Flow Through Porous Media II
MinE 173—Natural Gas Engineering

Group 2

CE 37—Elementary Structural Engineering
CE 53—Soils Mechanics
EE 41, 41A, 42—Principles of Electrical Networks and Fields; Laboratory; Electrical Engineering Survey: Machines
Hydr 101, 104—Fluid Mechanics; Laboratory
ME 30-31—Thermodynamics
PCh 107-108—Physical Chemistry
IE 153—Methods Engineering and Work Measurement
IE 165—Industrial Plants
IE 170—Production Planning and Control
IE 173—Engineering Economic Analysis
Geo 172—Introduction to Exploration Geophysics
ITM 147—Calculus V: Vector Analysis
ITM 148—Differential Equations
ITM 149—Determinants and Matrices

Group 3

(suggested substitutions for petroleum oriented students):
Geo 110—Stratigraphy I
ME 30-31—Thermodynamics
(or) PCh 107-108—Elementary Physical Chemistry
MinE 171, 171A—Fluid Flow Through Porous Media I; Laboratory
MinE 172—Fluid Flow Through Porous Media II
(for)
MetE 110, 111, 112—Mineral Dressing
Geo 155, 156—Mineral Deposits
MinE 122—Mine Plant Engineering

**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 mineral engineering curriculum and leads to the degree of bachelor of mineral 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 years 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 mineral 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 mineral engineering should contact the head of the School of Mineral and Metallurgical Engineering (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 Mineral and Metallurgical Engineering.

## 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 Liberal 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 Liberal 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 adition 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 recomended first year of college work (see following section).

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

**Six-year curriculum**—Completion of the B.A. degree with a major in architecture in the College of Liberal 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 June 1 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 253 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 | | |
|---|---|---|---|
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Phys 11, 12, 12A, 10, 10A—General Physics; Physics Laboratory | 5 | 5 | 5 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| Total credits | 18-17 | 18-17 | 18-17 |

The first year of prearchitectural work also may be taken in the College of Liberal Arts. This work should include Freshman English, Math 15 (College Algebra), Math 42, 43 (Analytic Geometry and Calculus I, II), and Phys 1-2-3, 1A-2A-3A and should total a minimum of 45 credits. If high school trigonometry is not offered, Math T (Trigonometry) (3 credits) must be taken prior to Math 15. In choosing electives, preference should be given to history, economics, political science, sociology, and foreign language.

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

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 51—Ancient Architecture | 3 | ..... | ..... |
| Arch 52—Byzantine and Medieval Architecture | ..... | 3 | ..... |
| Arch 53—Renaissance and Baroque Architecture | ..... | ..... | 3 |
| Arch 81-82-83—Architectural Design | 6 | 6 | 6 |
| Art 23A-24A-25A—Drawing and Painting I | 2 | 2 | 2 |
| MM 92, 93—Statics for Architects; Solid Mechanics for Architects | ..... | 4 | 4 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 5 | 3 | 3 |
| Total credits | 16 | 18 | 18 |

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 54—European Architecture: 1750-1900 | 3 | ..... | ..... |
| Arch 55—American Architecture: 1620-1900 | ..... | 3 | ..... |
| Arch 56—Twentieth-Century Architecture | ..... | ..... | 3 |
| Arch 71-72-73—Building Technology | 4 | 4 | 4 |
| Arch 91-92-93—Architectural Design | 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 |
| Total credits | 18 | 18 | 18 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 74-75-76—Building Technology | 4 | 4 | 4 |
| Arch 111-112-113—Architectural Design | 7 | 7 | 7 |
| Arch 115, 116—Skeleton Frame Structures; Surface Resistant Structures | 3 | 3 | ..... |
| Arch 133—Planning | ..... | ..... | 3 |
| Electives | 3 | 3 | 3 |
| Total credits | 17 | 17 | 17 |

**Fifth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 121-122—Architectural Design | 9 | 9 | ..... |
| Arch 123—Thesis | ..... | ..... | 12 |
| Arch 131, 132—Planning | 3 | 3 | ..... |
| Arch 126—Professional Relations | ..... | ..... | 3 |
| Electives | 3 | 3 | ..... |
| Total credits | 15 | 15 | 15 |

## FOUR-YEAR CURRICULUM

### First and Second Years

The first-year and second-year work is taken in the Lower Division of the College of Liberal 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 Liberal Arts as a major in architecture. The major sequence of courses is as follows:

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 51-52-53—Ancient, Byzantine and Medieval, Renaissance, and Baroque Architecture | 3 | 3 | 3 |
| Arch 81-82-83—Architectural Design | 6 | 6 | 6 |
| Arch 91-92-93—Architectural Design | 6 | 6 | 6 |

See the *Bulletin of the College of Liberal Arts* for complete Upper Division requirements.

## SIX-YEAR CURRICULUM

### First and Second Years

The first-year and second-year work is taken in the Lower Division of the College of Liberal Arts as outlined in its bulletin. The following requirements must be included for admission to the major in architecture in the Upper Division and completion of the professional work in the last 2 years:

| | | Credits—f, w, s | |
|---|---|---|---|
| Math 15—College Algebra | 5 | ..... | ..... |
| Math T—Trigonometry | ..... | 3 | ..... |
| Math 42—Analytic Geometry and Calculus I | ..... | ..... | 5 |
| Phys 1-2-3—Introduction to Physical Science | 3 | 3 | 3 |
| Phys 1A-2A-3A—Introduction to Physical Science Laboratory | 1 | 1 | 1 |
| Art 23A-24A-25A—Drawing and Painting I | 2 | 2 | 2 |
| Approved electives to make a minimum total of 90 credits | | | |

Prerequisites: High school higher algebra and solid geometry or college equivalents.

### Third and Fourth Years

During the third and fourth years the student is registered in the Upper Division of the College of Liberal Arts as a major in architecture. The following courses should be included:

| | | Credits—f, w, s | |
|---|---|---|---|
| Arch 51, 52, 53—Ancient, Byzantine and Medieval, Renaissance and Baroque Architecture | 3 | 3 | 3 |
| Arch 81-82-83—Architectural Design | 6 | 6 | 6 |
| Arch 91-92-93—Architectural Design | 6 | 6 | 6 |
| Art 60A-61A-62A—Drawing and Painting II | 2 | 2 | 2 |
| Math 43—Analytic Geometry and Calculus II | 5 | ..... | ..... |
| MM 92, 93—Statics for Architects; Solid Mechanics for Architects | ..... | 4 | 4 |
| Approved electives to make minimum total of 180 credits acceptable for B.A. degree | | | |

*Note*—CE 38, 39, 41 (Structural Design) or Arch 71-72-73 (Building Technology) may be taken but will not carry credit toward the B.A. degree.

See the *Bulletin of the College of Liberal Arts* for complete Upper Division requirements.

### Fifth and Sixth Years

During the fifth and sixth years the student is registered in the Institute of Technology as a candidate for the B.Arch. degree. To register as such, the student must have approval by the School of Architecture of a similar application as that submitted for entrance to Arch 81. The following courses should be included:

| | | Credits—f, w, s | |
|---|---|---|---|
| Arch 54, 55, 56—European, American, Twentieth-Century Architecture | 3 | 3 | 3 |
| Arch 71-72-73—Building Technology | 4 | 4 | 4 |
| Arch 74-75-76—Building Technology | 4 | 4 | 4 |
| Arch 111-112-113—Architectural Design | 7 | 7 | 7 |
| Arch 115, 116—Skeleton Frame Structures; Surface Resistant Structures | 3 | 3 | ..... |
| Arch 121-122—Architectural Design | 9 | 9 | ..... |
| Arch 123—Thesis | ..... | ..... | 12 |

| | Credits—f, w, s | | |
|---|---|---|---|
| Arch 126—Professional Relations | | | 3 |
| Arch 131, 132, 133—Planning | 3 | 3 | 3 |
| CE 38, 39, 41—Structural Design | 3 | 3 | 3 |
| Approved electives to make a minimum total of 291 credits for the 2 degrees | | | |

## SCHOOL OF CHEMISTRY

Two undergraduate curriculums are offered through the School of Chemistry: a 4-year program in chemistry and a 5-year program in chemical engineering. Each program is discussed separately below. A 4-year program is also offered to those chemical engineering 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 become 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 | | |
|---|---|---|---|
| GeCh 24-25-26—General Principles of Chemistry | 5 | 5 | 5 |
| ITM 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Engl A-B-C—Freshman Literature and Compositon | 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 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 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.

**Group Requirements and Electives**—A total of at least 54 credits must be taken in courses classified as Nontechnical Group Requirements and as technical and nontechnical electives. These are to be distributed as follows:

1. A minimum of 6 credits devoted to 1 subject in each of the 3 divisions of the Nontechnical Group Requirements which are listed under electives and are identified as Group H (humanities), Group N (environmental sciences), and Group S (social sciences). This adds up to a minimum of 18 credits.

2. A minimum of 16 credits from the technical and nontechnical elective courses listed here:

| | | |
|---|---|---|
| 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 |

3. A minimum of 20 credits in other electives chosen from courses not listed in paragraph 2 above, a major portion of these electives to be devoted to a single cultural area. In certain instances where specialization in an area such as microbiology, biochemistry, or geology is desired, the student may obtain permission by petition to use a smaller minimum of these other elective credits to achieve his goal.

**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 9.

**First Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| GeCh 24-25-26—General Principles of Chemistry | 5 | 5 | 5 |
| ITM 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: 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 |
| Electives | 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 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 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 Development | ..... | 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—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 graduate school 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 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 applications of chemistry, physics, and mathematics, as well as economics. Devoted to a rapidly changing industry, it requires knowledge of applied mathematics; material and energy balances; properties and physics of gases, liquids, and solids; fluid mechanics; heat and mass transfer; thermodynamics; reaction kinetics; process design, control, and optimization. Because of an emphasis on basic and engineering sciences, a chemical engineer is most nearly the universal engineer. He is particularly well suited to engage in a very wide variety of new and old industries and activities, in research on new products and ideas, in development of new processes, in manufacturing, or in marketing. Chemical engineering deals in particular with the unit operations such as materials handling, mixing, fluid flow and metering, heat exchange, filtration, drying, evaporation, distillation, absorption, extraction, crystallization, ion exchange, and processing in chemical reactors. These operations are vital in making an industry based on a chemical or physical transformation a commercial success. A chemist makes qualitative use of these operations in the laboratory; but to apply them to a larger-scale industrial process, the chemical engineer must have a complete and quantitative understanding of the engineering as well as the scientific principles on which they are based. The chemical engineer is primarily a producer, and it is his special 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, petroleum products; in the manufacture of gases—hydrogen, acetylene, helium; in the electrochemical industries such as the manufacture of graphite, calcium carbide, abrasives, wet and dry batteries, electroplating; in the metallurgical industries; in the food processing industries; and in the fermentation industry for production of chemicals such as antibiotics and feed supplements. Many other products such as fuel gas, gasoline, oil, nuclear materials, paper, glass, and cement concern the chemical engineer.

In such industries the chemical engineer does basic and applied research, development work, design and modifications of processes and equipment, and plant operation. Some enter sales engineering, marketing, and administration.

The chemical engineer may also enter into the field of nuclear engineering which encompasses processing, separation, development, and testing of materials for nuclear reactors; design and operation of nuclear reactors for research, isotope production, breeding, heat and power generation; and utilization as well as disposal of radionuclides and fission products. He may also enter the field of biochemical engineering which involves 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 | | |
|---|---|---|---|
| GeCh 24-25-26—General Principles of Chemistry | 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Electives—Group N or S (see Index for Nontechnical Group Requirements) | 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 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| Phys 7-8-9—General Physics | 5 | 5 | 5 |
| Electives—Group N or S (see Index for Nontechnical Group Requirements) | 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 Environmental Sciences Electives (Group N).*

## 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 |

| | Credits—f, w, s | | |
|---|---|---|---|
| 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 H (see Index for Nontechnical Group Requirements) | 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 41-43, 44—Principles of Electrical Networks and Fields; Survey—Electronics | 3 | 3 | 4 |
| EE 41A-43A—Electrical Engineering Laboratory | 1 | 1 | ..... |
| Engl 85—Technical Writing for Engineers | ..... | 3 | ..... |
| Met 60—Physical Metallurgy | 3 | ..... | ..... |
| Met 161—Corrosion of Metals | ..... | ..... | 2 |
| Electives | 3 | 5-2 | 3 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | ..... | ..... | 3 |
| Total credits | 16 | 18-15 | 15 |

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

# *SCHOOL OF EARTH SCIENCES*

## Department of Geology and Geophysics

The Department of Geology and Geophysics is the teaching department of the School of Earth Sciences. It offers a choice of 3 different 4-year programs in the undergraduate curriculum: Option A, general geology; Option B, mineralogy and petrology; and Option C, geophysics. A minimum of 200 credits is required for graduation with the degree of bachelor of science in geology, B.S.Geol., for Options

A and B, and in geophysics, B.S.Geophys., for Option C. The classrooms and the laboratories of the department are equipped with modern teaching aids and research equipment.

The earth sciences, as integrating sciences, are strongly dependent on a sound foundation in the primary sciences—physics, chemistry, mathematics, and biology. Common to each of the alternative curriculums, therefore, is the aim to provide such a foundation in the first 2 years; exposure to other than introductory courses in geology and geophysics is reserved until later. The first year is identical for all three options, students not being required to select an option until the second year. During the second year the three options remain similar enough that a transfer from one to another is still feasible. The main divergence between options comes in the third year.

All curricular options are designed to accommodate two types of students: (a) those preparing for graduate work, and (b) students for whom the B.S. is a terminal degree. The latter will be permitted to include additional geology and geophysics among their electives; the former will be encouraged to elect in other fields of science or nontechnical subjects, reserving advanced earth sciences until graduate school.

An advanced degree is generally necessary for employment at a fully professional level in research and development work or in teaching in the earth sciences. The bachelor of science degree is suitable preparation for employment on a subprofessional level. Geologists and geophysicists are employed by research institutions and government agencies of several types; by business, industrial, or engineering interests engaged in exploration for or exploitation of mineral resources, or needing evaluation of the natural distributions or physical properties of materials in connection with their business; or as teachers.

**First Year**

(For all 3 options)

| | Credits—f, w, s | | |
|---|---|---|---|
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | ..... | 1 | 1 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 0-3 | 0-3 | 0-3 |
| Total credits | 15-18 | 15-18 | 15-18 |

**Summer Field Course**

Nine credits are to be taken before senior year according to a departmentally approved plan.

All 3 options require a minimum of 9 credits of field work which can be satisfied by any approved combination of courses offered in the department and at accredited field camps of other universities. Under unusual circumstances, field credits can be satisfied by other means.

**Option A—GENERAL GEOLOGY**

In the general geology option the historical and dimensional aspects of geology are emphasized, including the record and evolution of animal and plant life, the succession and genesis of rocks in the earth's crust, rock deforming processes and events, and the origin of land forms. The background science requirement in this option is a balanced knowledge of chemistry, physics, mathematics, and biology.

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 11, 22, 62—Physical Geology; Historical Geology; Mineralogy and Lithology | 5 | 5 | 5 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory (ITM 27 is strongly recommended, but not required in Option A) | 5 | 5 | 5 |
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| Biol 1—General Biology | ..... | ..... | 5 |
| Electives—Groups H or S (see Index for Nontechnical Group Requirements) | 3 | 3 | ..... |
| Total credits | 17 | 17 | 15 |

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 120, 110, 115—Structural Geology; Stratigraphy I; Geomorphology | 4 | 4 | 4 |
| Biol 2—General Biology | 5 | ..... | ..... |
| Zool 81—Invertebrate Zoology (or Upper Division botany course) (see statement below) | ..... | 3 | ..... |
| OrCh 41—Elementary Organic Chemistry | ..... | ..... | 4 |
| Phys 14—General Physics | 4 | ..... | ..... |
| Phys 14A—Physics Laboratory | 1 | ..... | ..... |
| Electives | ..... | 6 | 7 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 3 | 3 | ..... |
| Total credits | 17 | 16 | 15 |

Any sequence of courses that works in the basic requirements and is approved by the adviser and the department chairman is acceptable.

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 140, 141—Mineral Systems I, II | 4 | 4 | ..... |
| PCh 107-108—Elementary Physical Chemistry | 3 | 3 | ..... |
| OrCh 42—Elementary Organic Chemistry | 4 | ..... | ..... |
| Ger 50-51-52—Reading German | 3 | 3 | 3 |
| Zool 82—Organic Evolution (or Upper Division botany course) (see statement following 3rd yr) | 3 | ..... | ..... |
| Geology elective | ..... | ..... | 3-4 |
| Electives | ..... | 6 | 9-8 |
| Total credits | 17 | 16 | 15 |

**Option B—MINERALOGY AND PETROLOGY**

In the option in mineralogy and petrology the chemical and physicochemical aspects of geology are emphasized, including the structure and composition of minerals, the study of rocks as chemical systems, the distribution and migration of elements, and the deposition of minerals and rocks from solutions and melts. The background science requirement in this option emphasizes chemistry and physical chemistry, with a broad sampling of the other primary sciences.

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 11, 22, 62—Physical Geology; Historical Geology; Mineralogy and Lithology | 5 | 5 | 5 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| GeCh 24-25-26—General Principles of Chemistry | 5 | 5 | 5 |
| Electives | 1 | 1 | 1 |
| Total credits | 16 | 16 | 16 |

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 120, 110, 115—Structural Geology; Stratigraphy I; Geomorphology | 4 | 4 | 4 |
| Biol 1-2—General Biology | ..... | 5 | 5 |

| | Credits—f, w, s | | |
|---|---|---|---|
| Phys 14, 50, 51—General Physics; Intermediate General Physics | 4 | 4 | 4 |
| Phys 14A—Physics Laboratory | 1 | ..... | ..... |
| Electives | 3 | ..... | 3 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 3 | 3 | ..... |
| Total credits | 15 | 16 | 16 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 140, 141, 142—Mineral Systems I, II, III | 4 | 4 | 4 |
| PCh 101-102-103—Physical Chemistry | 4 | 4 | 4 |
| Ger 50-51-52—Reading German | 3 | 3 | 3 |
| Electives (Geo 170, 171 recommended) | 2 | 2 | 5 |
| Electives—Group H or S (see Index for Nontechnical Group Requirements) | 3 | 3 | ..... |
| Total credits | 16 | 16 | 16 |

**Option C—GEOPHYSICS**

Geophysics, which we here restrict to solid-earth geophysics, is the study of the gross structure and physical properties of the earth. Seismology, the most widely recognized branch of solid-earth geophysics, leads to information concerning the major structural features and internal arrangement of the earth. The study of the gravity, magnetic, and electrical properties of the earth are also important and expanding branches of geophysics. Geophysics is also considered in some definitions to include the physics of the atmosphere, of extraterrestrial bodies, and of interplanetary and interstellar space. Preparation along these lines can be arranged under a combination of disciplines. This option requires intensive training in physics.

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 11, 22, 62—Physical Geology; Historical Geology; Mineralogy and Lithology | 5 | 5 | 5 |
| Phys 14, 50, 51—General Physics; Intermediate General Physics | 4 | 4 | 4 |
| Phys 14A—Physics Laboratory | 1 | ..... | ..... |
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| Elective | ..... | ..... | 2 |
| Total credits | 19 | 18 | 16 |

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 120—Structural Geology | 4 | ..... | ..... |
| Geo 170, 171, 172—Introduction to Earth Physics; Introduction to Earthquake Seismology; Introduction to Exploration Geophysics | 3 | 3 | 3 |
| ITM 147, 148, 149—Calculus V: Vector Analysis; Differential Equations; Determinants and Matrices (or) ITM 147, 151, 153—Calculus V, VI, VII: Advanced Calculus | 3 | 3 | 3 |
| Phys 100A-101A-102A—Introduction to Analytic Mechanics (see statement below) | 3 | 3 | 3 |
| Electives | 3 | 4 | 4 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | ..... | 3 | 3 |
| Total credits | 16 | 16 | 16 |

By departmental permission to students not planning graduate work, the Phys 100A-105A sequence can be replaced by Phys 144-146-148 in the 3rd year and by Phys 100-102-104 in the 4th year.

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Geo 140—Mineral Systems I | 4 | ..... | ..... |
| Phys 103A-104A-105A—Introduction to Electric and Magnetic Fields (see statement following 3rd year) | 3 | 3 | 3 |
| Ger 50-51-52—Reading German | 3 | 3 | 3 |
| Geology elective (see statement below) | ..... | 4 | 4 |
| Electives (Phys 144, 146, 148 recommended) | 3 | 3 | 6 |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | 3 | ..... |
| Total credits | 16 | 16 | 16 |

Geology electives should be chosen from Geo 110, 115, 116, 121, 141, 142, or 155.

# SCHOOL OF MATHEMATICS

## 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I and II: Analytic Geometry and Calculus | 5 | 5 | 5 |
| EG 25—Engineering Graphics (see statement below) | ..... | ..... | 4 |
| Engl 1B-2B-3B or 1A-2A-3A or A-B-C—Freshman English | 4 | 4 | 4 |
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | ..... | 1 | 1 |
| Electives | 0-3 | 0-3 | ..... |
| Total credits | 17 | 17 | 18 |

Students may substitute an elective for EG 25 by petition. However, students who are not certain whether to major in mathematics or engineering should take EG 25.

**Second Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory (see statement below) | 5 | 5 | 5 |

| | Credits—f, w, s | | |
|---|---|---|---|
| ITM 14—Laboratory | ..... | ..... | 1 |
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| MM 27—Rigid-Body Mechanics I (or) OrCh 16—Carbon Compounds (or) Elective (see statement below) | ..... | ..... | 3 |
| Phys 14, 50, 51—General Physics; Intermediate General Physics | 4 | 4 | 4 |
| Phys 14A, 50A—Physics Laboratory | 1 | 1 | ..... |
| Electives—Group H, N, or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| Total credits | 17 | 17 | 16 |

Students who took ITM 11 when it still was a credit course follow the mathematics sequence ITM 11, 12, 13A, 24A, 25A, 26A.

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 147, 151, 153—Calculus V, VI, VII: Vector Analysis; 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—Group H, N, or S (see Index for Nontechnical Group Requirements) | 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—Group H, N, or S (see Index for Nontechnical Group Requirements) | 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.

A minimum of 200 credits is 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 164-165-166—Theory and Programming of Modern Digital Computers
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 carries 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 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| ITM 14—Laboratory | ..... | ..... | 1 |
| GeCh 14-15—General Principles of 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—General Physics; 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 147, 151, 153—Calculus V, VI, VII: Vector Analysis; 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 | 0-1 | 0-1 | 3-4 |
| Electives—Group N or S (see Index for Nontechnical Group Requirements) | 3 | 3 | 3 |
| 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 Development | ..... | ..... | 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 65—Introduction to Programming Modern Digital Computers<br>ITM 184—Elementary Numerical Analysis in Engineering<br>ITM 193A—Axiomatic Geometry<br>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 |
| Electives | 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.

# SCHOOL OF PHYSICS AND ASTRONOMY

## Astronomy

Major undergraduate study in astronomy is offered in the Institute of Technology and in the College of Liberal Arts.

In the Institute of Technology a 4-year curriculum leads to the degree bachelor of astronomy, B.Ast. For details of this curriculum, see Professor Willem J. Luyten.

## Physics

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

In the Institute of Technology a 4-year curriculum is offered which leads to the degree 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 bachelor of physics and master of education, both conferred at the end of 5 years. For details of this curriculum, see page 78 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 GPA of 2.00 in Upper Division work must be maintained for continuation.

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

1. Nine credits chosen from Phys 148, 124-125, 108-110-112, 126, 131, 133A, 134, 136, 165, 166, 167, 171-172-173, 181-183-185.
2. From 0 to 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. EG 25, if taken during the first year, is an acceptable elective in this category.
3. Not less than 33 credits in the areas of humanities (Group H), environmental sciences (Group N), and social sciences (Group S), or from the Additional Electives list (see Index for Additional Electives and for Nontechnical Group Requirements). For physics students, courses offered in the Department of Astronomy and the Department of Geology and Geophysics are not included in the Additional Electives list. A 6-credit sequence in each of Groups H and S plus 6 credits in a sequence of Group N or in courses listed in Groups H and S must be selected.

### LOWER DIVISION

#### First Year

| | | Credits—f, w, s | |
|---|---|---|---|
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | | 1 | 1 |
| (Phys 7-8-9, requiring more advanced mathematics prerequisites, substitutes directly for Phys 11, 12, 12A, 13, 13A, 14, 14A and should be elected by adequately prepared students) | | | |

| | Credits—f, w, s | | |
|---|---|---|---|
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: 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—General Physics; Intermediate General Physics | 4 | 4 | 4 |
| Phys 14A, 50A, 51A—Physics Laboratory | 1 | 1 | 1 |
| GeCh 14-15—General Principles of Chemistry | 4 | 4 | ..... |
| OrCh 41—Elementary Organic Chemistry | ..... | ..... | 4 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 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 147, 151, 153—Calculus V, VI, VII: Vector Analysis; Advanced Calculus | 3 | 3 | 3 |
| Ger 50-51-52—Reading German: A Beginning Course for Juniors and Seniors (with 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 | 9 | 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 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*, 1962-1964.

In addition to the following prescribed courses, 42 credits of electives must be selected. The electives selected must include:

1. Six credits chosen from Phys 148, 124-125, 108-110-112, 126, 131, 134, 136, 165, 166, 167, 171-172-173, 181-183-185.

2. From 0 to 9 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. EG 25, if taken during the first year, is an acceptable elective in this category.

3. Not less than 27 credits chosen in the areas of humanities (Group H), environmental sciences (Group N), and social sciences (Group S), or from the Additional Electives list (see Index for Additional Electives and for Nontechnical Group Requirements). Twelve credits, including a 9-credit sequence (other than psychology), must be selected from Group S; 9 credits, including a 6-credit sequence, must be selected from Group H. Selection of a language (German or Russian) is strongly recommended to satisfy the Group H requirement.

**First Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Phys 11, 12, 13—General Physics | 5 | 4 | 4 |
| Phys 12A, 13A—Physics Laboratory | ..... | 1 | 1 |
| (Phys 7-8-9, requiring more advanced mathematics prerequisites, substitutes directly for Phys 11, 12, 12A, 13, 13A, 14, 14A and should be elected by adequately prepared students) | | | |
| 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 12, 13A, 24A—College Algebra and Trigonometry; Calculus I, II: 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—General Physics; Intermediate General Physics | 4 | 4 | 4 |
| Phys 14A, 50A, 51A—Physics Laboratory | 1 | 1 | 1 |
| GeCh 14-15—General Chemistry | 4 | 4 | ..... |
| OrCh 41—Elementary Organic Chemistry | ..... | ..... | 4 |
| ITM 25B, 26B, 27—Calculus III, IV: Analytic Geometry and Calculus; Series and Calculus of Functions of Several Variables; Differential Equations and Elements of Matrix Theory | 5 | 5 | 5 |
| Psy 1-2—General Psychology | 3 | 3 | ..... |
| PH 50—Personal and Community Health | ..... | ..... | 3 |
| Total credits | 17 | 17 | 17 |

**Third Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Phys 100A-101A-102A—Introduction to Analytic Mechanics | 3 | 3 | 3 |
| Phys 144, 146—Electrical Measurements; Physics of Vacuum Tubes and Associated Circuits | 4 | 4 | ..... |
| Phys 133, 133A—Physical Optics; Physical Optics Laboratory | ..... | ..... | 4 |
| ITM 147, 151, 153—Calculus V, VI, VII: Vector Analysis; Advanced Calculus | 3 | 3 | 3 |
| Electives | 6 | 6 | 6 |
| Total credits | 16 | 16 | 16 |

**Fourth Year**

| | Credits—f, w, s | | |
|---|---|---|---|
| Phys 103A-104A-105A—Introduction to Electric and Magnetic Fields | 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—Principles of Psychology of Human Learning | 3 | ..... | ..... |
| EdT 52—Student Teaching | 1 | 1 | 1 |
| EdT 68A, B, C—Teaching Secondary School Science | 3 | 1 | 1 |
| CD 132—Adolescent Development | ..... | ..... | 3 |
| EdT 67M—Teaching Secondary School Mathematics | ..... | ..... | 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 | | |
|---|---|---|---|
| Phys 123—Thermodynamics | 3 | ..... | ..... |
| Phys 120-121—Advanced Laboratory | 3 | 3 | ..... |
| EdCI 113—High School Curriculum (may be taken either fall or spring) | 3 | ..... | ..... |
| EdT 67—Student Teaching in Mathematics | ..... | 3 | ..... |
| EPsy 208—Methods in Educational Research | ..... | 3 | ..... |
| HEd 180—The School and Society | 3 | ..... | ..... |
| EdCI 199E—Internship | ..... | ..... | 12 |
| Electives | 6 | 9 | ..... |
| Total credits | 18 | 18 | 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)*

**5-6. Aerospace Survey and Laboratory.** Science, engineering, and aerospace technology. Course areas and technical electives in aero curriculum. Trajectories, orbits, flight mechanics, structures, and materials. Experimental and theoretical aerodynamics. Winged atmospheric, ballistic, and space vehicles. (1 cr per qtr)

**100. Aerodynamics I.** Kinematics of fluid field including continuity equation, vorticity, circulation, velocity potential, source, and doublet. Application of Gauss and Stokes's theorem to fluid flow. Flow about cylinder. (3 cr; prereq ITM 26A, MM 27; 3 rec hrs per wk)

**101. Aerodynamics II.** Irrotational incompressible flow in two dimensions. Method of complex variable, effect of branch line. Irrotational incompressible flow in three dimensions. Curvilinear co-ordinate systems, cylindrical and spherical. Dynamics, Euler's equation, Bernoulli's equation. Aerostatics. (3 cr; prereq 100; 3 rec hrs per wk)

**102. Aerodynamics III.** Viscous incompressible flow. Thin airfoil theory. Stress and strain rate. Navier-Stokes's equation. Boundary layer equation and Blasius solution. Von Karman momentum integral. Pohlhausen method. Turbulent boundary layer. (3 cr; prereq 101; 3 rec hrs per wk)

**103. Aerodynamics IV.** Basic concepts of thermodynamics. One-dimensional steady isentropic flow. Laval nozzle. Normal and oblique shock waves and reflections. Prandtl-Meyer flow. Thin airfoil theory. (3 cr; prereq 102; 3 rec hrs per wk)

**106. Aerodynamics of Lifting Surfaces.** Thin airfoil theory, finite wing, aspect ratio, planform and lift distribution, polar diagram of airplanes, dimensional analysis and dynamic similarity. (3 cr; prereq 103; 3 lect hrs per wk)

**107. Performance of Aircraft.** Analysis of speed, take off, landing, range, and endurance characteristics of propeller and jet propelled aircraft. Vtol and Stol vehicles. (3 cr; prereq 106; 3 lect hrs per wk; offered 1963-64 and alt yrs)

**108. Stability and Control of Aerospace Vehicles.** Longitudinal stability and control, power effects, lateral stability and maneuvering flight, introduction to dynamic stability, steady state aeroelasticity, tail and aileron efficiency, wing divergence and aileron reversal, longitudinal stability. Rigid and elastic vehicles. (3 cr; prereq 106; 3 lect hrs per wk; offered 1964-65 and alt yrs)

**109. Performance of Ballistic and Space Vehicles.** Equation of motion, control and thrust, burnout velocity of single and multistage missiles, ballistic trajectories with and without drag, simplified vertical, orbital, escape and re-entry trajectories. (3 cr; prereq 103; 3 lect hrs per wk; offered 1964-65 and alt yrs)

**110. Compressible Viscous Flow.** Navier-Stokes's equation of compressible viscous fluid. Energy equation. Boundary layer equations. Karman-Tsien solution. Momentum and energy relations. Turbulent boundary layer. Shock wave and boundary layer interaction. (3 cr; prereq 103; 3 lect hrs per wk; offered 1964-65 and alt yrs)

**115. Aerospace Structures I.** Aerospace vehicle load factors and structural design. Deformation analysis of multi-cell torsion box structures. Introduction to fuselage stress analysis; moment distribution, energy methods. (3 cr; prereq MM 41; 3 lect hrs per wk)

**116. Aerospace Structures II.** Pressurized vehicles. Application of matrix methods to deformation analysis of aerospace structures. Minimum weight design. (3 cr; prereq 115; 3 lect hrs per wk)

**130. Design Methods for Aerospace Systems.** Organization of engineering design efforts, establishment and application of criteria for judging designs. Parametric, feasibility, and systems studies. (3 cr; prereq Aero 5th yr or ♯; 3 lect hrs per wk)

**131. Aerospace Systems Design.** Preliminary design synthesis of a selected system. Planning and scheduling. (4 cr; prereq 130)

**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 ♯ prior to regis)

**145-146-147. Aeromechanics Laboratory.** Experiments in fluid and solid mechanics. Static and dynamic pressure, forces on wind tunnel models, shock wave patterns. Model analysis. Boundary layer measurements, lift and drag determination, flow visualization. Rheological and strength properties of materials and structures. Verification of equations of solid and fluid mechanics. Use of computers. (2 cr per qtr; prereq 103 or ¶103, MM 142, MM 193, ¶Engl 85A-B-C)

**148. Experimental Supersonics and Hypersonics.** Wind tunnel techniques and instrumentation. Flow and model studies. (3 cr; prereq 147; offered 1964-65 and alt yrs)

**150. Aeroelasticity I.** Aeroelastic oscillations of simple structures, wires, cylinders, suspension bridges. Wing divergence, aileron reversal, and tail efficiency. Flutter and buffeting. Control surface balancing and flutter prevention. (3 cr; prereq 103 and MM 193; offered 1963-64 and alt yrs)

**159. Aerodynamic Deceleration.** Aerodynamics of subsonic and supersonic retardation devices. Wake and interference effects. Trajectory calculations, re-entry problems, and recovery systems. (3 cr; prereq 103 or ♯; offered 1963-64 and alt yrs)

**180. Introduction to Astrodynamics.** Co-ordinate systems and dynamical equations of celestial mechanics; orbit determination for artificial satellites, perturbation theory; special topics. (3 cr; prereq MM 29; offered 1964-65 and alt yrs)

**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 103; offered 1963-64 and alt yrs)

**185. Rarefied Gas Dynamics.** Flow regimes, free molecular flow, slip flow and transition. (3 cr; prereq 103 or ♯; 3 lect hrs per wk)

**190. Introduction to Magnetohydrodynamics.** Fundamental equations and concepts of magnetohydrodynamics. Transport of magnetic field; magnetohydrodynamic channel flow. Alfven waves. (3 cr per qtr; prereq 103, ITM 147 or ♯; 3 lect hrs per wk; offered 1963-64 and alt yrs)

**193-194-195. Problems in Fluid Mechanics.** Investigation of analytical and experimental problems approved by faculty member. Undergraduate thesis. (0-3 cr per qtr; prereq ♯, faculty sponsor required before regis)

**For Graduate Students Only**

**201-202-203.† Compressible Fluid Dynamics**

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

**210-211-212.† Selected Topics in Fluid Mechanics**

**215-216-217. Theory of Turbulence**

**220-221. Astronautics and Re-entry**

**230-231-232. Transonic and Hypersonic Flow**

**250-251-252. Magnetofluiddynamics**

**297-298-299.† Seminar: Fluid Mechanics**

## *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, §Phys 100 or §Phys 100A; 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 101A; prereq 28; 3 lect hrs per wk)

**40. Deformable-Body Mechanics I.** Introductory treatment of stress and strain at a point. Stress-strain relation in two dimensions. Linear torsion. Bending stresses. (3 cr per qtr; prereq 27; 3 lect hrs per wk)

**41. Deformable-Body Mechanics II.** Deflection of determinate and indeterminate beams. Torsion of thin-walled shafts. Unsymmetrical bending and shear center. Shear flow. Combined stresses. Instability. (3 cr; prereq 40; 3 lect hrs per wk)

**92. Statics for Architects.** 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.** 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 I.** Strain gauges. Photoelasticity. Experimental stress analysis. Deformation of beams and columns. Torsion, tension, and shear tests. (2 cr; prereq 40; 1 lect and 2 lab hrs per wk)

**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 1½-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 1½-hr sessions per wk; offered 1964-65 and alt yrs)

**164-165-166.*‡ Problems in Mechanics and Materials.** Short duration individual research problems, literature studies, and reports. (0-3 cr per qtr; prereq *; faculty sponsor required before regis)

**180. Applied Elasticity I.** Stress and strain at a point in three dimensions. Equilibrium and compatibility equations. Generalized Hooke's Law. Formulation of the boundary value problem of elasticity. Strain energy and introduction to energy principles. (3 cr; prereq 40 or equiv; 3 lect hrs per wk)

**181. Applied Elasticity II.** Plane-stress and plane-strain problems of the narrow beam, thick pipe, rotating disc, and plate with circular hole. Introduction to torsion of various shaped bars. Energy principles and variational methods with application to the deformation analysis of trusses, arches, rings, and machine elements. (3 cr; prereq 180 or equiv; 3 lect hrs per wk)

**182. Applied Elasticity III.** Flexure of beams on elastic subgrades. Lagrange theory of thin plates. Stress concentrations and concentrated loads. Elastic instability of frames, narrow beams, and thin plates. (3 cr; prereq 180 or equiv; 3 lect hrs per wk)

**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; offered 1963-64 and alt yrs)

**184. Theory of Elasticity I.** Fundamental principles and equations of the theory of elasticity using cartesian tensors. Stress-strain relations for linear elastic crystals, anisotropic 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; 3 lect hrs per wk)

**187. Theory of Linear Viscoelasticity.** Linear viscoelastic behavior; linear viscoelastic constitutive laws; method of viscoelastic analysis; applications to simple quasi-static and dynamic viscoelastic problems. (3 cr; prereq 41, ITM 148 or 150; offered 1964-65 and alt yrs)

**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 Dynamics.** Fundamental theory; three-dimensional kinematics, Euler's angles, matrix representation of rigid-body rotations. Lagrange's equations. Holonomic and nonholonomic systems. Introduction to Hamiltonian mechanics. (3 cr; prereq 193 or 194 or ITM 162 or EE 150 or Phys 102 or equiv; 3 lect 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 or 184 and ME 133; 3 lect hrs per wk; offered 1963-64 and alt yrs)

**For Graduate Students Only**

**202. Gyroscopic Systems**

**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.*‡ Selected Topics on Mechanics and Materials**

**285. Continuum Mechanics**

**290. Theory of Plates and Shells**

**291. Advanced Theory of Shells**

**295-296. Theory of Elasticity II and III**

**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; 2 lect and 3 labs 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; 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

**145. Soils Engineering.** Mechanical and hydraulic properties of soils, moisture constants, pressure and bearing characteristics for structural and mechanical design. (3 cr; prereq Soil 126, MM 41; 2 lect and 3 lab 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 43; 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 24, 150; 2 lect and 3 lab hrs per wk) Strait

**171. Design of Agricultural Machinery.** Operating principles and problems. (3 cr; prereq 147, ME 24; 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 measure-

ment 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; 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.*

** No credit allowed in IT except upon completion of the program.

Air 31, 32, and 36 require no classroom work; only 1 hour per week attendance at AFROTC Leadership Laboratory is required. For further information, IT students should consult their advisers and the *Bulletin of the Army-Navy-Air Force ROTC.*

**31. Leadership Laboratory.** Introduction to AFROTC. Military customs and courtesies. Responsibilities of citizenship, past necessity for United States military power, and the United States in world affairs (No cr; 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; 1 hr per wk)

**33. Foundations of Aerospace Power.** An introductory examination of the factors of aerospace power, major ideological conflicts, and the organization of the armed forces as factors in the preservation of national security. (2 cr)

**34. The Air Force as a Profession and Fundamentals of Aerospace Weapon Systems I.** Development and traditions of the military profession, role and attributes of the professional officer in American democracy, and a survey of aerospace missiles and craft and their propulsion and guidance systems. (2 cr)

**35. Fundamentals of Aerospace Weapon Systems II.** (Continuation of 34) An introduction to chemical, biological, and nuclear warfare; electronic warfare; target intelligence; defensive, strategic, and tactical operations; problems, mechanics, and military implications of space operations; and a survey of contemporary military thought. (2 cr)

**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; 1 hr per wk)

**131. The Air Force Staff Officer I.** The function and utilization of the Air Force staff officer: the AF mission, the commander and his staff, military organization and channels, techniques of briefing, creative problem solving—including study of blocks to creative thinking. (3 cr; prereq △)

**132. The Air Force Staff Officer II; Military Justice.** The function and utilization of the Air Force staff officer: creative problem solving, practical logic, AF staff studies, the nature of military written communications, written and verbal performance exercises—including military briefings, conferences and staff meetings, co-ordination, decision making, and command. The final 15 class hours are devoted to a survey of military justice: history of Western military justice, military law as a function of command, pre-trial investigations, nonjudicial punishment, courts-martial, and appellate review. (3 cr; prereq △)

**133. Seminar: Leadership and Management.** The nature and requirement of military leadership; the application of knowledge of the behavioral sciences to problems in leadership and management, the biology of behavior, personality development and complex needs, intense motivation, American attitudes and values. Extensive reading in the area of the behavioral sciences is combined with practice of leadership in the Leadership Laboratory, and review of case studies and problems in human relations. Preparation for attendance at summer camp. (3 cr; prereq △)

**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, 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, high speed navigation, and civil air regulations. (3 cr; prereq △)

**135. Military Aspects of World Political Geography.** Geog 143, Political Geography, will be substituted for Air 135. A seminar of 1 hour per week will be given by the

Department of Air Science to supplement this course in order to meet over-all objectives. (3 cr; prereq △)

136. **International Relations and the Air Force Officer.** Major factors underlying international tensions, nations and nationalism, national goals, and 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. Introduction to insurgency and counter-insurgency. 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 △)

## 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)

51. **Ancient Architecture.** The development of architecture in ancient Egypt, Greece, and Rome. (3 cr; prereq soph; 3 lect hrs per wk)

52. **Byzantine and Medieval Architecture.** The development of architecture from the early Christian era to the end of the Gothic period. (3 cr; prereq 51; 3 lect hrs per wk)

53. **Renaissance and Baroque Architecture.** The development of architecture and city planning in Italy, France, and England from the 15th to the mid-18th century. (3 cr; prereq 52; 3 lect hrs per wk)

54. **European Architecture: 1750-1900.** Stylistic revivals in England, France, and Germany and experimentation leading to modern architecture. (3 cr; prereq 53 or ♯; 3 lect hrs per wk)

55. **American Architecture: 1620-1900.** Colonial and early Republican architecture, stylistic revivals, and effects of industrialization. (3 cr; prereq 53 or ♯; 3 lect hrs per wk)

56. **Twentieth-Century Architecture.** The development of modern architecture in Europe and the United States. (3 cr; prereq 53 or ♯; 3 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.** 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 College of Liberal Arts students and △; 18 lab hrs per wk; entrance fall qtr only)

91-92-93.† **Architectural Design.** 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 pr wk)

107. **Dwelling Unit Design.** Open to seniors and graduates in home economics. (2 cr) Vivrett

111-112-113.†°° **Architectural Design.** Advanced architectural problems involving city planning, detailed study of buildings, interiors, mechanical and electrical equipment. Individual effort and group collaboration. (21 cr [normally 7 cr per qtr]; prereq 93 and MM 93; 21 lab hrs per wk)

°° 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.

**115. Skeleton Frame Structures.** Contemporary structural systems composed with linear elements; investigation into the behavior and their relationship to form and space. (3 cr; prereq MM 92; 2 lect and 3 lab hrs per wk)

**116. Surface Resistant Structures.** Contemporary structural systems composed with planar elements; investigation into their behavior and their relationship to form and space. (3 cr; prereq 115; 2 lect and 3 lab hrs per wk)

**121-122.†** Architectural Design.** 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)

**131. Planning.** History and theory of planning. (3 cr; prereq 4th yr or #; 3 lect hrs per wk)

**132. Planning.** (Same as Pol 123, Soc 106) Conceptualization of the role of individual disciplines in the planning process: architecture, economics, engineering, geography, public administration, public health, and sociology. (3 cr, §104; prereq 131 or #; 3 lect hrs per wk)

**133. Planning.** Community facilities and housing. (3 cr, §106; prereq 4th yr)

**134. Planning.** Tutorial work in community facilities and housing. (3 cr; prereq 133 or 106)

**For Graduate Students Only**

**201-202-203.* Special Research in Architectural History**

**231-232-233.* Planning**

**251-252-253.* Architectural Design**

**254-255-256.* Theory of Architecture**

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

## Astronomy

See School of Physics and Astronomy

## Biology (Biol)

(College of Liberal Arts)

**1A-2A.† General Biology.** Introduction to living things and to the major biological concepts. (3 cr for 1A, 4 cr for 2A; not open to students who have taken Zool 1-2-3, 14-15, Bot 1-2-3, 4-5, or NSci 7-8-9)

** 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.

# Business Administration

## Accounting (Acct)

**55A-B. Elementary Accounting.** The equivalent of Acct 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 Arts College)

**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)

## Business Finance (BFin)

**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)

## Business Law (BLaw)

**58. Business Law: Contracts.** Law of contracts. Case method used in BLaw 58, 78, 88, 98. (3 cr, §158; prereq Econ 2 or equiv)

## Industrial Relations (IR)

**52. Systems of 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)

## Insurance (Ins)

**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)

## Management (Mgmt)

**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 business administration, or social studies majors in education with no previous business administration)

**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)

## Marketing (Mktg)

**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)

## Production (Prod)

**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)

## Quantitative Analysis (QA)

**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, §Psy 70; prereq Math 10 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)

## Transportation (Tran)

**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 2T or equiv)

# 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)

**122-123. Biochemical Engineering.** Application of biochemical and microbiological principles to industrial processes. (3 cr; prereq 103, MicB 53 or ‡) 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 171-172) Additional methods such as as the root-locus and Guillemin's method 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 GeCh 6 or 26) Swofford

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

**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 GeCh 26) 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) Meehan

**103. Quantitative Inorganic Microanalysis.** Representative methods of micro- and semi-micro-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) Bruckenstein and staff

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

**113. Physicochemical Methods of Analysis.** Laboratory. A more advanced treatment of the material covered in 112. (3 cr; prereq 111) Swofford

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

**116. Solution Equilibria.** Lecture. Systematic treatment of aqueous and nonaqueous equilibria and the principles underlying volumetric endpoint detection techniques. (3 cr; prereq 115 and PCh 103) Bruckenstein

**117. Electrochemical Methods of Analysis.** Lecture. Potentiometric, coulometric, polarographic, and other electrical methods. (4 cr; prereq 111) Bruckenstein

**118. Electrochemical Methods of Analysis.** Laboratory course. (3 cr; prereq 117) Swofford

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

**127.* Optical Methods of Analysis.** Lecture. (2 cr; prereq PCh 103; offered 1963-64 and alt yrs) Meehan

**138. Advanced Volumetric Analysis.** (3 cr; prereq 116)

**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) Bruckenstein

**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**

## *General Chemistry (GeCh)*

**4-5.† General Principles of 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, advanced algebra and trigonometry strongly recommended; 3 lect, 1 quiz, 1 rec, and 3 lab hrs per wk) Brasted and staff

**6. Principles of Solution Chemistry.** Lecture and laboratory work related to the chemistry of selected cations and anions. The detection and behavior of these ions are included in the study as well as heterogeneous and homogeneous equilibria systems. Attention is given to oxidation-reduction systematics, complex ion formation as it relates to aqueous solution chemistry, and general chemical phenomena interrelated with structure. (4 cr; prereq 5 or 15 or 25; 3 lect and 4 lab hrs per wk) Brasted and staff

**14-15.† General Principles of Chemistry.** Fundamental principles and survey of inorganic chemistry. (4 cr per qtr; limited to College of Engineering students; prereq Phys 11, 12 or ♯; 3 lect, 1 rec, 1 quiz, and 3 lab hrs per wk) Johnson, Tobias, and staff

**24-25†-26. General Principles of Chemistry.** 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: General Principles of Chemistry.** (5 cr per qtr; prereq 24 for 25H, 25 or 25H for 26H) Bent and staff

## *Inorganic Chemistry (InCh)*

**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.** 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 1964-65 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 1963-64 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 1963-64 and alt yrs) O'Connor

**113.* Mechanisms of Inorganic Reactions.** Prevalent ideas concerning the mechanisms of inorganic oxidation-reduction and substitution reactions. (3 cr; prereq PCh 103; 3 lect hrs per wk; offered 1963-64 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) staff

**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) Carbon compounds, with special emphasis upon those useful as engineering materials, together with the processes by which such compounds are made. (4 cr; prereq GeCh 15; 4 lect hrs per wk; 16 cannot be substituted for OrCh 61 or 62) Noland

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

**41-42. Elementary Organic Chemistry.** (AFHE) 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 GeCh 4 and 5 or equiv; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk) Leete

**61-62.† Elementary Organic Chemistry.** (For all colleges) Important classes of organic compounds, both aliphatic and aromatic. Laboratory work includes the preparation of typical substances. (4 cr per qtr; prereq 12-15 cr in chemistry for 61 . . . 61 or 41, ‡ for 62; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk) Dodson, Koelsch, Kreevoy

**63. Elementary Organic Chemistry.** (Continuation of 61-62) Lecture course. (3 cr; prereq 42 or 62; 63 is prerequisite to all other advanced courses in organic chemistry; 3 lect and 1 quiz hr per wk) Parham, Leete

**64. Elementary Organic Chemistry Laboratory.** (3 cr; prereq 63 or ¶63; 6 lab hrs and 1 conf hr per wk) Hill

**96-97-98.‡ Senior Thesis.** (Cr ar; prereq 4th yr) Any staff member of Division of Organic Chemistry

**101. Intermediate Organic Chemistry.** Important modern topics: organic theory, unusual types of aliphatic, aromatic, and heterocyclic compounds. (3 cr; prereq 63 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) Koelsch

**130. Organic Quantitative Analysis.** Microcombustion analyses of the elements usually found in organic compounds. (3 cr; prereq 63 and 64, AnCh 102 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 acetogenins, terpenes, alkaloids, biogenesis. (3 cr; prereq 63; offered 1963-64 and alt yrs) Leete

**143. Chemistry of Natural Products.** The steroidal hormones, their isolation, proof of structure, synthesis, and action. (3 cr; prereq 63; offered 1963-64 and alt yrs) Dodson

**144. Heterocyclic Compounds.** Typical classes of heterocyclic compounds, their chemical and physical properties and uses, synthesis. (3 cr; prereq 63 and 64; offered 1964-65 and alt yrs) Leete

**For Graduate Students Only**

**201-202-203. Seminar: Organic Chemistry**

**220. Graduate Survey**

**221. Graduate Survey**

**222. Graduate 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)

**100 A-B. Elementary Physical Chemistry.** Primarily for premedical students and for students of biology. (3 cr per term; prereq 1 yr college chemistry, 1 yr college physics, Math 40; offered summer sessions only)

**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 44) Mead

**101H-102H-103H. Honors Course: Physical Chemistry.** General survey. For students with GPA greater than 2.75 in mathematics, physics, and chemistry. (4 cr per qtr; prereq 1 yr chemistry, Phys 9, ITM 25A or Math 44) Lumry

**104-105-106. Physical Chemistry Laboratory.** (1 or 2 cr per qtr; prereq 101 or 107 or ¶101 for 104 . . . 102 or 108 or ¶102 for 105 . . . 103 or 108 or ¶103 for 106) Overend

**107-108. Elementary Physical Chemistry.** Brief general survey. (3 cr per qtr; prereq 1 yr college chemistry, Phys 9 or Phys 6 with △, ITM 25A or Math 44) Lipsky

**109.* Physical Chemistry.** Elementary atomic and molecular structure, wave mechanics, nuclear chemistry, photochemistry. (4 cr; prereq 103 or 103H) Wertz

**110. Thermodynamics and Chemistry.** Principles of classical thermodynamics; their application to physical and chemical phenomena. (4 cr; prereq 103 or 103H and calculus) Livingston

**111. Thermodynamics.** Application of principles of thermodynamics to chemical phenomena including those occurring in solutions of electrolytes. (2 cr; prereq 110) Livingston

**112. Atomic and Molecular Structure.** An experimental viewpoint. (3 cr; prereq 103 or 103H) 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 or 103H) Lipsky

**118.* Introduction to Quantum Theory.** Fundamentals of quantum mechanics and their application to simple physical and chemical problems. (3 cr; prereq 103 or 103H and calculus) Prager

**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 118) Prager

**128. Colloid and Surface Chemistry.** Fundamental principles of colloid chemistry, surface chemistry, electrokinetic phenomena, lyophobic and lyophilic colloids. (3 cr; prereq 103 or 103H) Lumry

**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: Radiation Chemistry**

**250-251-252.‡ Seminar: Physical Chemistry**

**253-254-255.‡ Seminar: Molecular Spectroscopy**

**256-257-258.‡ Seminar: Theoretical Chemistry**

**259-260-261.‡ Seminar: Photochemistry**

**263. General Survey of Physical Chemistry**

**265-266-267.‡ Seminar: Magnetochemistry**

**268-269-270.‡ Seminar: Statistical Mechanics**

**271-272-273.‡ Seminar: Physical Chemistry of Biological Systems**

**274-275-276.‡ Seminar: Quantum Mechanics**

**290-291-292.‡ Selected Topics in Physical Chemistry**

**301-302-303.‡ Research in Physical Chemistry**

## Civil Engineering (CE)

*General:* CE 1, 2, 124, 125, 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, 261-262, 264, 276, 277.

*Structural Engineering:* CE 31, 32, 33, 34, 37, 38, 39, 41, 130, 131, 132, 136, 137, 138, 141, 142, 143A, 144A, 145, 147, 234-235, 236, 240-241-242, 243, 244, 247-248-249.

*Surveying:* CE 18, 19, 20, 23, 111, 112, 113.

**1-2. 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 25, 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

**101. Contracts and Specifications.** Synopsis of the law of contracts, sales, agency, negotiable instruments, real property, personal property, partnerships, corporations, insurance contracts, workmen's compensation, labor law, mechanics' liens, government construction contracts, and torts with applications to the performance of engineering and construction contracts. (3 cr; prereq 4th yr or 5th yr or grad or ♯; 3 rec hrs per wk)

**102. Building and Construction Contracts.** Contracts with public authorities; the invitation, bid award; potential problems. Private construction. Legal problems in construction; contract administration. (3 cr; prereq 101 [formerly GE 101]; 3 lect hrs per wk) Westin

**111. Land Surveying.** Study of Minnesota Public Land Survey. Federal and state laws governing resurveys and subdivision surveys. Study of court decisions and legal principles involving boundary lines. Interpreting and writing deed 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. Principles of horizontal and vertical control nets, state co-ordinates, and astronomy as used in large scale mapping projects. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk) Fant

**113. Land Planning and Subdivision Design.** The study and analysis of land planning and development problems such as street design, lot and block layout, drainage, utilities, etc. Requirements, computations, and preparation of record plats. (3 cr; prereq 23 or 111 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)

**125. Introduction to Computer Applications in Civil Engineering.** Basic instruction in Fortran programming and utilization of digital computers in the solution of civil engineering problems. Execution of actual problems in surveying, structures, hydromechanics, etc., in co-operation with the Numerical Analysis Center. (3 cr; prereq 20, 130, 160; 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)

**138. Numerical Structural Analysis.** Application of finite difference equations, iterative procedures, and relaxation methods to solution of structural problems. Analysis of highly redundant structures by matrix methods. Solutions of continuous beams, rigid frames, space frameworks and stiffened shell structures using flexibility and stiffness matrices. (3 cr; prereq 130 or equiv; 3 hrs per wk) Graves

**141. Reinforced and Prestressed Concrete.** Elastic and ultimate strength design of reinforced and prestressed concrete beam and column elements. Investigation of bond and shear stresses. (3 cr; prereq 33; 2 lect and 3 lab hrs per wk) Graves

**142. Design of Reinforced and Prestressed Concrete I.** Application of principles of reinforced concrete design to floor systems, complete building frames, footings and retaining walls. Application of prestressed concrete to design of building elements. (3 cr; prereq 130 and 141; 2 lect and 2 lab hrs per wk) Graves

**143A. Design of Reinforced and Prestressed Concrete II.** Composite construction. Design of prestressed bridge girders. Deflection of concrete members. Design of selected

reinforced and prestressed concrete structures including spherical domes and cylindrical tanks. (3 cr; prereq 142 or equiv; 3 lect hrs per wk) Graves

**144A. Arch Analysis and Design.** Analysis and design of steel and reinforced concrete arches. (3 cr; prereq ‡; 3 lect hrs per wk) Andersen

**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 141) 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.** Engineering phases and relationships of public works. Historical survey. Federal, state, and local administration problems. Present trends and practices. The need for adequate public planning design and construction. Responsibilities of the engineer. Typical problems. (3 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.** (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: 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 and Industrial Wastes)**

**280-281-282.* Civil Engineering Research**

## Economics (Econ)

(College of Liberal Arts)

**1-2. Principles of Economics.** Same as Econ 1T-2T.

**1T-2T. Principles of Economics.** Principles underlying economic activity and the way these principles work out through economic institutions. 1T: Demand and supply,

competition and monopoly, and the distribution of income. 2T: National income, money and banking, business cycles, and international trade. (3 cr per qtr, §1-2, C-B, 50A-B; prereq ITM 13A or equiv or #)

**62. Labor Economics.** Labor as a factor of production; population and the labor force; economics of labor markets; theories of wages and employment; unions and collective bargaining; public policy. (3 cr, §IR 52; prereq 2 or equiv)

**65T-66T. Intermediate Economic Analysis.** Behavior of firms and industries under competitive and monopolistic conditions; factors influencing production, price, and advertising decisions. Determinants of national income, employment and price level; aggregate consumption and investment. Introduction to household and welfare theory; applications of evaluative techniques to various market phenomena and government policies. (3 cr per qtr; prereq ¶ITM 25A 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 competition; purposes and effects of antitrust laws and laws relating to "unfair business practices." (3 cr, §189A; prereq 65T or #)

**114A. International Trade.** Gains from trade, tariffs, customs unions, impact of trade on wages, balance of payments, exchange rates. (3 cr, §104; prereq 65T or equiv)

**177A. Intermediate Monetary Economics.** Economic role of principal financial institutions. Determinants of value of money. Problems of monetary policy. (3 cr; prereq 66T or equiv)

**178A. Public Finance.** Economic effects of various kinds and amounts of taxes, public debt and public expenditures. (3 cr; prereq 65T-66T or equiv)

## Electrical Engineering (EE)

**12-14. 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)

**41-43-45. Prinicples of Electrical Networks and Fields.** Basic concepts of electrical circuits and network analysis methods. Introduction to electric and magnetic fields. Behavior of charged particles in fields, unilateral circuit elements. (3 cr per qtr; not open to EE majors; prereq Phys 14, ITM 26A or ¶ITM 26A; 3 lect hrs per wk)

**41A-43A-45A. Electrical Engineering Laboratory.** Supporting laboratory for EE 41-43-45. Experimental study of electric circuits and circuit elements, instrumentation. (1 cr per qtr; not open to EE majors; prereq ¶41-43-45; 2 lab hrs per wk)

**42. Electrical Engineering Survey—Machines.** Polyphase circuits, magnetic circuits with D.C. and A.C. excitation. Principles of operation of electric machines. Type study of transformers, motors, generators and their application in electrical systems. (4 cr; not open to EE majors; prereq 41; 3 lect and 2 lab hrs per wk)

**44. Electrical Engineering Survey—Electronics.** Semiconductor physics. Transistor and vacuum tube fundamentals. Analytical and graphical analysis of electron devices and their associated circuitry, applications. (4 cr; not open to EE majors; prereq 43; 3 lect 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, ¶Engl 85A-B-C; 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)

**100A-B-C. Fundamentals of Electronics.** Basic concepts of transistors and multielectrode vacuum tubes. Graphical analysis methods, linear equivalent circuits. Piecewise-linear methods. Use of Laplace transforms, introduction to electromechanics. (3 cr per qtr; not open to EE majors; prereq 45; 2 lect and 2 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 EE 104-105-106. (3 cr per qtr; prereq 63 and 73, ¶111H-112H-113H, ¶114H-115H-116H, △; 3 lect hrs per wk)

**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)

**131-133-135. Applied Electronics.** Analysis and design of both linear and nonlinear electronic circuits. Laboratory study of design problems. (3 cr per qtr; prereq 106, 113, 116; 2 lect and 2 lab hrs per wk)

**138-139-140. Electric Power Systems and Power Control.** Circuit analysis applicable to electric power systems. Balanced polyphase systems and analysis of unbalanced systems by use of balanced symmetrical components. Response characteristics of synchronous and induction machines. Commutator type machines, including metadynes. The complete electric power system; generation, transmission, distribution, and utilization of electric energy. Stability problems of large interconnected power systems. (3 cr per qtr; prereq 113, 116; 2 lect hrs and 2 lab hrs per wk)

**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 44 or 45 or 63, 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 147 or 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 148 or 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)

**157-158-159. Control Systems.** Analysis and applications of typical linear control elements. Analytical and graphical treatment of system stability. Application of Boolean algebra to control logic; analogue and digital computers in control systems. (3 cr per qtr; prereq 106, 113, 116; 2 lect and 2 lab hrs per wk)

**160A-B-C. Electrical Energy Conversion.** Study of energy conversion processes applying the general methods of thremodynamics, analytical and statistical mechanics: thermoelectric, thermionic, magnetohydrodynamic, electromechanical, photoelectric, and electrochemical conversion. Kinetic and transport properties of materials; interaction with electric, magnetic, thermal, and mechanical fields. Application to typical converters, including design considerations. (3 cr per qtr; prereq 104, 113, ME 30; 2 lect and 2 lab hrs per wk)

**164-165-166. Communication.** 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 106, 113, 116; 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 113, ♯; 2 lect and 2 lab hrs per wk)

**170-171-172. Linear Network Theory.** Descriptions of passive and active linear networks in the time and frequency domains; network models of active devices; properties of 2- and 3-element-kind networks. The approximation and realization problems in network synthesis. Selected topics in feedback and stability. Active and passive circuit applications. (3 cr per qtr; prereq 106 and 113 or equiv, ♯; 3 lect hrs per wk)

**173-174-175. Physical Electronics.** Physical principles underlying devices used in electrical engineering; elementary quantum and statistical mechanics, semiconductor properties, electron emission from surfaces, magnetism, special topics of current interest. (3 cr per qtr; prereq 104 or equiv, ♯; 2 lect and 2 rec hrs per wk)

**178-179-180. Nonlinear Circuit Analysis.** Semiconductor, ferromagnetic, and ferroelectric devices as switching elements; regenerative switching circuits, digital logic circuits. Free and forced response of nonlinear circuits, amplitude and frequency of oscillatory circuits; phase-plane analysis. (3 cr per qtr; prereq 106, 113, 116, ITM 148 or equiv, ♯; 3 lect hrs per wk)

**183-184-185. Special Investigations.** Undergraduate studies of approved topics, theoretical or experimental in nature. (Cr ar; prereq approval of faculty sponsor)

**186A-B-C. Communications Theory.** Theoretical aspects of the problem of communicating with electrical signals in the presence of noise, practical applications. Representation

of random signals, modulation, information theory, analysis of networks with random inputs, coding, statistical decision-theory. (3 cr per qtr; prereq 106, 113, ♯; 3 lect hrs per wk)

**190A-B-C. Principles of Digital Computer Systems.** A treatment of digital computers including computer organization, logic and control circuitry, memory systems, input-output arrangements, and practical computer design limitations. (3 cr per qtr; prereq 180, ♯)

**194-195-196. Control Theory.** Analysis of linear feedback control systems, Nyquist and Bode diagrams, root-locus, and gain-phase techniques. Compensation and minor loops. Load disturbances. Performance criteria. Multivariable controls. Introduction to statistical methods. Experimental laboratory on typical control systems, analogue computer simulation. (3 cr per qtr; prereq 106, 113, 116, ♯; 3 lect hrs per wk)

**For Graduate Students Only**

**200A-B-C. Introduction to the Properties of Solids**

**211-212-213. Advanced Topics in Network Synthesis**

**221-222-223. Electric Power Seminar**

**227-228-229. Stability of A.C. Power Systems**

**233-234-235. Fluctuation Phenomena**

**239. Solid State Devices**

**242-243-244. Plasma Physics**

**245-246-247. Seminar: Plasma Physics**

**250A-B-C. Quantum Electronics**

**251A-B-C. Properties of Semiconductors**

**252A-B-C. Magnetic, Dielectric, and Superconductive Phenomena in Solids**

**255-256-257. Analysis of A.C. Power-System Circuits**

**261-263-265. Problems in Electromagnetism**

**262-264-266. Seminar: Communication**

**267-268-269. Statistical Theory of Communication**

**272-273-274. Fundamentals of Acoustics**

**281-282-283. Seminar: Energy Conversion**

**287-288-289. Microwave Generation and Amplification**

**291-292-293. Seminar: Electronics**

**294-295-296. Advanced Control Theory**

## English (Engl)

(College of Liberal Arts)

**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 Liberal 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 Liberal 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 literature as one means of providing subject matter for the writing. It satisfies the Group A requirement for graduation in the College of Liberal 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

**85. Technical Writing for Engineers.** Theory and practice in technical and professional writing. (3 cr; prereq C or 3A or 3B; 3 rec hrs per wk) Haga and others

**85A-B-C.† Technical Writing for Engineers.** (See Engl 85) (1 cr per qtr; prereq C or 3A or 3B, and concurrent enrollment in a course designated by the major department and requiring preparation of technical reports) Guthrie and others

## General Engineering (GE)

**70. The Slide Rule.** (See Engineering Graphics, EG 1)

**101. Contracts and Specifications.** (See Civil Engineering, CE 101)

## Geology and Geophysics (Geo)

(School of Earth Sciences)

*INTRODUCTORY COURSES*

**1. Physical Geology.** A first course in geology for science majors and an introduction to the scientific method and the nature of the earth for others. Survey of the main features of the physical world and of the processes that have evoked them. (4 cr; prereq high school physics and chemistry recommended; 3 lect hrs and one 2-hr lab per wk) Deffeyes, Craddock

**2. Historical Geology.** Evolution of the earth from its origin to the present, with special attention to the succession of physical and biological events of the past 600 million years. (4 cr; prereq 1 or 11; 3 lect hrs, one 2-hr lab per wk) Sloan

**11. Introductory Physical Geology.** (Intensive sequence) For prospective majors and others desiring more intensive course. (5 cr; prereq high school or college chemistry or ♯; 3 lect hrs, 1 rec hr, and two 2-hr labs per wk) Deffeyes

**22. Introductory Historical Geology.** (Intensive sequence) For prospective majors and others desiring more intensive course. (5 cr; prereq 11 or ♯; 3 lect hrs, 1 rec hr, and two 2-hr labs per wk) Sloan

**62. Mineralogy and Lithology.** Introduction to crystallography, crystal chemistry, and mineralogy. Descriptive and determinative mineralogy. Classification of rocks. Textural, structural, and mineralogical variations of rocks and some ores. (5 cr; prereq 1 or 11 or ♯; 3 lect and 6 lab hrs per wk) Zoltai, Phinney

*A. GENERAL GEOLOGY*

**100-101. Field Geology.** Measurement of stratigraphic sections; study of fossils and igneous, sedimentary, and metamorphic rocks. Geological surveying on aerial photographs and topographic maps and by the plane table method. Preparation of

geologic maps and cross-sections. Study of structural and geomorphic features and geologic setting of mineral deposits. (Cr ar by special or co-operative arrangement; prereq 120 or ♯)

**103.* Geologic Problems.** Individual research in laboratory or field problems at Upper Division or graduate levels. (1-6 cr) Staff

**104.* Advanced General Geology.** Considers central problems in modern and classical geology through seminar-type discussion, evaluation of professional publications, and special projects. (3 cr; open to science majors in any field with supplemental reading by nongeologists; prereq ♯; offered 1964-65 and alt yrs) Cloud, James, and staff

**105. Introduction to Paleontology.** Introduction to morphology and classification of major fossil groups. (5 cr; prereq 2 or 22 or ♯) Sloan

**106.* Invertebrate Paleontology.** Detailed studies of morphology, classification, and ecology of selected groups of invertebrate fossils. (5 cr; prereq 105; 3 lect and 4 lab hrs per wk) Sloan

**107.* Vertebrate Paleontology.** Morphologic and stratigraphic aspects of fossil vertebrates. (5 cr; prereq 105 or Zool 56 or ♯) Sloan

**110. Sedimentology and Stratigraphy.** Sedimentary processes and products with particular reference to modern sedimentary environments; principles of physical stratigraphy, correlation, facies, tectonic control, classification of stratigraphic units. (4 cr; prereq 62; 3 lect and 2 lab hrs per wk) Deffeyes, Swain

**111.* Stratigraphy.** Analysis of stratigraphy of typical and unique sequences of (a) Precambrian and Paleozoic rocks, or (b) Mesozoic and Cenozoic rocks. Methods of presentation of stratigraphic data. Term paper required. (3 cr; prereq 110) Swain

**112.* Micropaleontology.** Biology and paleontology of microorganisms of geologic importance including Foraminifera, Radiolaria, flagellate Protista, Diatomaceae, Characea, Ostracoda, and conodonts. (3 cr; prereq 105) Swain

**115.* 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. (4 cr; prereq 2 or 22; 3 lect and 2 lab hrs per wk) Wright

**116.* Glacial Geology.** Physics of modern glaciers. Glacial erosion and deposition. Stratigraphy and chronology of the Pleistocene in glaciated and nonglaciated areas. (3 cr; prereq 2 or 22) Wright

**117.* Pleistocene Geology.** Problems in Pleistocene history of glaciated and nonglaciated areas, particularly North America, Europe, and the Mediterranean. Relation of Pleistocene climatic changes to soils, biogeography, and archeology. Pollen analysis. (3 cr; prereq 116; offered 1963-64 and alt yrs) Wright

**118.* Advanced Geomorphology.** Detailed study of selected geomorphic processes, especially those of arctic and desert regions. (3 cr; prereq 115; offered 1964-65 and alt yrs) Wright

**120. 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 62 or 162 or ♯; 3 lect and 2 lab hrs per wk) Craddock

**121.* Advanced Structural Geology.** Fundamental problems and genesis of secondary structural features; detailed analysis of typical examples. Comprehensive term paper required for graduate credit. (3 cr; prereq 120) Craddock

**125. Principles of Sedimentology.** Sedimentary processes and environment, the tectonic framework, and the resultant rock types. (3 cr; prereq 62 or ♯; 2 lect and 2 lab hrs per wk) Deffeyes

**126. Diagenesis in Sediments.** Processes by which sediments are altered and converted into rocks. (3 cr; prereq 125, PCh 108 or ♯; 2 lect and 2 lab hrs per wk) Deffeyes

*B. MINERALOGY AND PETROLOGY*

**140.* Mineral Systems I.** Basic and compound symmetry elements. Derivation and study of point groups, co-ordinate systems, crystal forms, lattices, plane groups and space groups. Introduction to x-ray diffraction. Introduction to crystal chemistry and crystal structures. (4 cr; prereq 62 or ♯, trigonometry, a year of college physics and chemistry; 3 lect and 4 lab hrs per wk) Zoltai

**141.* Mineral Systems II.** Survey of mineral structures and crystal growth. Optical mineralogy; the behavior of light and of isotropic and anisotropic media in polarized light. Correlation of geometric and electromagnetic theories of optical mineralogy. Laboratory includes the study of structure models, thin and polished sections; immersion techniques. (4 cr; prereq 140; 3 lect and 4 lab hrs per wk) Phinney, Zoltai

**141A.* Mineral Systems IIA.** Optical mineralogy portion of Geo 140. (3 cr; prereq 140; 2 lect and 4 lab hrs per wk) Phinney

**142.* Mineral Systems III.** Application of basic physical sciences to geologic problems. Discussion of rocks as chemical systems. Laboratory consists of macroscopic and microscopic study of rocks and minerals. (4 cr, §145 or §150; prereq 141, PCh 102 or 108, ITM 26B; 3 lect and 4 lab hrs per wk) Phinney, Gast

**144. Principles of Petrology.** Igneous and metamorphic mineral assemblages and textures discussed in terms of phase diagrams and physical processes. Summary of important petrologic problems. (3 cr; prereq 62; offered 1963-64 and alt yrs) Phinney

**145.* Phase Equilibrium in Mineral Systems.** Graphical and mathematical treatment of 1-, 2-, 3-, and 4-component systems. Includes the phase rule, open vs closed systems, and effects of disequilibrium. (3 cr; prereq 141, PCh 108 or 103) Phinney

**146.* Igneous Petrology.** Fractional crystallization, disequilibrium, nucleation, assimilation, volatiles, granites, serpentines, and other problems in the light of modern experimental data and theory. (3 cr; prereq 145; offered 1964-65 and alt yrs) Phinney

**147.* Metamorphic Petrology.** Solid state phase equilibrium, reaction rates, partial fusion, metasomatism, methods of graphical projection for several component systems, geologic thermometers, and the effect of nonhydrostatic stress. (3 cr; prereq 146; offered 1964-65 and alt yrs) Phinney

**150.* Principles of Geochemistry.** Application of principles of thermodynamics to systems of geologic interest, with emphasis on aqueous solutions. (3 cr; prereq PCh 102 or 108 or ♯) Gast

**151.* Isotopic and Nuclear Processes in Geology.** Measurement of geologic time using isotopic methods. Variations in isotopic compositions due to radioactivity and to natural isotope fractionation processes. (3 cr; prereq 142, PCh 103 or ♯; offered 1963-64 and alt yrs) Gast

**152.* Problems in Geochemistry.** Selected topics in geochemistry. (2 cr; prereq 151 or ♯; offered 1964-65 and alt yrs) Gast

**155-156.* Mineral Deposits.** Nature and distribution of mineral deposits, and analysis of the processes by which elements are concentrated in magmatic, hydrothermal, sedimentary, and surface environments. (3 cr per qtr; prereq 120, 142 or ♯) James

**157. Mineral Fuel Deposits.** Origin and distribution of petroleum and coal deposits: source materials, reservoir rocks and structures, stratigraphic distribution of important deposits. (3 cr; prereq 110, 120 or ♯) Swain

**160.* X-ray Mineralogy.** Physics of X rays. Diffraction of X rays by crystalline material. Description of X-ray powder instruments. The use of powder pattern for mineral identification and for mineralogical and crystallographical research. (3 cr; prereq 140 or ♯) Zoltai

**161.* Single Crystal X-ray Diffraction.** Introduction to the principles and practice of single crystal X-ray diffraction. Lattice and space group determination. Introduction to crystal structure determination. (2 cr; prereq 160 or ♯) Zoltai

**162. Soil Mineralogy.** Introduction to crystallography, crystal chemistry, and mineralogy. Descriptive and determinative mineralogy. Classification of rocks. Textural, structural,

and mineralogical variations of rocks and some ores. Term paper. (4 cr; not open to geology, mining and metallurgy majors; prereq 1 or 11 or ♯, a term of college chemistry; 3 lect and 6 lab hrs per wk) Zoltai, Phinney

### C. GEOPHYSICS

**170. Introduction to Earth Physics.** Physics of the solid earth; evidence and data on origin, age, size and shape, internal constitution, thermal history, gravity, and magnetic fields. (3 cr; prereq 2 or 22, Phys 9 or 14)

**171. Introduction to Earthquake Seismology.** Physics and geology of earthquakes; causes, effects, distribution, seismic waves. (3 cr; prereq 120 or ♯)

**172. Introduction to Exploration Geophysics.** Principles of exploration by gravity, magnetic, seismic, and electrical measurements. (3 cr; prereq 2 or 22, Phys 9 or 14)

**175. Principles of Gravity and Magnetic Exploration.** Instrumentation, surveying techniques, reduction of data, interpretation, case histories. (3 cr; prereq 1 or 11, Phys 9 or 14, ITM 25B)

**176. Principles of Seismic Exploration.** Reflection and refraction seismology; theory, interpretation, instruments. (3 cr; prereq 2 or 22, Phys 9 or 14, ITM 25B)

**177. Principles of Electrical Exploration.** Resistivity, electromagnetic, and other methods; theory, interpretation, instruments. (2 cr; prereq 2 or 22, Phys 9 or 14, ITM 25B)

## For Graduate Students Only

### A. GENERAL GEOLOGY

**200. Seminar: Paleoecology**

**201. Research in Biological, Sedimentary, and Oceanographic Aspects of Geology**

**202. Seminar: Marine Geology**

**203. Advanced Invertebrate Paleontology**

**205. Research in Paleontology**

**206. Seminar: Paleontology**

**210. Research in Stratigraphy**

**211. Seminar: Stratigraphy**

**215. Research in Geomorphology and Pleistocene Geology**

**216. Seminar: Geomorphology and Pleistocene Geology**

**220. Geotectonics**

**221. Research in Structural Geology**

**222. Seminar: Structural Geology**

**225. Research in Sedimentology**

**226. Seminar: Sedimentology**

### B. MINERALOGY AND PETROLOGY

**245. Research in Petrology**

**246. Seminar: Petrology**

**250. Research in Geochemistry**

**251. Seminar: Geochemistry**

**255. Advanced Mineral Deposits I**

**256. Advanced Mineral Deposits II**

**257. Research in Mineral Deposits**

**258. Seminar: Mineral Deposits**

**260. X-ray Crystallography**

**261. Research in Mineralogy and Crystallography**

**262. Seminar: Mineralogy and Crystallography**

C. *GEOPHYSICS*

**270-271. Theory of Elastic Wave Propagation**

**275-276-277. Seminar: Geophysics**

## German (Ger)

(College of Liberal Arts)

**1A-2A-3A. Beginning German: "Active" Approach.** Five class meetings a week. Provides basic experience in speaking, reading, and understanding the German language and its structure through the acquisition of basic patterns of speech and later through the reading and analysis of texts. (5 cr per qtr)

**1B-2B-3B. Beginning German: Language and Culture.** Five class meetings a week. Provides a foundation for a reading knowledge adequate for cultural and professional purposes; experience in understanding spoken German; an introduction to representative German figures such as Goethe, Heine, Thomas Mann, through a variety of German and English texts; an elementary introduction to the nature of linguistic change through comparisons of the common Germanic features of English and German. (5 cr per qtr)

**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 Liberal Arts)

**1-2-3.† Civilization of the Modern World.** 1: Rise of the European state system as framework within which Western civilization developed, and economic, cultural, political, intellectual, and religious implications to the emerging system. 2: Struggle for control over the Western states system, and emergence of liberal democracy in the modern world. 3: Impact of industrialism upon Western and world civilization in the 20th century. (3 cr per qtr) Bamford, Mulholland, Uroff, Wolf, Wright

**17-18-19.† History of Asia.** A survey of the history of China, Japan, India, and Southeast Asia from ancient times to the present. 17: Ancient history and culture of China, Japan, and India to A.D. 1200. 18: Asia, A.D. 1200-1800 (Chinese empire period; India: Muslim domination; Japanese feudalism; the beginning of Western influence). 19: Modern Asia: The impact of Europe, nationalism, post–World War II Asia. (3 cr per qtr) Stein and Taylor

**20-21-22.† American History.** Survey of political, economic, and social history of the United States with emphasis on forces that resulted in 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

**53-54-55.† Civilization of the Modern World.** (3 cr per qtr, §1-2-3) Altholz

**79-80-81.‡ The United States in the Twentieth Century.** Political, economic, diplomatic, and social history of United States from Spanish-American War to present. 79: 1898-1914. 80: 1914-1932. 81: 1932 to present. (3 cr per qtr) Chambers

**93-94-95.‡ American Diplomatic History.** 93: American diplomacy, 1776-1848. 94: Period of national development. 95: United States as a world power. (3 cr per qtr) Beatty

**134-135-136.‡ World War II.** 134: Origins and background. 135: War period, 1939-1942. 136: Period 1943-1945. (3 cr per qtr) Deutsch

**149-150-151.‡ Intellectual History of the United States.** (3 cr per qtr) Noble

## Humanities (Hum)

(College of Liberal Arts)

**1A-2A-3A. Humanities in the Modern World.** A 3-hour per quarter credit sequence, each quarter corresponding to the respective quarter of Hum 1-2-3, but with reduced hours of class and a reduced reading list. (3 cr, §corresponding qtr of 1-2-3 or of 51-52-53; prereq 1A or 1 for 2A, 2A or 2 for 3A)

**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)

**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)

(Department of Civil Engineering)

**101. Fluid Mechanics.** 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 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. Algebra and Trigonometry** (High School). 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. (Prereq 9 or equiv; 5 rec hrs per wk)

**12. College Algebra and Trigonometry.** 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 4 yrs high school mathematics, including trigonometry, or 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)

**25B. Calculus III: Analytic Geometry and Calculus.** Integration by parts, change of variable, rational functions, tables. Differentials, Simpson's rule, moments, center of gravity, centroids, liquid pressure. Basic properties of continuous and differentiable functions, indeterminate forms, improper integrals, Taylor's formula. Parametric equations, tangent lines. Vectors in 2 dimensions, motion in a plane. Polar co-ordinates, conic sections, areas, arc length, areas of surfaces of revolution. Solid analytic geometry: rectangular co-ordinate systems, direction numbers, angle between lines. Equations of planes, lines, surfaces, curves, cylindrical and spherical co-ordinates. Vector algebra, geometry, equations of lines and planes in vector notation. (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 25B. (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, §27; prereq 25A; 5 rec hrs per wk)

**26B. Calculus IV: Series and Calculus of Functions of Several Variables.** Infinite series; convergence, alternating series, absolute convergence. Power series, differentiation and integration of power series. Binomial series, Taylor's series. Functions of several variables, partial differentiation. Limits, chain rule, implicit differentiation. Directional derivatives, tangent planes, extrema. Complex polynomials, fundamental theorem of algebra, uniform continuity, line integral. Double integrals; repeated integrals. Volumes, polar co-ordinates, center of gravity, moments of inertia. Triple integrals, applications. Cylindrical and spherical co-ordinates. (5 cr; prereq 25B; 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 26B. (5 cr; prereq 25H or ♯ or △, 5 rec hrs per wk)

**27. Differential Equations and Elements of Matrix Theory.** Determinants, matrix algebra, vector-matrix notation for systems of linear algebraic and differential equations, adjoint and inverse, Cramer's rule, rank of a matrix. Differential equations, equations of first order, standard methods of solution, linear equations with constant coefficients, applications. Systems of differential equations, integration by series, numerical methods. (5 cr, §26A; prereq 26B; 5 rec hrs per wk)

**27H. Honors Course: Differential Equations and Elements of Matrix Theory.** A more theoretical and intensive treatment of the topics in ITM 27. (5 cr; prereq 26H or ♯ or △; 5 rec hrs per wk)

**60. Operational Methods for Linear Systems.** (Primarily for EE students) Review of Fourier series and their applications to linear ordinary differential equations. The Fourier transform, mathematical properties, amplitude and phase spectra, energy. The Laplace transform, mathematical properties and elementary inversion techniques, applications to systems of ordinary differential equations, transfer function of a filter, time and frequency domain relations. (3 cr; prereq 26A or 27; 3 rec hrs per wk)

**65. Introduction to Programming Modern Digital Computers.** Number systems. Computer organization. Elementary coding techniques. Scaling. Introduction to problem oriented language. Program organization. Informal laboratory. (3 cr, §old 165A or §164-165-166; prereq 25A or 26B or ♯; 3 rec hrs per wk)

**90. Elementary Engineering Statistics.** Probability, permutations, and combinations. Frequency distributions. Introduction to sampling significance tests, regression charts. (3 cr; prereq 25A or 26B or ¶25A or ¶26B; 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 25A or 26B; 3 rec hrs per wk)

**99A. Mathematical Problem Seminar.** (Continuation of ITM 99) For special students interested in developing insight and originality in mathematics through problem solving. (1-3 cr; prereq 99) Rosenbloom

**104. Variational Problems in Engineering.** Euler-Lagrange equations, isoperimetric problems, geodesics, Fermat's and Hamilton's principles, 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 ♯; 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 25A or 26B; 3 rec hrs per wk)

**133-134.* Statistical Theory with Applications.** Statistical decision theory, sampling, estimation, testing hypotheses, parametric and nonparametric procedures for 1-sample and 2-sample problems, regression, analysis of variance. (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 25A or 26B; 3 rec hrs per wk)

**147.* Calculus V: 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, applications. (3 cr, §152; prereq 25A or 26B; 3 rec hrs per wk)

**147H.* Honors Course: Calculus V: Vector Analysis.** A more theoretical and intensive treatment of the topics in ITM 147. (3 cr; prereq 27H or ♯; 3 rec hrs per wk)

**148.* Differential Equations.** Linear differential and difference equations with constant coefficients, isoclines, phase plane, reduction in order, Picard's method, uniform convergence, series solutions, Bessel functions, Legendre polynomials, introduction to boundary value problems. (3 cr, §150; prereq 26A or 27; 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 25A or 26B; 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 26A or 27; 3 rec hrs per wk)

**151. Calculus VI: Advanced Calculus.** Limits, properties of continuous functions of one and several variables, partial differentiation, implicit functions, maxima and minima, Taylor's theorem, transformations and mappings, integrals containing a parameter or variable limits, Stieltjes integral. (3 cr; prereq 25A or 26B; 3 rec hrs per wk)

**151H. Honors Course: Calculus VI—Advanced Calculus.** A more theoretical and intensive treatment of the topics in ITM 151. (3 cr; prereq 25A or 26B or ♯; 3 rec hrs per wk)

**153.* Calculus VII: Advanced Calculus.** Infinite series, computation with series, series with variable terms, uniform convergence, power series. Improper integrals. Fourier series and orthogonal functions. Fourier integrals. 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 151H 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.** Basic laws and principles. Lagrange's equations. Motion of particles and rigid bodies, e.g., satellites and gyroscopes. Matrix methods for small oscillations. Variational methods, Hamilton's principle, extremal properties of eigenvalues. Hamilton's equations, transformation theory, separable systems. (3 cr per qtr; prereq 147, 149 or 142, 152 or ♯; 3 rec hrs per wk) Koehler

**164-165-166.* Theory and Programming of Modern Digital Computers.** Number systems. Analysis of arithmetic algorithms. Logical organization. Storage, control, and input-output units. Basic and advanced machine language and compiler programming. Libraries, advanced assembly techniques, interpretive systems, compilers. Application to mathematical and physical problems. Informal laboratory. (3 cr per qtr, §65 or §old 165A; prereq 26A or 27 or ♯; 3 rec hrs per wk)

**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, 174 or 147, 174 or ♯; 3 rec hrs per wk) Serrin

**173.* Elementary Partial Differential Equations.** Partial differential equations of theoretical physics, one-dimensional wave equation, characteristics, classification of second order equations, heat and Laplace equations, uniqueness, maximum principle, orthogonal systems, Fourier series, separation of variables. (3 cr; prereq 147, 148 or 147, 153 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 26A or 27; 3 rec hrs per wk)

**175.* Integral Transforms.** Fourier and Laplace transforms and their inversion, method of residues, applications to ordinary and partial differential equations, applications to the heat, wave, and Laplace equations. (3 cr; prereq 173, 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 147, 153 or ♯; 3 rec hrs per wk)

**184. Elementary Numerical Analysis in Engineering.** Finite differences, interpolation, summation of series, numerical integration. Euler-Maclaurin formula and asymptotic expansions. Numerical solutions of systems of algebraic and transcendental equations. Newton's and Graeffe's method. (3 cr; prereq 26A or 27; 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 148 or 150 and 151 and 184 or ♯; 3 rec hrs per wk)

**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 147, 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 147, 153 or ♯; 3 rec hrs per wk)

**193C.* Elementary Differential Geometry.** Curves and surfaces in Euclidean 3-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 147, 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**

**224A-B-C.* Lie Groups and Lie Algebras**

**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**

241.* Information Theory

242.* Mathematical Aspects of Boundary Layer Theory

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

264A-B-C.* Conformal Mapping

265A.* Quasiconformal Functions

266A-B-C.* Riemann Surfaces

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

274A-B-C.* Partial Differential and Integral Equations of Applied Mathematics

275A-B-C.* Theory of Partial Differential Equations

276A. Second Order Elliptic Partial Differential Equations

277-278-279.* Calculus of Variations and Minimal Surfaces

280A.* Galois Theory

280B.* Rings and Ideals

280C.* Algebraic Numbers

280D.* Representations of Groups

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

296A-B-C.* Jordan Algebras and Their Application to Analysis

297A-B-C.* Theory of Sheaves

298.* Modern Theory of Differentiation

299A-B.* Topics in Number Theory and Algebraic Geometry

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)*

1. **The Slide Rule.** Computation practice and theory. Design of special scales. (1 cr [0 cr for students registered in IT]; prereq higher algebra and trigonometry or ♯; 1 rec hr per wk)

25. **Engineering Graphics.** Engineering representation and analysis of systems of projection; the co-ordinate system, graphical solution of space problems, intersections and developments. Precision in graphics and techniques of sketching; pictorial projection

systems, size description, standard and simplified practices applied to graphic communication. (4 cr; prereq ¶ITM 13A or ♯; 3 lect, 1 rec, and open lab hrs per wk)

**26. Graphical Computation.** Graphical computation of engineering problems involving algebra, calculus, and statics. Functional scales, nomography, representation and analysis of empirical data. (2 cr; prereq 25; 2 lect and open lab hrs per wk)

**27. Graphical Communication and Analysis.** Engineering representation and analysis. Single and multiview systems, specification and control of size. Graphical summation and resolution of 2- and 3-space vectors. (2 cr; prereq 25; 2 lect and open lab hrs per wk)

**101. Illustration for Design.** Graphical approach relating functional design to space requirements and aesthetic considerations. Orthographic and pictorial presentation of information. Principles of shading, sketching. (3 cr; prereq 27 or ♯; 2 lect hrs per wk; lab ar)

**118. Graphic Analysis of Experimental Data.** Derivation of empirical equations correlating graphic and algebraic methods. (3 cr; prereq 26, ITM 25A or ♯; 3 lect hrs per wk)

**120. Advanced Descriptive Geometry.** Graphic solutions involving one view drawings; intersection, tangency, and clearance determinations of curves and warped surfaces. (3 cr; prereq 27, ITM 24A or ♯; 3 lect hrs per wk)

**130. Nomography.** Application of geometry to the development of alignment charts. Parallel and nonparallel straight line scale and curved scale nomograms; transverse, concurrent, proportionality and combined charts. (3 cr; prereq 26, ITM 24A or ♯; 3 lect hrs per wk)

**131. Graphical Mathematics.** Graphical approach to problems involving algebra, differential and integral calculus; use of straight and curved line networks and combinations of networks. Correlation of algebraic and descriptive geometry solutions particularly relating to numerical control of automatic machines. (3 cr; prereq 26, ITM 25A or ♯; 3 lect hrs per wk)

**194. Graphics in Engineering Problems.** A synthesis and extension of the procedures of graphical mathematics, nomography and descriptive geometry in the solutions of complex problems within the individual student's area of interest. (2-4 cr; prereq 130 or 131 or ♯; hrs ar)

## *Industrial Engineering (IE)*

**100. Introduction to Industrial Engineering Analysis.** Management and decision making, analytical methods in production management, design of production systems, operation and control of production systems. (3 cr; prereq ME 99 or ♯; 3 lect hrs per wk)

**140. Process Economics.** Quantitative and qualitative comparison of competitive manufacturing processes. Emphasis placed on the economics of process selection and optimization. Linear programming methods of assignment of work to available facilities. (3 cr; prereq ME 172; 3 lect hrs per wk)

**141. Industrial Metrology.** Fundamental concepts of the science of industrial measurements. Variability of manufacturing process, process capability, errors of measurement. (3 cr; prereq ME 99 and ME 172; 2 lect and 3 lab 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 100; 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)

**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 100; 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 ME 99 or ♯; 3 rec hrs per wk)

**172. Manufacturing Cost Analysis.** Financial accounting concepts, standard cost systems, manufacturing cost accounting, cost information for management decision making. (3 cr; prereq 100; 3 lect hrs per wk)

**173. Engineering Economic Analysis.** Analysis of capital expenditures and annual operating costs as the basis for management decisions. (3 cr; prereq 100; 3 rec hrs per wk)

**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 ME 99; 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 ME 99; 3 lect hrs per wk)

**176. Probability Models in Engineering.** Concepts of compound statements, sets and functions, conditional probabilities and simple stochastic processes (including finite Markov chains) and their relation to selected problems in engineering. (3 cr; prereq ME 99 or equiv; 3 lect hrs per wk)

**177. 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; 3 lect hrs per wk)

**180. Management for Engineers.** Management functions and relations with employees, other supervisors, and staff departments. (3 cr; prereq 100; 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 100; 3 rec hrs per wk)

**193. Introduction to Optimal Control and Dynamic Programming.** Concepts of optimization, linear and nonlinear optimal systems, adaptive systems, stochastic optimization problems and introduction to dynamic programming. (3 cr; prereq ME 199; 3 lect hrs per wk)

**194. Topics in Management Science.** Analytical tools for decision making and management of the production function. Emphasis upon topics appearing in the current literature; mathematical models, assumptions, limitations, and new developments. (3 cr; prereq 15 cr in industrial engineering; 3 lect hrs per wk)

**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; hrs ar)

**198. Design and Analysis of Experiments I.** One-factor experiments, design constructed to reduce the experimental error, general linear regression model, the analysis of variance, estimation and comparison of effect, orthogonal contrasts, components of variance, fixed random, and mixed models, incomplete block designs, introduction to general factorial experiments. (3 cr; prereq ME 99 or ITM 132 or ♯; 3 lect hrs per wk)

**199. Design and Analysis of Experiments II.** Two or more factor experiments, designs involving crossed, nested, and mixed classifications; qualitative and quantitative

factors; experiments, block confounding, fractional factorial experiments, introduction to response surface analysis. (3 cr; prereq 198 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)*

**21. Analysis of Mechanical Engineering Systems.** Determination of response of engineering systems utilizing transfer function representation. Analogies between engineering systems with equivalent block diagrams. Stability of linear systems. (3 cr; prereq MM 28; 2 lect and 3 lab hrs per wk)

**22. Kinetics of Mechanism Systems.** Analysis of mechanism arrays to predict response to various forcing functions. Degrees of freedom of rigid body mechanisms. Energy techniques applied to rigid body mechanisms with linear environment. (3 cr; prereq 21; 2 lect and 3 lab hrs per wk)

**23. Synthesis of Mechanism Systems.** Creation of mechanism arrays based upon desired motion or power transfer requirements. Shape and size optimization of mechanism designs based upon strength and transfer criteria. (3 cr; prereq 22; 2 lect and 3 lab hrs per wk)

**24. Optimum Design of Mechanical Elements.** Application of fundamental principles to the design of typical mechanical components. Engineering approach to the analysis and synthesis of machines. Optimum design criteria. (3 cr; prereq MM 40; 2 lect and 3 lab hrs per wk)

**30-31-32. Thermodynamics.** Properties, equations of state, and processes of engineering thermodynamic systems and devices. Application of fundamental laws correlating energy with heat, work, and mass transfer. Equilibrium and irreversibility. (3 cr per qtr; prereq ITM 26A or ¶ITM 26A, Phys 14; 3 rec hrs per wk)

**33-34. Measurements Laboratory I, II.** Fundamental principles of measurement. Standards, accuracy, and calibration. Treatment of experimental data. Static and dynamic characteristics of generalized measurement systems. Electromechanical transducers. Measurement of temperature, pressure, vacuum, humidity, density, viscosity, heating values, speed, power, force, stress, strain, and radioactivity. (2 cr per qtr; prereq 31 and EE 43; 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)

**99. Introduction to Engineering Analysis.** Principles of measurement, concept of uncertainty and variability, models in engineering analysis, decision methods, estimation methods, introduction to design of experiments. (3 cr; prereq ITM 24A or #; 3 rec hrs per wk)

**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 172; 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 172 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 172; 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 172; 2 lect and 3 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. Friction and Lubrication.** Friction mechanism and boundary lubrication. Hydrodynamic and hydrostatic lubrication theory applied to finite bearings. Introduction to gas bearings. (3 cr; prereq Hydr 103 or equiv; 3 rec 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 31 and Hydr 101 or 103 or Aero 100 or ♯; 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)

**140-141. Thermodynamics of Modern Power Devices.** Study of modern power devices including gas and solid state thermocouple, magnetohydrodynamic systems, fuel cells, and solar energy systems. Emphasis is placed on the thermodynamic principles and transport phenomena involved in each device. (3 cr per qtr; prereq 133; 3 rec hrs per wk)

**142. Vapor Cycle Power Systems.** Vapor cycle analysis, regeneration, reheat, compound cycle modifications, combined gas turbine–vapor cycle systems, binary systems. Combustion problems; solar, nuclear, and unusual energy sources for space power systems. (3 cr; prereq 32 and 133; 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)

**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, GeCh 15 or ♯; 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 the diesel engine, combustion of stratified charge, knock, theory of spray formation and vaporization. Fuels and deposits, engine lubrication, air and liquid cooling. (3 cr; prereq 150; 3 rec hrs per wk)

**152. Gas Turbines and Compound Engines.** Gas turbine cycles, regeneration, reheat, and intercooling. Free turbine and free piston gasifier. Scavenging of two-stroke engines, matching of compressor and turbine to engine. Turbo-jet engine performance. (3 cr; prereq 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 109 or ♯; 3 rec hrs per wk)

**159. Power and Propulsion Laboratory.** Quarterly group student projects relating to performance of power and propulsion system components. Performance of engines, turbines, and rockets. Combustion, fluid flow, and heat transfer problems in power systems. (2 cr; prereq 34, 146; 1 lect and 3 lab hrs per wk)

**160. Psychrometrics and Air Conditioning.** Mechanical vapor compression refrigeration; refrigerants; thermodynamic properties of moist air; psychrometric charts; psychrometry and humidity measurement; psychrometric processes; psychrometric systems. (3 cr; prereq 32, 133; 3 lect hrs per wk)

**162. Thermal Environmental Engineering.** Solar radiation; weather and climates; steady-state and periodic heat transmission in structures; thermal loads for enclosed spaces; effects of thermal environment upon people, processes, and materials; systems for year-around control of thermal environment. (3 cr; prereq 160; 3 lect hrs per wk)

**164. Refrigeration and Cryogenics.** Thermoelectric cooling gaseous air cycle; steam jet refrigeration; production of dry ice; thermodynamics of binary mixtures, the h-x diagram, absorption refrigeration. Liquefaction of air, hydrogen, and helium; production of oxygen and nitrogen by separation of air; other cryogenic topics. (3 cr; prereq 160; 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. Psychrometrics and Air Conditioning Laboratory.** Psychrometry and humidity measurement; experimental studies on refrigeration systems and on the processing of moist air. (2 cr; prereq 34, 160; 1 lect and 3 lab hrs per wk)

**171. Process Engineering I.** Analytical and physical fundamentals of fabrication processes including casting, forging, and welding. Emphasis is placed on the operating characteristics of the process and methods of optimizing process and product output. (3 cr; prereq Met 56 and MM 142; 2 lect and 3 lab hrs per wk)

**172. Process Engineering II.** Analytical and physical fundamentals of postfabrication processes including machining, shearing, forming, and assembly. Emphasis is placed on the materials, mechanics, economics, heat transfer, and functional characteristics of the metal cutting processes. (3 cr; prereq 171; 2 lect and 3 lab hrs per wk)

**183-184. Principles of Particle Technology.** Definition, theory and measurement of particle properties, particle statistics, fluid dynamic, optional, electrical, thermal behavior of particles, particle transport, gas cleaning and particle processing. (3 cr; prereq 32 or ♯; 3 lect hrs per wk)

**191-192-193.‡ Mechanical Engineering Design.** Design of mechanical engineering elements and systems. Interdivisional problems involving thermodynamics, mass and heat transfer, solid and fluid mechanics, economics and production, operations analysis, and automatic controls. (2 cr per qtr; prereq 5th-yr engr status or #; 4 lab 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 GPA; 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 44 or EE 45; 2 lect and 3 lab hrs per wk)

**199. Introduction to Feedback Control Systems.** Study of basic theory of linear feedback control systems. Steady state analysis and transient response analysis. Design of simple feedback control systems. (3 cr; prereq EE 44 or EE 45 or equiv, ITM 26A; 3 lect 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 Fluid Thermodynamics**

**233. Conduction**

**234. Convection**

**235. Radiation**

**236. Advanced Theory of Heat Transfer**

**242. Advanced Power Plants**

**246. Energy Transport in Chemically Reacting Gases**

**247. Mass Transfer in Chemically Reacting Gases**

**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 Environment Control**

**266. Advanced Psychrometric Processing**

**267. Advanced Air Conditioning**

**270-271-272. Magnetohydrodynamics**

**280. Theoretical Refrigeration**

**282. Reverse Applications of Refrigeration—Heat Pump**

**290-291-292. Mechanical Engineering Research**

**293. Graduate Seminar**

**296-297-298. Feedback Control Systems**

## 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)

**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

**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)

**136.* Metallurgical Unit Processes.** Integration of operations and processes on a plant basis. Applications in ferrous metallurgy. (3 cr; prereq 108)

**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

**150-151. Introduction to Mineral Processing Research I, II.** General principles, techniques, and procedures used in mineral processing research. Each student will carry out guided scientific investigations using advanced methods in experimental design and data analysis. Application of the use of digital computers is emphasized. (3 cr per qtr; prereq ITM 90 or MinE 126 or IE 198 or #; 1 lect and 4 lab hrs per wk) Lawver

**155. Electric and Magnetic Separation of Minerals.** Electric separation of dielectric minerals using electrostatic fields, and separation of conductors from insulators by corona discharge. Laboratory methods for determining electric properties of minerals and laboratory experiments using high and low intensity magnetic separators. (2 cr per qtr; prereq 112; 1 lect and 3 lab hrs per wk) Lawver

**For Graduate Students Only**

**201-202-203.*‡ Research in Process Metallurgy**

**204-205-206.‡ Research in Mineral Dressing**

**210-211-212.*‡ Seminar: Metallurgical Engineering**

**220. Flotation Theory**

## Metallurgy (Met)

**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, 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

**101-102-103. Introduction to Science of Materials.** Relation between atomic and electronic structure of metals, semiconductors, insulators, and polymers and important properties of materials. (3 cr per qtr; prereq Phys 50) Swalin, Sivertsen

**101A-102A-103A. Science of Materials Laboratory.** (1 cr; prereq ¶101-102-103)

**153-154-155. Physical Metallurgy.** Solidification and transformations in metals and alloys. Their influence on structure and properties. Cold working and annealing of metals. (3 cr per qtr; prereq 103 or #) Jerabek, Nicholson

**153A-154A-155A. Laboratory in Physical Metallurgy.** (1 cr per qtr; prereq ¶153-154-155) Jerabek, Nicholson

**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 155) Sivertsen

**167. Control of Mechanical Properties in Metals and Alloys.** Mechanical properties of metals and alloys are discussed in terms of dislocation behavior. Attention to *control* of mechanical properties through manipulation of microstructure by metal processing. (3 cr; prereq 155) Nicholson

**168. Principles of Metal Fabrication.** 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, 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.** Geometry and properties of metal crystals. X-ray diffraction, electrical and thermal conductivity, Hall effect, optical properties, and elastic and plastic behavior of metals. (3 cr; prereq 103) Sivertsen

**174. Modern Theory of Metals and Alloys.** Free electron theory of metals and application. Imperfection in crystals. (3 cr; prereq 173 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 course in thermodynamics) Swalin

**For Graduate Students Only**

**207-208-209. Research in Physical Metallurgy**

**213-214-215.‡ Seminar: 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**

**271-272.‡ Structure and Cohesion of Metals and Semiconductors**

## 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, ‡) Rogers

**122. Physiology of Bacteria Laboratory.** Techniques employed in the study of bacterial physiology and metabolism. (3 cr; prereq 121, ‡) 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 Army-Navy-Air Force ROTC* of the University of Minnesota, or call the Military Science office, 108 Armory.

The Institute of Technology will accept and apply toward degree requirements a minimum of 9 credits for satisfactory completion of the ROTC program. In addition, credits from concurrent courses will apply toward degree requirements.

### LOWER DIVISION COURSES

#### Military Science I

**41. Employment of Firepower.** To provide the student with an understanding or organization of the Army for modern tactical and strategic environments. Modern units and techniques of the individual soldier. (1 cr; ¶leadership laboratory)

**42. School of the Soldier.** United States Army customs and courtesies. Practical exercises in leadership, command, and individual and unit drill formation. Includes requirement of satisfactory completion of a concurrent course in communications, psychology, science, or political science as approved by PMS. IT students must also have the approval of their departmental adviser for the concurrent courses. (No cr; prereq 41)

**43. United States Army and National Security.** Survey of the problems of national defense as pertains to the United States Army in general war, limited and cold war, joint operations, and the impact of modern technology on warfare techniques with emphasis on the individual's personal responsibilities as a citizen and a leader. (1 cr; ¶leadership laboratory)

#### Military Science II

**44. Military Maps and Aerial Photography.** Tactical and strategic use of United States and foreign military maps, elementary cartography, and land navigation. Use of aerial photographs and modern surveillance systems in military mapping and tactical operations. (1 cr; ¶leadership laboratory)

**45. American Military History.** United States Army operations from the American Revolution to the Korean War. A comprehensive survey of the history of land warfare as applied to the significant political, economic, social, and technical growth of the United States. (3 cr; coop Hist 45)

**46. Introduction to Basic Tactics.** Small unit operations in conventional and unconventional battle field environments. The training of the combat soldier to include physical

** No credit allowed in IT except upon completion of the program.

and psychological conditioning, technical proficiency, and motivation through leadership. (1 cr; ¶leadership laboratory)

**UPPER DIVISION**

**Military Science III**

**151. Problems of Special Warfare.** Problems of the law of war, guerrilla warfare, psychological warfare, and counterinsurgency/counterguerrilla operations as applied in modern military operations. (1 cr; ¶leadership laboratory, ¶academic course)

**152. Advanced Tactics and Training.** Small unit leadership and psychology of small groups in identification of personality characteristics, study of individual needs, values, and capabilities. Emphasis is placed on the solving of leadership problems. Conduct of military training and development of Army instructor. Includes practice teaching by the student. Advanced small unit operations in conventional and unconventional battle field environments. (5 cr; prereq 151)

**153. Functional Organization of the United States Army.** A survey of the history, training, equipment, and developmental trends of all combat arms and services of the Army. Tactical operations in all phases of land warfare. A field exercise encompassing all material studied in Mil 152 and 153, stressing the practical application of techniques and principles under simulated tactical conditions. (3 cr; ¶leadership laboratory)

**Military Science IV**

**154. Command and Staff Operations.** Comprehensive study of combat operations and logistics as related fields. Principles of command management, staff organization and staff procedures, supervision, and co-ordination by the commander. (4 cr; ¶leadership laboratory)

**155. Role of United States in World Affairs.** Analysis of the United States geographical position, economic potential, and military potential, as compared with other world powers. (1 cr; ¶academic course)

**156. Army Administration.** Study of military personnel management procedures to include records, classification and assignment, unit fund accounting, and legal and military justice matters. Conduct of a field exercise stressing practical application of material studied in Mil 152-156. Service orientation for the newly commissioned officer. (4 cr; ¶leadership laboratory)

*Leadership laboratory* is taught concurrently to all cadets during the fall and spring quarters. This laboratory is designed so that individual students can demonstrate their progressive ability in individual and group drill. Progressive and extensive practice in voice and command, unit formations, exercise of command bearing, and posture. Assists in identification and development of individual leadership traits and qualities of character.

*Concurrent registration in academic course* includes requirement of satisfactory completion of a concurrent Upper Division course, 3 or more credits, in communications, psychology, science, or political science as approved by PMS. Institute of Technology students must also have the approval of their departmental adviser for the concurrent course.

## Mineral Engineering (MinE)

**1. Mineral Engineering Laboratory.** The fields of mining, geological, petroleum, and metallurgical engineering are 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. (4 cr per qtr; prereq CE 18 or ♯; 3 lect and 3 lab hrs per wk) Yardley

**15A. Mine Surveying Field Work.** Open pit and underground surveying, shaft plumbing; stripping estimates; plane table work; solar and stellar observations; special problem. (3 cr; prereq 13; hrs ar) Yardley, Lacabanne

**70. Geological Engineering I.** Geology and geotechnics in relation to engineering problems. Emphasis is on geologic factors in engineering. Geologic structures and material, subsurface water, foundations, construction sites, and earth vibrations are among the topics considered. (3 cr; prereq Geo 1 and Phys 14 or ♯) Yardley

**90-91-92-93-94.† 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 required. (2 cr per course; prereq ♯) Staff

**111-112-113. Principles of Mineral Engineering: I, Exploration; II, Development and Exploitation; III, Earth Fluids and Flow.** Principles and techniques of exploration, factors and concepts involved. Sampling design, combining theory, geostatistics. Mining systems; unit operations, drilling, explosives, and transportation. Sedimentary rock and earth fluids characteristics. Fluid flow through reservoir rocks and aquifers. Energies and mechanisms of petroleum production. (3 cr per qtr; prereq 3rd yr; 3 lect hrs per wk) Yardley, Lacabanne

**121. Mine and Petroleum Plant Engineering I.** 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 ME 30 or ♯; 3 lect and 3 lab hrs per wk) Dorenfeld

**122. Mine Plant Engineering II.** 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; 3 lect and 3 lab hrs per wk) Dorenfeld

**124-125.* Mill-Plant Engineering I-II.** 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

**126.* Operations Analysis in Mineral Engineering.** Statistical methods, tests of significance, correlation techniques; applications to cost estimates, sampling, mine and mill operations, blending, automation, equipment and process selection, and optimization techniques. (3 cr; prereq 122 or 125 or ♯; 3 lect 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. Engineering Field Study.** Study of mining and petroleum operations; mine and petroleum plants, and metallurgical plants in selected regions. (3 cr; prereq ♯; hrs ar) Staff

**141. Mineral Economics I.** Minerals in national and world affairs, their importance and distinctive features. Distribution, demand, and conservation of strategic supplies. Marketing and prices. State and national policies affecting development. Analysis of mineral data. (3 cr; prereq Geo 62 or ♯; 3 lect hrs per wk) Pfleider

**142.* Mineral Economics II.** Examination and valuation of mining and oil properties. Geologic factors and mineral titles. Sampling and reserve estimates. Analysis of

costs and profitability. Taxation, depreciation, and depletion. Present worth computations and mine financing. (3 cr; prereq 141 or ♯; 3 lect hrs per wk) Pfleider

**144-145.* Mine Systems Analysis.** Systems design in the exploration, development, and exploitation of a mineral property. Integration of concepts from geology and geophysics, rock mechanics, mine or petroleum plant engineering, and mineral economics and valuation principles to a specific problem chosen by student. Preparation of report. (2 cr for 144, 4 cr for 145; prereq 142 or ♯; 6 lab hrs per wk for 144, 9 lab hrs per wk for 145) Pfleider and staff

**151-152-153.*‡ Special Engineering Problems.** Literature survey or research work on mining problems. (Cr and hrs ar; prereq 112)

**155.* Materials Handling and Bulk Flow.** Unit operations of excavation, loading, and transportation as related to mass movement of materials. Bulk material properties and systems. Strength theories, cohesion, flow principles. Engineering calculations and laboratory experiments. (3 cr; prereq MM 142 or ♯) Pfleider

**160.* Mining and Processing Industrial Minerals.** Survey of minerals and rocks industrially important but primarily not mined for recovery of metals. Origin, unique features, mining methods, processing, evaluation. (Cr ar; prereq 112 or ♯; 2 lect hrs per wk) Yardley

**171. Fluid Flow Through Porous Media I.** Petrophysics of porous rocks and aquifers; single and polyphase flow for compressible and incompressible fluids. Ground water hydrology. Fracture flow. Electrical characteristics of porous rocks. (2 cr; prereq Phys 9 or 13; 2 lect hrs per wk) Lacabanne

**171A. Fluid Flow Laboratory.** Core analysis, porosity, permeability, surface areas, saturation measurements, linear and radial flow. Resistivity, formation factors, etc. (1 cr; prereq 171 or ¶171; 3 lab hrs per wk) Lacabanne

**172. Fluid Flow Through Porous Media II.** Reservoir and aquifer energies and mechanisms of fluid movement and production. Material balance equations; fractional flows; effects of rock and fluid compressibilities. Steady and unsteady states. Water well hydraulics. (3 cr; prereq 171; 3 lect hrs per wk) Lacabanne

**173. Natural Gas Engineering.** Properties of natural gas; critical conditions of gases, compressibility factor, retrograde condensation. Estimation of gas reserves. Gas flow measurement, orifice meters and gas well back pressure tests; gas hydrates. (2 cr; prereq 4th yr or ♯; 2 lect hrs per wk; offered when demand warrants)

**180.* Geochemical Exploration.** Geochemical techniques and principles involved in 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 1964-65 and alt yrs) Yardley

**For Graduate Students Only**

**201-202-203.*‡ Seminar: Mineral Engineering**

**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**

**251-252.* Advanced Rock Mechanics I, II**

## Natural Science (NSci)

**4-5.†** **The Physical World.** Essential elements of astronomy, physics, chemistry, and geology, selected to illustrate methods of science and to acquaint student with the physical universe around him. (3 cr per qtr)

## Naval Science (Nav)**

(Department of Naval Science)

The course in naval science is designed to give those students enrolled in the Naval ROTC program a background in naval subjects to prepare them upon graduation to receive a commission in the Navy, Naval Reserve, Marine Corps, or Marine Corps Reserve. This course is, however, available to any student in IT as well as to those in other colleges of the University. For information concerning the requirements and the opportunities in the NROTC program consult the *Bulletin of Army-Navy-Air Force ROTC* or call at the Naval Science office, 203 Armory.

### LOWER DIVISION COURSES

(All NROTC students)

*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 Weapons.** (No cr)

**22-23. Naval Weapons and National Policy.** The underlying reasons and circumstances under which the family of naval weapons is developed; the impact of these developments on naval warfare; the influence of weapons on national policy and those considerations of national policy which govern and influence the development of weapons; the integration of the family of naval weapons into modern effective naval weapons systems; and possible courses of future development of naval weapons systems. (3 cr per qtr)

### UPPER DIVISION COURSES

**I. Line Sequence**

*3rd Year*

**51. Naval Operations.** Elements of shipboard operations: relative motion, tactical communications, rules of the nautical road, and naval maneuvering. (3 cr)

**52. Naval Operations: Introduction to Navigation.** Fleet communications and meteorology. 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)

** No credit allowed in IT except upon completion of the program.

*4th Year*

**61. 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)

**62. Naval Engineering: Leadership.** Types and theory of internal combustion engines and shipborne nuclear propulsion plants. Principles of Naval Management and functions of the Uniform Code of Military Justice. (3 cr)

**63. Leadership.** Principles of Naval Leadership. Management psychology in the Navy: individual differences, group dynamics, and human relations. 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*

**63. Leadership.** (See 4th year of Line Sequence)

**67. Retail Sales.** Ship's stores afloat introduction. Organization and operation of ship's stores afloat. Problems and case studies in ship's stores. (3 cr)

**68. Retail Sales: Leadership.** Operation and management of service activities, balance sheets, and operating statements. Problems and case studies in ship's stores afloat. Principles of naval leadership and group management. (3 cr)

**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)

# Philosophy (Phil)

(College of Liberal 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) Staff

**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) Staff

**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)

**70. 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) Maxwell

# Physics and Astronomy

## *Astronomy (Ast)*

**11. Descriptive Astronomy.** Brief survey of what is known about the sun, the moon, the planets and their motions, followed by a description of the constellations and a summary of our knowledge of the stellar universe to which the sun belongs. This course is completely non-mathematical. (5 cr, §51) Luyten

**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)

**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 ITM 25A or 26B or Math 44 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 ITM 25A or 26B or Math 44 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 ITM 26A or 27 or Math 106)

**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)

## Physics (Phys)

**1-2-3. Introduction to Physical Science.** Demonstration lectures on the principles of physics and the physical phenomena underlying these principles. 1: Mechanics. 2: Heat and electricity. 3: Sound and light. (3 cr per qtr; prereq high school algebra and plane geometry for 1, 1 or ♯ for 2, 1 or ♯ for 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; combination of 1-2-3 with 1A-2A-3A may be used to fulfill the laboratory science group requirement in CLA but does not serve as prereq for advanced physics courses; 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.** (Primarily for students majoring in physics, mathematics, or chemistry) 7: Mechanics. 8: Heat, electricity. 9: Sound and light. Laboratory work is an integral part of course. (5 cr per qtr; prereq ITM 13A or Math 42, ITM 24A or ¶ITM 24A or Math 43 or ¶Math 43 for 7...7 and ITM 25A or ¶ITM 25A or Math 44 or ¶Math 44 for 8...8 for 9; 4 lect, 1 quiz, 2 lab hrs per wk)

**10. General Physics.** (For IT architecture students only) Wave motion, sound, optics, electricity, and magnetism. (4 cr; prereq 12, ¶10A, ITM 24A or ¶ITM 24A or Math 43 or ¶Math 43; 4 lect and 1 quiz hr per wk)

**10A. Physics Laboratory.** Laboratory exercises in wave motion, electricity, and magnetism. (1 cr; prereq ¶10; 2 lab hrs per wk)

**11. General Physics.** Kinematics and classical dynamics. (5 cr; prereq ITM 12 or ¶ITM 12 or Math 15 or ¶Math 15; 4 lect, 1 quiz, 2 rec per wk)

**12. General Physics.** Mechanics (continued), heat, elementary kinetic theory. (4 cr; prereq 11, ¶12A, ITM 13A or ¶ITM 13A or Math 42 or ¶Math 42; 4 lect and 1 quiz hr per wk)

**12A. Physics Laboratory.** Laboratory exercises in mechanics. (1 cr; prereq ¶12; 2 lab hrs per wk)

**13. General Physics.** Wave motion, sound, geometrical and physical optics. (4 cr; prereq 12, ¶13A, ITM 24A or ¶ITM 24A or Math 43 or ¶Math 43; 4 lect and 1 quiz hr per wk)

**13A. Physics Laboratory.** Laboratory exercises in heat, sound, optics. (1 cr; prereq ¶13; 2 lab hrs per wk)

**14. General Physics.** Electricity and magnetism. (4 cr; prereq 13, ITM 25B or ¶ITM 25B or Math 44 or ¶Math 44; 4 lect and 1 quiz hr per wk)

**14A. Physics Laboratory.** Laboratory exercises in electricity and magnetism. (1 cr; prereq ¶14; 2 lab hrs per wk)

**14H. Honors Course: General Physics.** Electricity and magnetism. (4 cr; prereq 13 and ITM 25B or ¶ITM 25B or Math 44 or ¶Math 44, △; 4 lect and 1 quiz hr per wk)

**15H. Honors Course: Physics Laboratory.** Parallel to Phys 14H. (1 cr; prereq ¶14H, △; 3 lab hrs per wk)

**20. Elementary Physical Acoustics.** (Intended primarily for music and music education majors) Physical principles of acoustics and wave motion with particular application to the field of music and musical instruments. Laboratory work is an integral part of the course. (5 cr, §Phys 3, 6, 9 or 13; prereq 1 yr high school algebra)

**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 26B or ¶ITM 26B or Math 55 or ¶Math 55; 4 lect and 1 quiz hr per wk)

**50A. Physics Laboratory.** Parallel to 50. (1 cr; prereq ¶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 14H, ITM 26B or ¶ITM 26B or Math 55 or ¶Math 55, △; 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 27 or ¶ITM 27 or Math 106 or ¶Math 106; 4 lect and 1 quiz hr per wk)

**51A. Physics Laboratory.** Parallel to 51. (1 cr; prereq ¶51; 2 lab hrs per wk)

**51H. Honors Course: Intermediate General Physics.** Elementary nuclear physics, wave motion, wave phenomena. (4 cr; prereq 50H and ITM 27 or ¶ITM 27 or Math 106 or ¶Math 106, △; 4 lect and 1 quiz hr per wk)

**52H. Honors Course: Physics Laboratory.** Parallel to 50H. (1 cr; prereq ¶50H, △; 3 lab hrs per wk)

**53H. Honors Course: Physics Laboratory.** Parallel to 51H. (1 cr; prereq ¶51H, △; 3 lab hrs per wk)

**60-61. Intermediate Physics.** (Primarily for premedical students and students majoring in biological sciences) Atomic, molecular, and nuclear physics emphasizing implications for the biological sciences. Topics selected from: atomic, molecular, and nuclear structure; interaction of electromagnetic radiation with matter; radioactivity; hydrodynamics; thermodynamics; kinetic theory and elementary statistical mechanics; transport phenomena; reaction kinetics. (3 cr per qtr; prereq 6 and Math 40 or △)

**70. Industrial Summer Employment.** Employment (contracted by the student) 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, △ during previous spring qtr)

**100-102-104. Mechanics, Electricity, and Magnetism.** Theoretical course designed to prepare students for advanced work. (4 cr per qtr, §100A or §MM 29; prereq 3rd yr, 9 or 14, ITM 26A or Math 106 for 100 ... 100 or MM 29 for 102 ... 102 for 104; 4 lect hrs per wk)

**100A-101A-102A. Introduction to Analytic Mechanics.** 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 co-ordinates and the Lagrange formulation of mechanics. Mathematics beyond the prerequisites is developed as required. (3 cr per qtr, §100 or §MM 28 for 100A, §100 or §MM 29 for 101A; prereq 3rd yr, 9 or 14, ITM 26A or Math 106 for 100A...majors in fields other than physics may use MM 28, 29 as prereq for 102A; 3 lect hrs per wk)

**103A-104A-105A. Introduction to Electric and Magnetic Fields.** The classical theory of electric and magnetic fields, developed with the aid of vector calculus. Topics include electrostatics and potential theory, magnetostatics, Maxwell's equations, material media and plasmas, electromagnetic waves, and electromagnetic radiation. (3 cr per qtr; prereq 4th yr or ♯, 9 or 14, ITM 26A or Math 106 for 103A; 3 lect hrs per wk)

**107-109-111. Atomic and Nuclear Physics.** Interpretation of experimental phenomena. Topics include kinetic theory, Maxwell-Boltzmann distribution, special relativity, the nuclear atom, atomic and molecular structure and spectra, black-body radiation, wave mechanics, nuclear physics, modern developments in classical physics, astrophysics, particle physics. (3 cr per qtr, §50 or 51; prereq 9 or 14, ITM 26A or Math 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 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 51 or ♯, ITM 153 or Math 108; 3 lect hrs per wk)

**113. Techniques of Nuclear Physics.** Statistics of random events; interactions of photons, charged, and neutral particles with matter; detection devices; beam handling; measurement and analysis of cross sections. (3 cr; prereq ¶103A)

**114-116-118.† Elementary Physical Investigation.** Problems, either experimental or theoretical, of special interest to student. Written report required. (Cr ar; prereq 3rd yr, △)

**120-121-122.† Experimental Atomic and Nuclear Physics.** A course in techniques and methods used in physics research laboratories. Experiments deal with vacuum gauges and equipment; mass spectroscopy; X-ray diffraction; health physics; detection of charged particles, neutrons and gamma rays; and the measurement of several fundamental atomic constants. (3 cr; prereq 51 or ¶107 or ¶108, ♯; 6 lab hrs per wk; student may take 1 or 2 qtrs of this sequence in any order)

**123. Thermodynamics.** Intended primarily for fourth-year physics majors. Formulation of the basic laws of thermodynamics concerning temperature, energy, and entropy and their application to simple systems. (3 cr; prereq 9 or 14, ITM 26A or Math 106; 3 lect hrs per wk)

**124-125. Kinetic Theory and Statistical Mechanics.** Kinetic theory, dealing principally with gases, the Maxwell-Boltzmann distribution, and the elementary theory of transport processes; and the principles of statistical mechanics, dealing with the equilibrium properties of both classical and quantum systems of independent or interdependent particles. (3 cr; prereq 123 or ♯; 3 lect hrs per wk)

**126-127-128. Elementary Solid State Physics.** 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 51, ITM 26A or Math 106)

**131. Geometrical Optics.** Ray optics and study of its applications to optical instruments and their components. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 44; 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 44; 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 44; 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 44; 1 lect and 5 lab hrs per wk)

**144. Electrical Measurements.** Ballistic and current galvanometers, magnetic flux measurements, potentiometers, D.C. and audio-frequency A.C. bridges, elementary D.C. and A.C. circuit theory. (4 cr; prereq 9 or 14, ITM 26A or Math 55; 3 lect and one 3-hr lab per wk)

**146. Physics of Vacuum Tubes and Associated Circuits.** Characteristics of vacuum tubes, power supply and amplifier 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.** Use of tubes and transistors in amplifier, oscillator, and pulse generating circuits 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.** A survey of the physical processes which determine the mean state of the atmosphere. Topics in radiative transfer and thermodynamics are reviewed in preparation for the discussion of the heat budget

and temperature distribution of the atmosphere. Atmospheric properties and phenomena treated include: formation of clouds and precipitation, convection and stability, atmospheric electricity and ozone. (3 cr; prereq 50, ITM 26A or Math 106)

**166. Meteorology I.** Quantitative description of large-scale atmospheric motions. The basic equations of meteorological hydrodynamics are introduced and applied in actual weather situations. (3 cr; prereq 165 or ♯)

**167. Meteorology II.** Theoretical meteorology. Critical examination of the mathematical models used to describe the large-scale flow processes; energy transformations in atmospheric flow; atmospheric turbulence and eddy transport. (3 cr; prereq 166, vector analysis or ♯)

**171-172-173. Classical Theoretical Physics.** Principal topics are classical mechanics, special theory of relativity and classical electrodynamics. Emphasis is placed on the application of advanced mathematical techniques to these subjects. (3 cr per qtr; prereq 104 or both 102A and 105A, ITM 153 or Math 108 or equiv; 3 lect hrs per wk)

**171A-172A-173A. Techniques of Theoretical Physics.** Drill in the solution of mathematical physics problems. (1 cr per qtr; prereq ¶171-172-173 or ♯)

**181-183-185. Atomistics and Elementary Quantum Mechanics.** Elementary quantum mechanics, with applications from atomic and nuclear physics. Schrödinger's equation, wave mechanics, matrix representations, perturbation theory, electromagnetic radiation, scattering, and the many-body problem. (3 cr per qtr; prereq 111 or 112, ITM 153 or Math 108 or equiv; 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: Contemporary Experimental Physics**

**216-217-218.‡ Seminar: 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**

**234-235. Low Temperature Physics**

**236. Radiofrequency Spectroscopy**

**237-238-239.‡ Seminar: Radiofrequency Spectroscopy**

**240-241-242.‡ Seminar: Solid State and Low Temperature Physics**

**246-247-248. Cosmic Ray Physics**

**249-250-251. Solid State Physics**

**252-253-254.‡ Seminar: Nuclear Physics**

**255-256-257.‡ Seminar: Mass Spectroscopy**

**258-259-260.‡ Seminar: Cosmic Ray Physics**

**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)

(Medical School)

**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, GeCh 15, ¶ITM 26A)

## Political Science (Pol)

(College of Liberal Arts)

**1-2†-3. 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)

**A-B-C. 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; C may be taken concurrently with B) Fogelman, Lippincott

**5. American Government and Politics.** Covers most of Pol 1-2. (5 cr, §1-2)

**25. World Politics.** Introduction to contemporary international relations; policies of the great powers; nationalism; internationalism. (3 cr) Dibble

**26. American Foreign Policy.** An introduction to the institutions and processes which determine American foreign policy. Traditional and postwar foreign policies. (3 cr) Holt

**27. Analysis of International Relations.** Methods of systematic analysis of the problems of international relations and the factors affecting them. Theoretical positions. (3 cr; prereq 25 or 26 or ♯) Holt

## Psychology (Psy)

(College of Liberal 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) Greenberg, Jenkins, LaBerge, Trapold

**155. Industrial Psychology.** Application of psychological methods in business and industry. Staffing, personnel development and training; employee motivation and morale; social psychological factors in industry; biomechanics and production; theories of industrial organization; communication and leadership in industrial setting. (3 cr; prereq 2, 5 or 3 cr in statistics) Dunnette

## Public Health (PubH)

(College of Medical Sciences)

**50. Personal and Community Health.** Fundamental principles of health conservation and disease prevention (3 cr, §2, §3, §3A, §3B, §4, §5, §51, §52)

**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, 3A, or 50 and a course in bacteriology)

**102. Environmental Sanitation.** Methods for promoting man's health and comfort by controlling environment. (3 cr; prereq sr, 100A or §100A and #)

**154. Radiological Health I.** Orientation in radiation effects and study and control of radiation hazards in laboratories, hospitals, and industrial plants. (Cr ar; prereq #)

## Social Science (SSci)

(College of Liberal Arts)

**1-2-3. Personality, Work, and Community.** 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) Altschuler, Berman, Drobac, Roshwald, Rubin, Uppal

## Sociology (Soc)

(College of Liberal 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)

**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)

## Soil Science (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 GeCh 5)

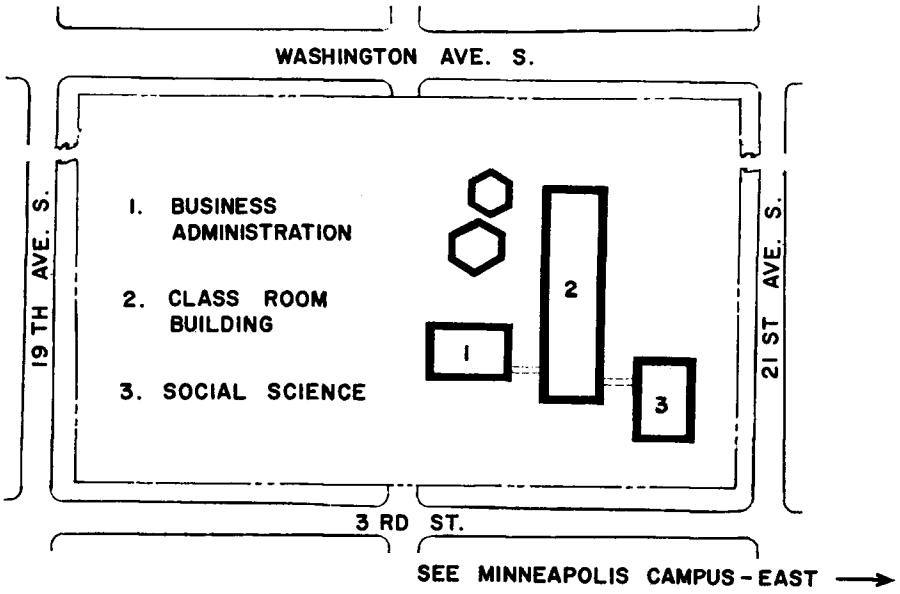
**126. Soil Physics.** Soil structure, compaction, tilth, tillage; water infiltration, retention, availability, movement and evaporation; heat capacity, flow, air porosity, diffusion, deficiency effects on plants, drainage requirements. Lectures and laboratory. (4 cr; prereq 3 or 19, Math 10 or MeAg 23 or equiv)

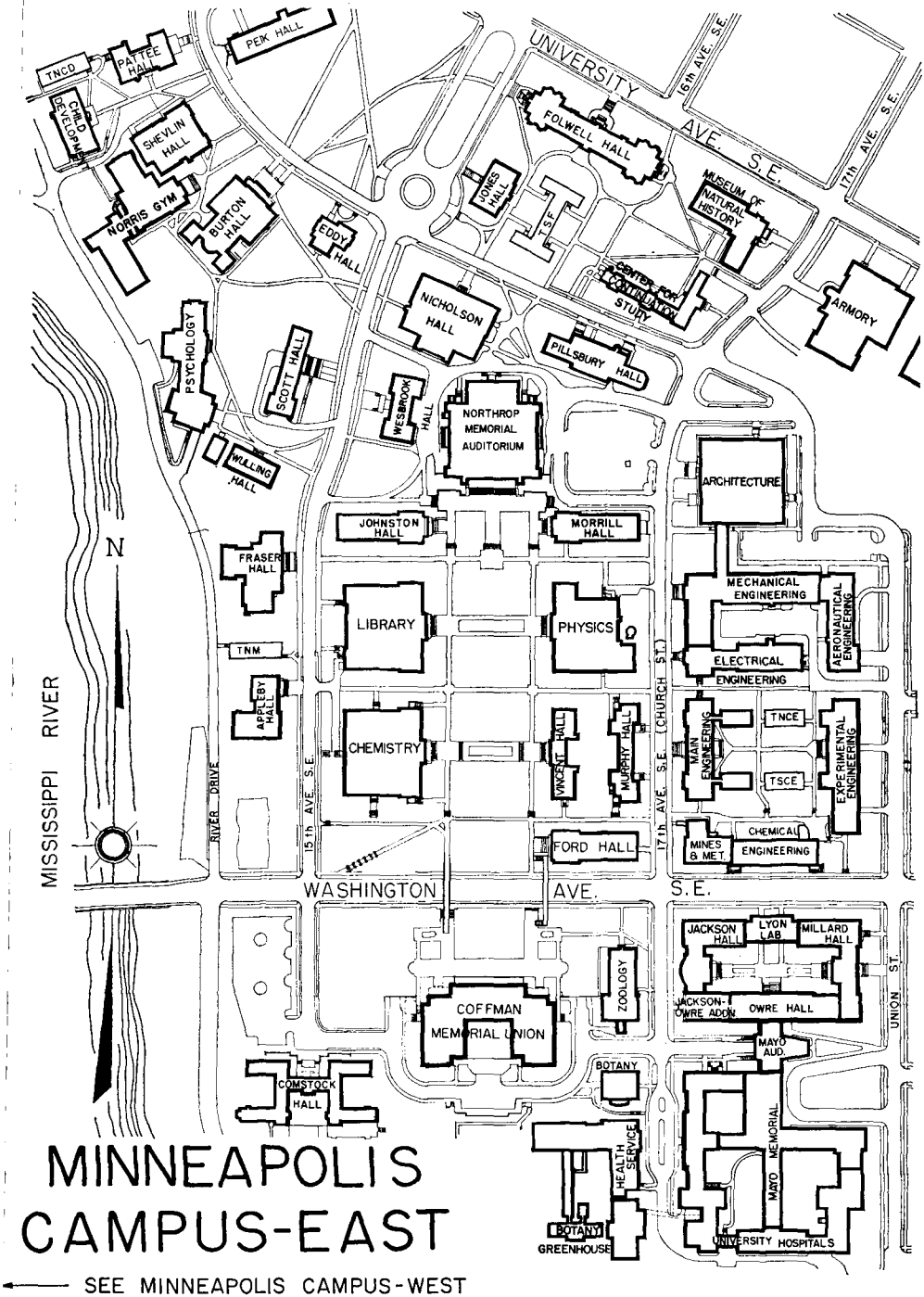
## Speech and Theatre Arts (Spch)

(College of Liberal Arts)

**50. Public Speaking.** Principles of preparing and presenting public speeches; directed practice in public speaking. Consideration of the functions of public speaking in contemporary life. (3 cr, §5; prereq upper division standing)

# MINNEAPOLIS CAMPUS—WEST






# MINNEAPOLIS CAMPUS-EAST

SEE MINNEAPOLIS CAMPUS-WEST

# INDEX